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SHORT COMMUNICATION

FOSSIL PROWFISH, *ZAPRORA KOREANA*, SP. NOV. (PISCES, ZAPRORIDAE), FROM THE NEOGENE OF SOUTH KOREA

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Zaproridae is represented by a single extant member, *Zaprora silenus* Jordan, the prowfish (Nelson et al., 2016). This species is broadly distributed in the North Pacific, from the northern Bering Sea to southern California, U.S.A., in the east, and Hokkaido, Japan, in the west (Mecklenburg et al., 2016). The prowfish is a marine fish: adults are demersal on the continental shelf and the upper slope to a depth of 800 m, whereas juveniles are pelagic (Tokranov, 1999; Mecklenburg, 2003). Pelagic juveniles are frequently encountered far offshore and are often found in association with jellyfish, hiding under their umbrellas (Hilton and Stevenson, 2013; Mecklenburg et al., 2016).

The main prey of *Zaprora* are soft-bodied invertebrates, mainly jellyfish (Scyphozoa), followed by comb jellies (Ctenophora), and less often small crustaceans (Tokranov, 1999). Apparently, this fish bites off pieces of jellyfish umbrellas with its sharp, uniserial teeth (Tokranov, 1999).

Prowfishes are characterized by a stout, slightly elongated, and laterally compressed body; comparatively large head with big terminal mouth, short blunt snout, single nostril, and conspicuous sensory pores; short and deep caudal peduncle; large, rounded pectoral and caudal fins; long-based continuous dorsal fin, consisting only from spines; short-based anal fin, with its base less than half the length of the dorsal fin base; absence of a pelvic fin (Clemens and Wilby, 1961; Hart, 1973; Lindberg and Krasjukova, 1975; Mecklenburg et al., 2002, 2016); adults with three lines of trunk neuromasts; small cycloid scales densely covering the entire body, fin bases, and partly the head; and spatulate anterior jaw teeth (Hilton and Stevenson, 2013). The head and the eye are proportionally smaller in larger specimens (Hilton and Stevenson, 2013). The heights of the body and dorsal and anal fins appear to be greater in juveniles (Fedorov et al., 2003:fig. 259; Mecklenburg et al., 2016:219).

The relationships of this family are still unresolved. Both morphological and molecular data show the closest kinship of zaprorids to some groups of the prickleback family Stichaeidae sensu Makushok (1958) in different combinations with other

families within the superfamily Stichaeoidea (see review in Hilton and Stevenson, 2013). The most recent study reveals the position of *Zaprora* within the clade uniting the Cryptacanthodidae and part of stichaeid Opisthocentrinae (Clardy, 2014).

The Neogene fish †*Araosteus rothi* Jordan and Gilbert, 1920, is currently the only known fossil member of the family Zaproridae. The remains of this species were found in two late Miocene formations of California, U.S.A. (Fierstine et al., 2012). There are no diagnostic characters allowing separation of this Miocene genus from the recent *Zaprora*, as revised by David (1943). Both nominal zaprorid genera are very similar in body proportions, counts, and even in the shape of some bones (David, 1943). Thus, †*Araosteus* should probably be placed in *Zaprora*.

In this paper, we report the discovery of a new fossil prowfish, described below as a new species of the genus *Zaprora*. This is the only other find of a fossil representative of the family to date.

LOCALITY, MATERIALS, AND METHODS

The holotype, and only known specimen, was collected by K.-S.N. from a locality in the Duho Formation near Pohang, South Korea (Fig. 1). The most common Neogene deposits to the north of Pohang City belong to the Duho Formation. It consists of siltstones, sandstones, mudstones, and conglomerates (Yun, 1986; Yoon, 1992). Accumulation of these layers occurred at middle or lower bathyal depths (deeper than 500 m) (Kim, 1999; Sohn et al., 2001). The Duho Formation is dated to the middle Miocene, with an age of about 15 Ma (Lee et al., 1992). The rich complex of fossils from the Duho Formation comprises demersal, mesopelagic, and epipelagic fishes of the families Lamnidae, Myctophidae, Phosichthyidae, Clupeidae, Cyprinidae, Scorpaenidae, and Pleuronectidae. The fossil described herein was collected from a construction site in the town of Heunghae, about 10 km northeast of Pohang City and about 6 km from the sea coast. The fossiliferous beds are light gray mudstones intercalated with thin layers of shales. The fish fossils are concentrated in the very thin shale layers. At the present time, this

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fossil locality is inaccessible because of completion of the building construction.

The holotype is deposited in the collection of the Geological Museum, Korea Institute of Geoscience and Mineral Resources, Daejeon, South Korea (KIGAM). The cleaning of the specimen was carried out with needles under a stereomicroscope. The outline drawing was based on digital photographs. Measurements were made by digital calipers to the nearest 0.1 mm. The skeletal structure of the modern *Zaprora silenus* was studied under X-rays using specimens from the collection of Zoological Institute of Russian Academy of Sciences, St. Petersburg, Russia (ZIN).

Comparative Material Examined—ZIN 50761, Sea of Okhotsk, 210 mm standard length (SL); ZIN 39003, Bering Sea, 100 mm SL.

SYSTEMATIC PALEONTOLOGY

Subdivision TELEOSTEI sensu Patterson and Rosen, 1977

Clade ACANTHOMORPHA Rosen, 1973

Series PERCOMORPHA Rosen, 1973

Order PERCIFORMES Bleeker, 1859

Suborder ZOARCOIDEI sensu Anderson, 1994

Family ZAPRORIDAE Jordan, 1896

Genus *ZAPRORA* Jordan, 1896

†*ZAPRORA KOREANA*, sp. nov.

(Fig. 2)

Holotype—KIGAM 9A168, the specimen in part and counterpart, representing the caudal body region (Fig. 2).

Diagnosis—A *Zaprora* species with 21 segmented rays in the anal fin, 29 caudal vertebrae, short caudal peduncle consisting of six vertebrae behind the last anal-fin pterygiophore, and fully developed neural spine of the second preural vertebra.

Etymology—Named after the country of origin.

DESCRIPTION

The caudal body part with a posterior fragment of the dorsal fin, the damaged caudal fin with its skeleton, and the complete anal fin are preserved. A total of 33 vertebrae are visible, including the complex terminal vertebra of the first preural plus ural centra. Anterior abdominal vertebrae are lost. Four posterior-most abdominal centra with greatly elongated parapophyses are preserved. Four more abdominal vertebrae can be traced by their long and thin neural spines in the anterior part of the specimen. There are 29 caudal vertebrae. All the visible vertebral centra are short, with their height greater than their length. The neural and hemal spines are thin, high, and closely spaced. The neural spines are usually slightly shorter than the corresponding hemal spines. The longest neural spine height is approximately equal to the length of 8.5 caudal centra. The neural spines of anterior caudal vertebrae are directed dorsally, whereas the hemal and posterior neural spines are slightly inclined posteriorly. The first to third hemal spines are much shorter than the more posterior ones. The parapophyses and the neural and hemal arches are fused to the centra, with the exception of the hemal spine of the second preural vertebra, which appears to be autogenous. Pre- and postzygapophyses on the neural and hemal arches are weakly developed and recognizable on some caudal vertebrae. The distal parts of the posterior four or five pairs of slender ribs are visible anterior to the first hemal spine. Epineurals are not preserved.

The dorsal fin entirely consists of spines. There are 29 posterior spines preserved. These spines are very thin and, apparently, flexible. In the anterior portion of the specimen, the

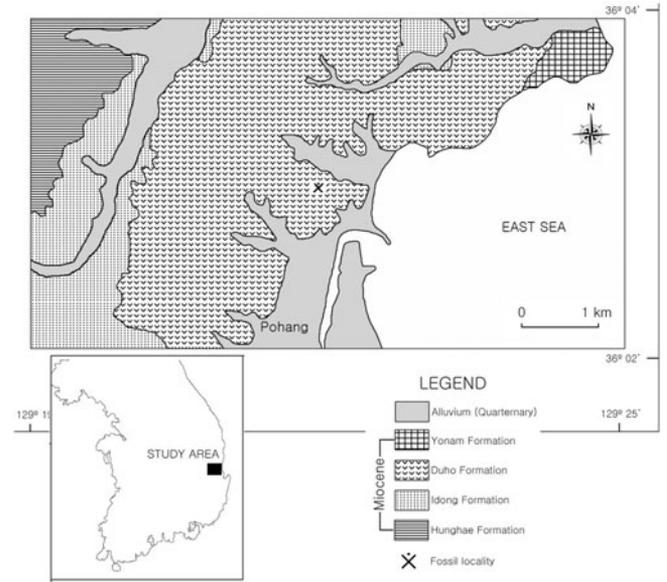


FIGURE 1. Sketch map of South Korea showing Pohang area and the position of the fossil locality (black cross).

height of the spines is almost half of the body depth beneath them. The height of the seven posterior spines gradually decreases, and the posterior-most one is one-third the height of the tallest spine. The bases of the dorsal-fin spines are slightly expanded laterally and form the rings for a chain-link association with the corresponding pterygiophores. The proximal-middle radials of the dorsal fin are thick, and half the height of the spines. They are inserted singly in interneural spaces to half of their height or sometimes more. There are 31 preserved dorsal pterygiophores, with the last one placed between the spines of preural vertebrae 5 and 6. This posterior-most pterygiophore supports two posterior dorsal spines. Proximal parts of both the dorsal- and anal-fin pterygiophores are slightly expanded. The distal radials are not preserved in either fin.

The anal fin consists of three flexible spines and 21 segmented rays. The anal-fin spines are similar to the dorsal spines in their form. The height of the anal spines gradually increases posteriorly, and the third spine is 60% the height of the highest dorsal spines. The distal parts of the anterior segmented anal rays are lost, and their height is therefore unknown. The longest anal rays, the 14th and 15th, are about 80% of the longest dorsal spines. The length of the rays following them gradually decreases posteriorly. Most anal-fin rays are definitely branched at least once.

There are 21 anal-fin pterygiophores. Two anterior-most pterygiophores are much longer than the rest; they are placed before the hemal spines of the fifth and sixth caudal vertebrae. The anal-fin pterygiophores are usually inserted individually in each interhemal space, with the exception of elements 17 and 18, which occupy the same interhemal space. The posterior pterygiophore is between the hemal spines of the sixth and seventh preural vertebrae.

The caudal peduncle, although short and deep, is well pronounced. Its length only slightly exceeds the height. The caudal fin is badly damaged. At least 16 principal caudal rays can be recognized, and about five procurrent rays are visible on the upper and lower lobes. The distal parts of the principal rays are damaged, so their length and the branching condition are unknown. In the caudal skeleton, the large lower hypural plate is guessed; the position of the opening for the caudal blood

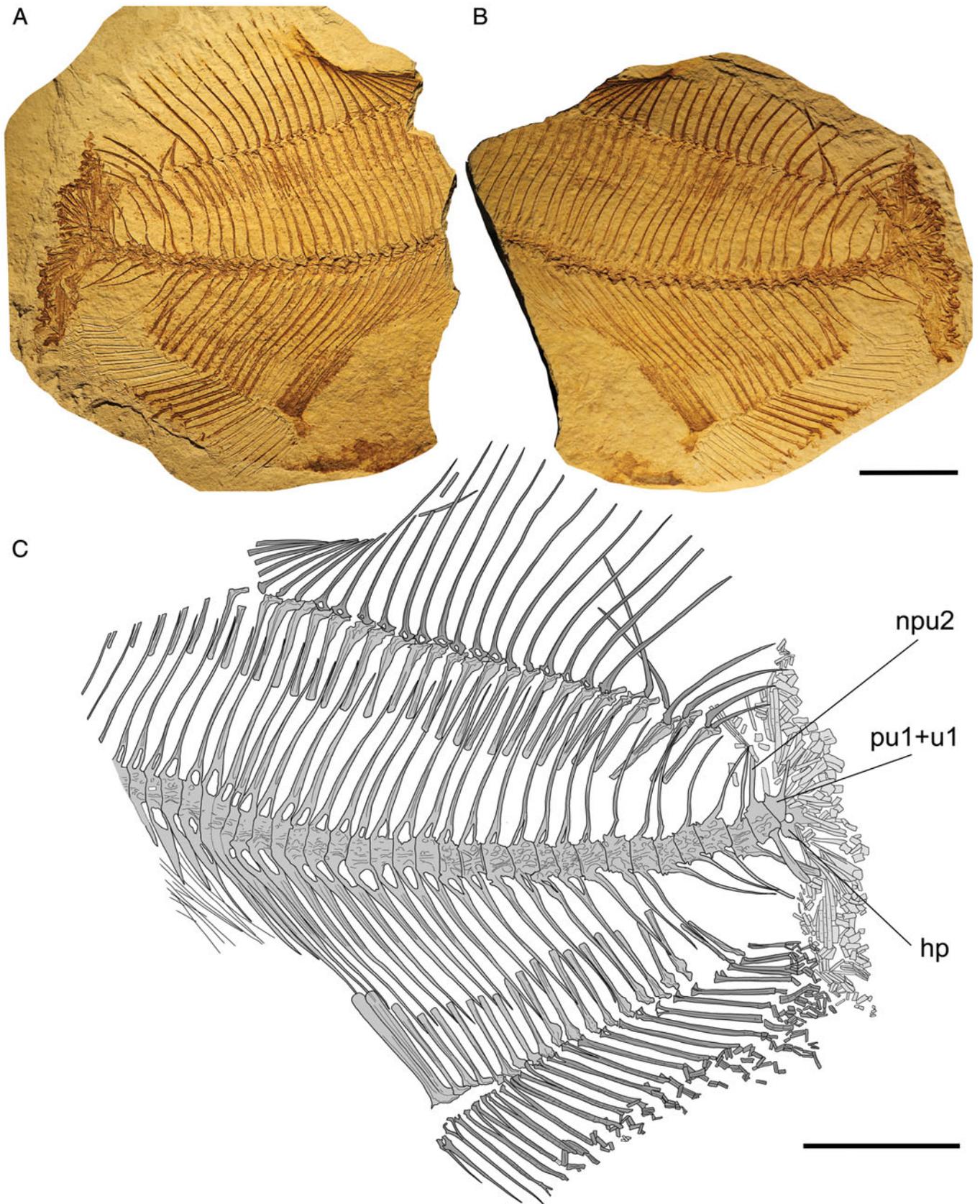


FIGURE 2. †*Zaprora koreana*, sp. nov., from the middle Miocene of Duho Formation, Pohang area, South Korea. **A**, part, **B**, counterpart, **C**, outline drawing of the holotype, KIGAM 9A168. **Abbreviations:** **hp**, hypaxial hypural plate; **npu2**, neural spine of the second preural vertebra; **pu1 + u1**, terminal centrum complex. Scale bars equal 10 mm.

vessels is unclear due to the very bad condition of this region. The condition of other hypurals and uroneurals is indiscernible. The terminal centrum (preural 1 + ural 1) with the prominent posterodorsal outgrowth. An elongated element positioned posteriorly to the neural spine of preural vertebra 3 is interpreted here as the fully developed neural spine of the second preural centrum because there are no visible inconsistencies or breaks between the centrum and this spine. The neural and hemal spines of preural vertebrae 2 and 3 are expanded distally. The hemal spine of the second preural centrum is probably autogenous.

Measurements (in mm): specimen length measured to the end of the hypurals, 52.2; body height at the beginning of the anal fin, 30.8; caudal peduncle height, 10.4; caudal peduncle length, 12.3; the length of 10 caudal vertebrae, 15.1; greatest dorsal spine length, 14.0; greatest anal spine length, 6.8; greatest anal ray length, 9.5. The standard length of the fossil specimen restored based on the proportions of *Z. silenus* ZIN 39003 is 86.8 mm.

DISCUSSION

Although it is very incomplete, the specimen described above shows characters easily allowing its identification as a member of the family Zaproridae. These characters are the high caudal body part in combination with the spinous dorsal fin, comparatively short-based anal fin with three anterior spines, well-pronounced caudal peduncle, and very high neural and hemal spines and fin spines and rays. Both molecular and morphological data show Zaproridae to be closely related to at least a portion of the Stichaeidae and some other families of the superfamily Stichaeoidea sensu McAllister and Krejsa, 1961 (Hilton and Stevenson, 2013). Within the mentioned group, there are several species that also possess the deep caudal body part, spinous dorsal fin, and long fin rays. These include some representatives of the prickleback subfamily Opistocentrinae (Stichaeidae) and wolffish (Anarhichadidae). These fishes are distinguished from zaprorids in having many more caudal vertebrae (more than 35, and usually more than 40) and anal fin rays (more than 30), and no more than two anal spines (Makushok, 1958; Barsukov, 1959; Hastings and Walker, 2003). The holotype of †*Z. koreana* reveals no essential differences from *Z. silenus* at the generic level and is treated as a species of the genus *Zaprora*.

Zaprora koreana, sp. nov., differs from other Zaproridae by its relatively short-based anal fin with 21 segmented rays and smaller number of caudal vertebrae (29). The known limits of variation of these characters for *Z. silenus* are 25–29 rays and 35–37 caudal vertebrae (Hilton and Stevenson, 2013; our data). †*Araeosteus rothi* has about 26–27 anal-fin rays and 34 caudal vertebrae (David, 1943). The new Neogene species differs from the modern congener also in having a shorter caudal peduncle: there are only six vertebrae posterior to the last pterygiophore of the anal fin in †*Z. koreana*, whereas there are 9–11 vertebrae in *Z. silenus* (Hilton and Stevenson, 2013; our data). Unlike the modern species, †*Z. koreana* is characterized by the long neural spine of the second preural vertebra (vs. short and much reduced spine in *Z. silenus*).

The locality of the new fossil prowfish is 5° south from the modern range of *Z. silenus* in the West Pacific. It is located at 36°N, i.e., approximately at the same latitude as the southern limits of the modern species in the East Pacific and as the location of the fossil †*Araeosteus* in California (34°N). Apparently, the range of Zaproridae in the West Pacific in the middle Miocene was wider than today and included the Eastern Sea (a.k.a. Sea of Japan). Probably, the disappearance of the

prowfishes from this sea is related to the cold intervals of the Pleistocene, which led to the extinction of many organisms, especially deep-sea inhabitants, in this basin.

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