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Taxonomic Review of the Rare Deep-sea Eelpout, *Lycenchelys maculata* (Pisces, Zoarcidae)

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Abstract Morphological characters and distribution of the rare deep-sea zoarcid fish, *Lycenchelys maculata*, are reviewed, including osteology and coloration. Eleven additional specimens document the species distribution in the Pacific Ocean from off Simushir Island (Kuril Islands) to off Kakegawa (Shizuoka Prefecture, Japan) at depths of 200–489 m. A photograph of a fresh specimen (32 cm TL) reported to be the species, published in 1984 and 1988, is not in part of the type specimens. Intraspecific variations are also reported for the color of tail and the pelvic fins. Diagnostic characters are revised and the taxonomic history and associated problems provided.
Key words: CT, distribution, fresh color, morphology, osteology, specimens, taxonomy.

Introduction

The zoarcid fish genus *Lycenchelys* Gill, 1884 is mainly distributed in the Northern Hemisphere, but species also occur in the South Pacific, southwestern Atlantic, Subarctic, and Antarctic (Shinohara and Anderson, 2007). The genus comprises more than 60 deep-sea species, about a quarter of the total number of valid species of the family (Kawarada *et al.*, 2020).

Lycenchelys maculata was originally described from 8 specimens collected at Onahama, Fukushima Prefecture, Japan (Toyoshima, 1985). Hatooka (2002, 2013) reported *L. maculata* from the type locality only, but had overlooked a record of 5 more specimens of the species reported in a catalog of zoarcid specimens deposited in the Russian Academy of Sciences (Balushkin *et al.*, 2011). Recently, Kawarada *et al.* (2020) extended the distribution of the species to the Pacific coast of the Kuril Islands, based on Balushkin *et al.* (2011).

This species first appeared in an illustrated book of the Japanese fishes (Toyoshima, 1984: 307), identified as *Lycenchelys* sp. with the Japanese name "Kurobuchi-hebigenge," and characterized by "irregular dark blotches on body, head, and dorsal fin." Subsequently, Toyoshima (1985) formally described the species without intending the previously published color photograph (Toyoshima, 1984: pl. 274-D) to represent the species and referred to its color only as the monochromatic tones dark or light (e.g., dark blotches on body), except for the branchial cavities (grayish) and peritoneum (black). Size of the photographed specimen (32 cm) does not match the holotype (288.0 mm TL) or the paratypes (282.6–298.4 mm TL).

A recent opportunity to examine the paratype and additional specimens in Japan and Russia, the latter including newly collected specimens, allow us to describe these specimens in detail (including the osteology) and to resolve some taxonomic problems for the species.

Materials and Methods

Specimens examined are deposited in the Hokkaido University Museum, Hakodate (HUMZ), the National Museum of Nature and Science (NSMT) and the Zoological Institute, Russian Academy of Sciences, Saint-Petersburg (ZIN); photographs of Mr. Hajime Masuda are in the Kanagawa Prefectural Museum of Natural History, Odawara (KPM).

Methods for taking counts and measurements follow Peden and Anderson (1978) and Anderson (1982), except for caudal-fin ray count, which follows Anderson (1982) only. Counts of vertebrae, vertical-fin and caudal-fin rays, and the examination of other osteological elements are based on radiographs. Terminology of head pores follows Anderson (1994). Total length (TL) and standard length (SL) were recorded throughout.

A map of collection sites (Fig. 1) showing bathymetric imagery was made with GMT 4.5.9 using data from ETOPO1 (Amante and Eakins, 2009)

Osteological characters (HUMZ 71362 and NSMT-P 109687) were investigated with computed tomography (CT) scanning using inspeXio SMX-225CR FPD HR Plus (Shimadzu, Kyoto), and three-dimensional reconstruction images produced by the rendering software VGSTUDIO MAX ver. 3.3 (Volume Graphics, Nagoya).

Taxonomy

Class Osteichthyes
Order Scorpaeniformes
Family Zoarcidae
Genus *Lycenchelys* Gill, 1884

Lycenchelys maculata Toyoshima, 1985
[Japanese name: Korobuchi-hebigenge]

(Figs. 2–7; Table 1)

Lycenchelys sp.: Toyoshima, 1984a: 293, pl.274-D (brief description with new Japanese name, Onahama); Toyoshima, 1984b: 307, pl.274-D (brief description, Onahama); Toyoshima, 1988a: 293, pl.274-D (brief description with new Japanese name, Onahama); Toyoshima, 1988b: 307 (brief description, Onahama)

Lycenchelys maculatus Toyoshima, 1985: 149, figs. 8–9 (original description, Onahama); Hatooka, 1993: 904, unnumbered fig. (key, Onahama); Imamura, 1998: 31 (list, Onahama); Shinohara *et al.*, 2009: 723 (list)

Lycenchelys maculata: Anderson, 1994: 117 (list); Hatooka, 2000: 1035, unnumbered fig. (key, Onahama); Hatooka, 2002: 1035, unnumbered fig. (key, Onahama); Anderson and Fedorov, 2004: 17 (list, Onahama); Shinohara and Anderson, 2007: 64 (key); Balushkin *et al.*, 2011: 980 (list, Pacific Ocean off Kuril Islands and Japan); Hatooka, 2013: 1229, unnumbered fig. (key, Onahama); Kawarada *et al.*, 2020: 19 (redescription, Pacific off Fukushima and Ibaraki prefectures and Kuril Islands)

Description. Counts and measurements are provided in Table 1.

Body elongated, cross section oval anteriorly, compressed laterally near tail. Snout length larger than eye diameter. Eye oval, not included to dorsal profile of head. Interorbital space narrow, its width less than 1/2 eye diameter. Nostril single, its tube short, not reaching upper lip when depressed. Mouth subterminal. Posterior end of upper jaw reaching below eye. Labial lobe present in lower jaw. Teeth on jaws, vomer and palatine. Gill slit not reaching to lower end of pectoral fin base. Opercular flap present. Gill rakers short, triangular. Pseudobranch filaments present. Lateral line single, positioned ventrally, incomplete, terminating above middle of anal fin base. Cycloid scales covering nape, body, tail and basal half of vertical fins. Dorsal fin origin above pectoral fin base. Pectoral fin reaching to middle of abdomen. Pelvic fins present or absent.

Osteology and dentition. Suborbital bones 6: 1st bone large and long, articulating with palatine; others tubelike. Suborbital bone configuration L-shaped pattern (*sensu* Anderson, 1994).

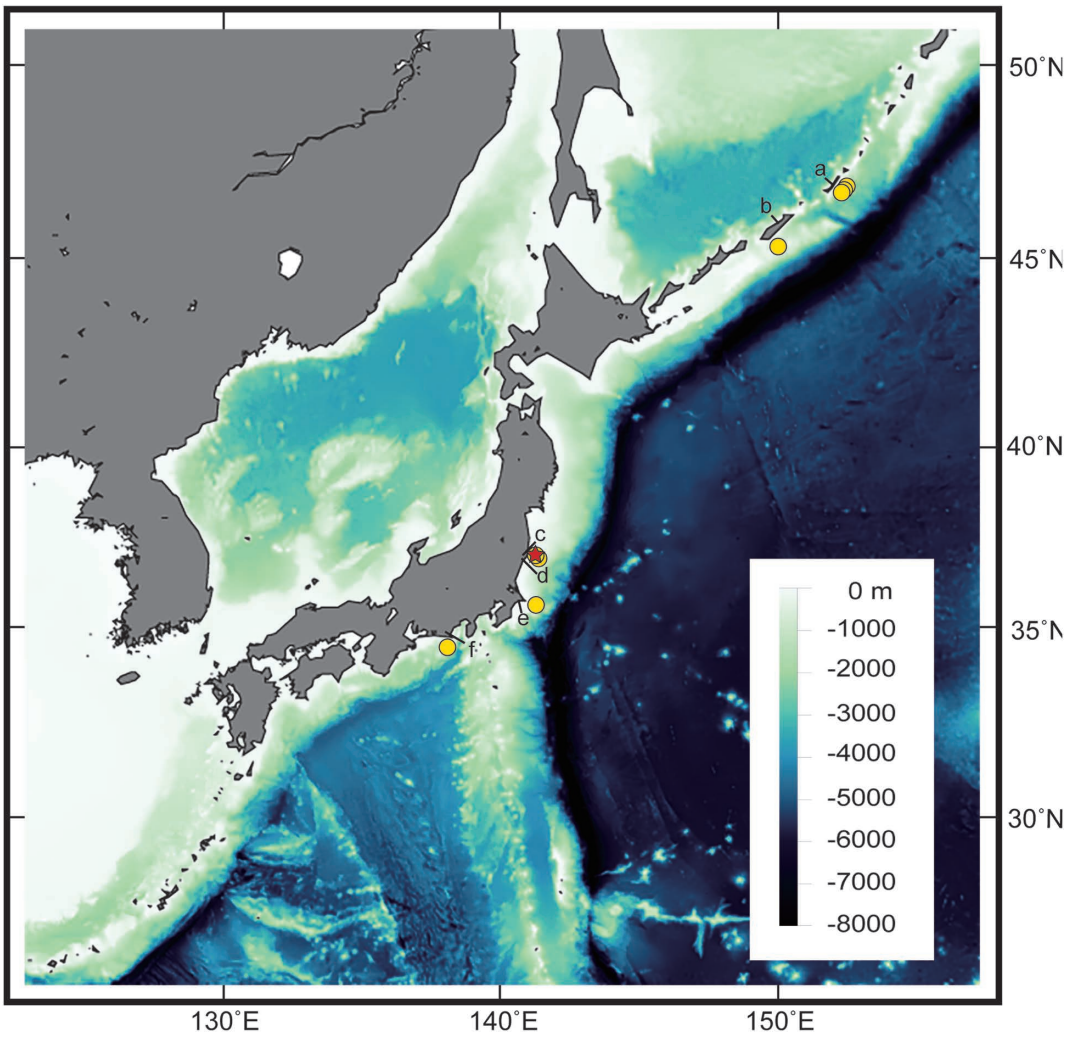

Fig. 1. Collection localities of *Lycenchelys maculata*. Red star, type specimens; yellow circles, additional specimens. a—Simushir Island, b—Urup Island, c—Onahama (Fukushima Prefecture), d—Nakoso (Fukushima Prefecture), e—Choshi (Chiba Prefecture), f—Kakegawa (Shizuoka Prefecture).

Supraorbital canal developed on nasal and frontal; postorbital canal on pterotic; temporal canal on parietal. Parietal small and squarish, both side bones separated by supraoccipital. Parasphenoid wing reaching mid-height of trigeminofacialis foramen, attached to frontal and pterosphenoid. Vomer with conical teeth (Fig. 4C). Posttemporal ventral ramus well developed. Maxilla long, slender; its posterior end slightly expanded. Premaxilla with developed ascending process, its alveolar process with conical teeth in single row ventrally (Fig. 4C). Groove supporting mandibular canal system developed on dentary and anguloarticular. Dentary with conical teeth dorsally; teeth arranged in 2 rows anteriorly and single row in middle and posteriorly. Hyomandibular with 2 articular heads for cranium dorsally, one for opercle posteriorly. Metapterygoid firmly attached to hyomandibular and symplectic posteriorly and to quadrate ventrally. Palatopterygoid series (mesopterygoid and ectopterygoid) slightly reduced. Palatine with conical teeth in single row ventrally (Fig. 4C). Preopercle largest and opercle 2nd largest in opercular bones. Preopercular

Fig. 2. Fresh condition of *Lycenchelys maculata*. A, NSMT-P 109687, 150.8 mm SL, off Onahama, Japan; B, KPM-NR 121356–121360, 32 cm TL, off Onahama, photographs taken by Mr. Hajime Masuda.

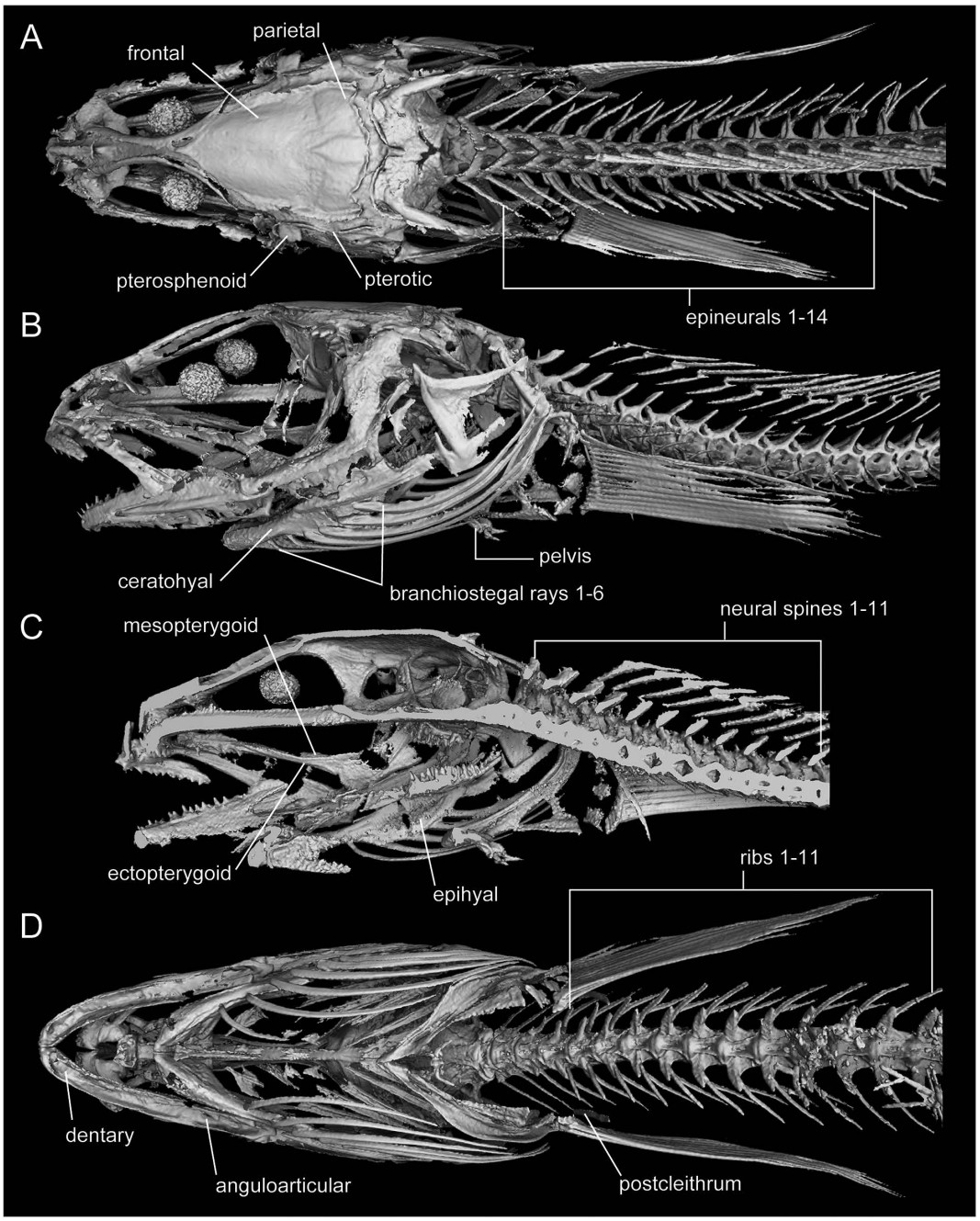

Fig. 3. CT images of head and anterior body osteology in *Lycenchelys maculata*, NSMT-P 109687, 150.8 mm SL. A, dorsal view; B, lateral view; C, medial view of right side (cross section); D, ventral view.

foramina for 7th preoperculomandibular pore at mid-height and 8th below dorsal edge. Ceratohyal-epihyal articulation smooth. Four branchiostegal rays on ceratohyal, 1 on ceratohyal-epihyal junction, and 1 on epihyal. Lower pharyngeal teeth developed. Upper pharyngeals with 3 tooth patches, associated with gill arches 2–4. First epibranchial rod-like. Scapular not

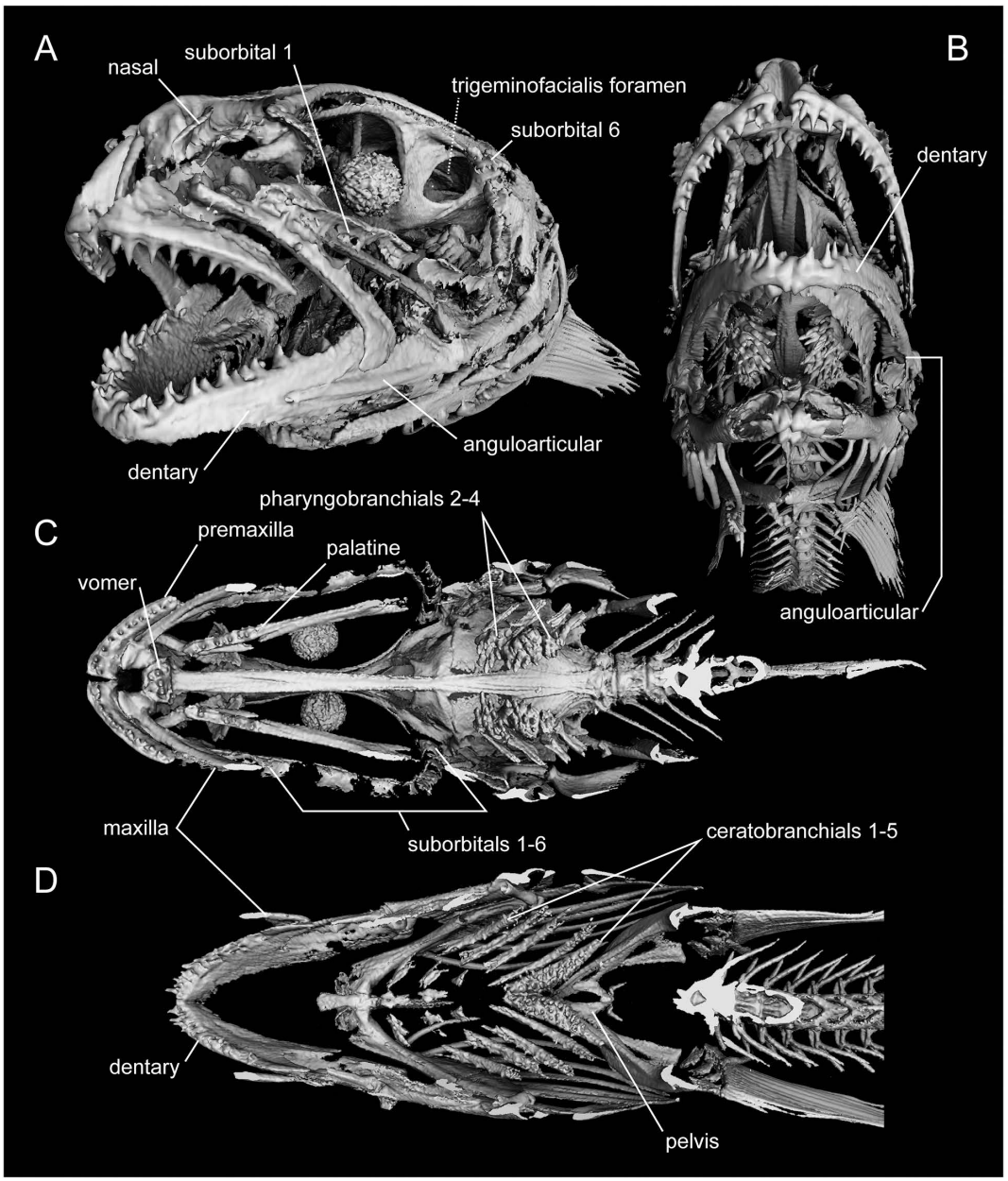

Fig. 4. CT images of head osteology in *Lycenchelys maculata*, NSMT-P 109687, 150.8 mm SL. A, frontal view of left side; B, frontal view of ventral side; C, ventral view of upper half (cross section); D, dorsal view of lower half (cross section).

attached to coracoid. Postcleithrum single, thin, rod-like. Actinosts 4: uppermost smallest. Pelvis attached to inside of cleithrum, supporting 0–2 rays. First dorsal fin pterygiophore associated with 3rd vertebra. Epineurals and ribs present. First neural spine small.

Color when fresh based on color photographs of NSMT-P 109687 and KPM-NR 121359–121360. Ground color of head and body light grayish (Fig. 2). Dorsal half of head dark brown with dark gray around eyes and in postorbital region. Occipital region slightly reddish brown. Head

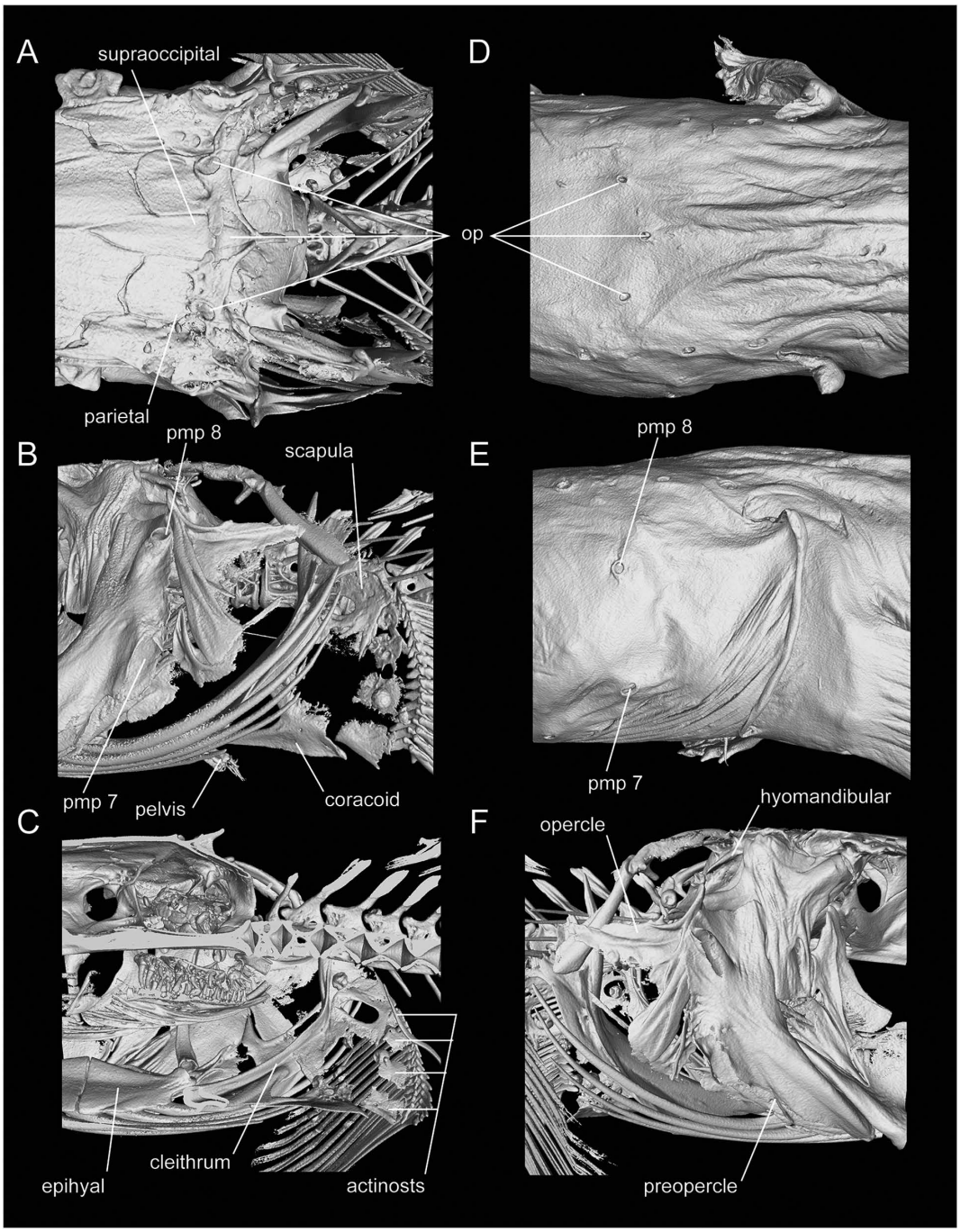

Fig. 5. CT images of osteology (A–C, F) and skin (D–E) in *Lycenchelys maculata*, HUMZ 71362, paratype, 279.5 mm SL. A, dorsal view; B, lateral view of left side; C, medial view of right side (cross section); D, dorsal view; E, lateral view of left side; F, lateral view of right side. op—occipital pores; pmp—preoperculomandibular pores.

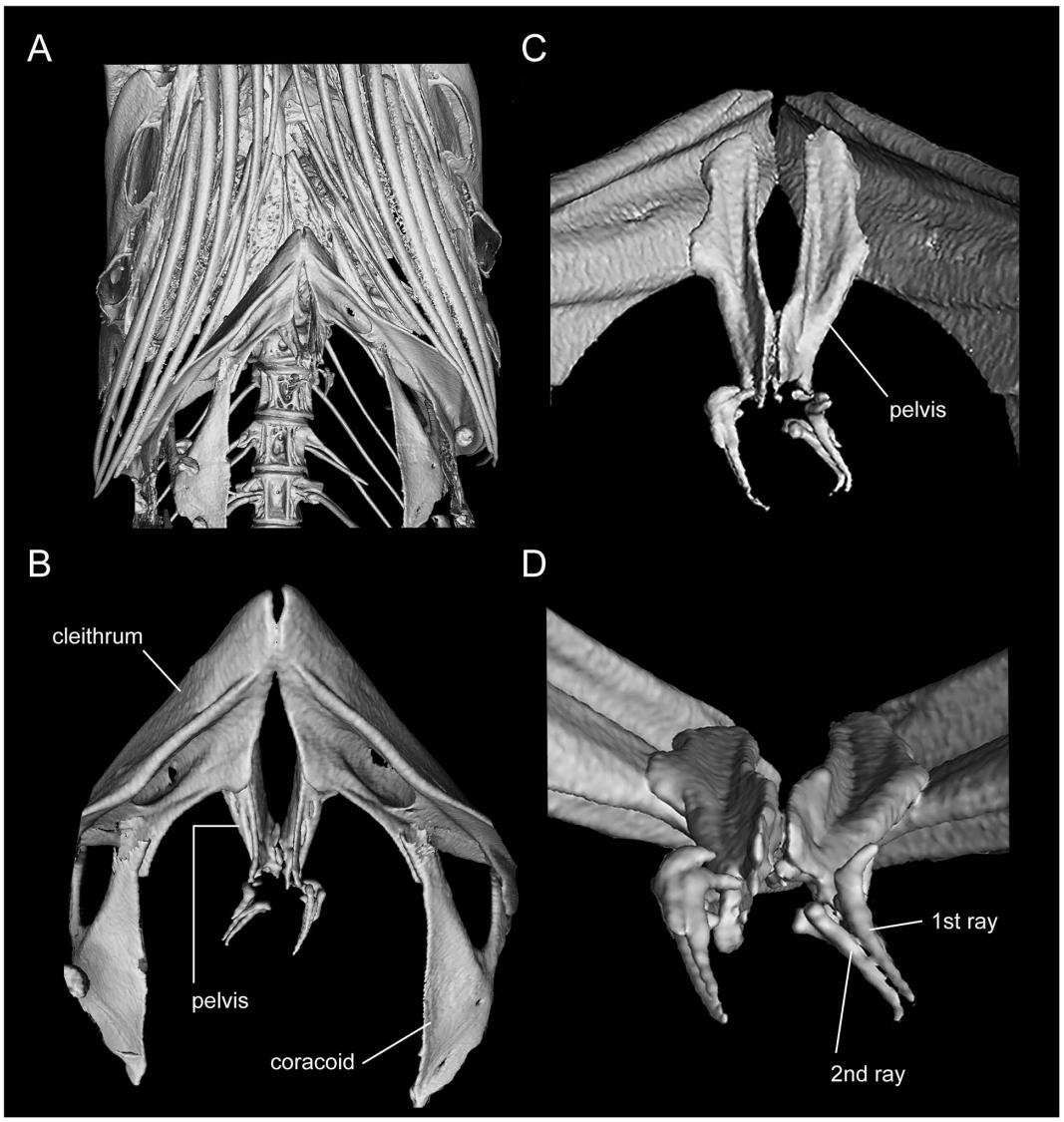

Fig. 6. CT images of pelvic girdle and fin rays in *Lycenchelys maculata*, HUMZ 71362, paratype, 279.5 mm SL. A, ventral view of head and throat; B, ventral view of pectoral and pelvic girdles with pelvic fin rays; C, dorsal view of pelvic girdle with rays; D, rear view of pelvic girdle with rays.

pores whitish on dorsal half of head. Black ocellus dorsally on opercle. Body with dark grayish irregular blotches dorsally and laterally but not on belly and anal fin base. Outer margin of dorsal fin dark brown. Upper lobe of pectoral fin dark near its base.

Color in alcohol. Head and body uniformly light to dark brownish. Outer margin of dorsal fin dark. Upper lobe of pectoral fin dark near its base. Branchial cavities light brown. Peritoneum dark brown. Dark irregular blotches present on head and body dorsally and laterally except for largest specimen (body color darkened) from Simushir Island (Fig. 7A) and the smallest specimen (body color faded) from Kakegawa (Fig. 7J), which lack prominent blotches. Some of specimens from Kuril Islands (Fig. 7A–D) with pale tail.

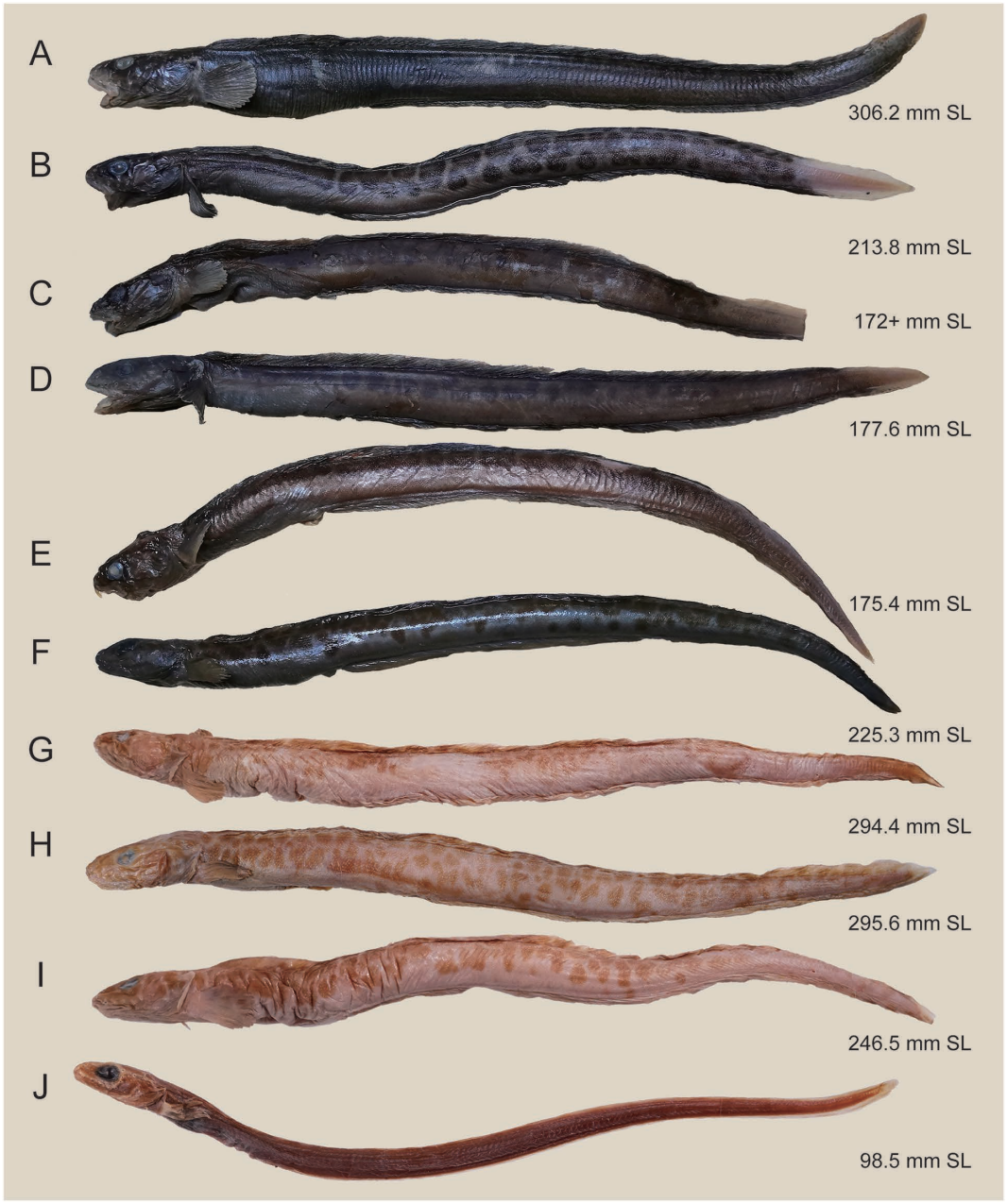

Fig. 7. Alcohol-preserved specimens of *Lycenchelys maculata*. A, ZIN 46270 (Simushir Island); B, ZIN 46271 (Simushir Island); C–D, ZIN 46272 (Simushir Island); E, ZIN 46273 (Urup Island); F, ZIN 44945 (Nakoso, Fukushima Prefecture); G, NSMT-P 10929 (Choshi, Chiba Prefecture), H, NSMT-P 10930 (Choshi); I, NSMT-P 10931 (Choshi); J, NSMT-P 102466 (Kakegawa, Shizuoka Prefecture).

Distribution. Known from Pacific off Simushir and Urup islands and off Onahama (Fukushima Prefecture), Nakoso (Fukushima), Choshi (Chiba) and Kakegawa (Shizuoka) at depths of 200–489 m.

Table 1. Counts and measurements of *Lycenchelys maculata.*

	Holotype (paratypes)*	NSMT-P 10929	NSMT-P 10930	NSMT-P 10931	NSMT-P 109687	NSMT-P 102466	ZIN 44945	ZIN 46271	ZIN 46272a	ZIN 46272b	ZIN 46270	ZIN 46273
SL (mm)	281.1 (264.4–287.5)	294.4	295.6	246.5	150.8	98.5	225.3	213.8	177.6	172 +	306.2	175.4
Sex	male (5 males, 2 females)	male	male	male	female	female	female	female	male	male	female	male
Counts												
Dorsal-fin rays	137 (134–138)	138	138	137	139	138	135	133	132	N/A	135	135
Anal-fin rays	118 (115–120)	119	118	118	120	120	117	109	109	N/A	112	113
Pectoral-fin rays	15 (14–15)	15	15	15	14	15	15	15	15	15	15	15
Caudal-fin rays	2 + 5 + 5 (2 + 5 + 5)	2 + 5 + 5	2 + 5 + 5	2 + 5 + 5	2 + 5 + 5	2 + 5 + 5	2 + 5 + 6	2 + 5 + 6	2 + 4 + 5	N/A	2 + 4 + 5	2 + 5 + 5
Precaudal vertebrae	29 (28–30)	29	30	29	30	29	29	32	32	32	32	32
Caudal vertebrae	112 (110–112)	112	111	109	112	115	110	106	104	N/A	106	106
Total Vertebrae	141 (137)	141	141	138	142	144	139	138	136	N/A	138	138
Gill rakers	11	11	12	11	11	11	10	13	11-13	11	13	12
Nasal pores	2 (2)	2	2	2	2	2	2	2	2	2	2	2
Postorbital pores	4 (4)	4	4	4	4	4	4	5	5	5	5(left)/6(right)	5
Suborbital pores	9 (8–9)	9	9	9	9	9	9	8	8	8	8	8
Preoperculomandibular pores	8 (8)	8	8	8	8	8	8	8	8	8	8	8
Interorbital pores	1 (1)	1	1	1	1	1	1	1	1	1	1	1
Occipital pores	3 (3)	3	3	3	3	3	3	3	3	3	3	3
Measurements as % SL												
Head length (HL)	12.2 (11.7–13.7)	13.9	13.8	14.0	10.7	11.5	11.5	11.8	13.1	N/A	12.6	11.4
Head width	6.8 (4.8–6.0)	7.1	6.8	6.2	7.2	4.8	5.3	5.5	6.4	N/A	5.9	5.1
Head depth	4.9 (4.6–5.3)	5.3	5.2	5.4	6.7	4.5	4.7	6.0	6.1	N/A	6.0	5.5
Upper jaw length	6.3 (4.1–6.4)	6.4	6.6	6.3	5.5	3.6	4.3	3.9	4.8	N/A	4.5	3.8
Snout length	3.8 (3.0–3.7)	4.4	4.4	4.6	5.0	3.3	3.2	3.6	3.8	N/A	3.6	3.1
Eye diameter	2.1 (2.4–2.8)	2.4	2.2	2.6	3.5	2.3	2.5	2.2	2.6	N/A	2.0	2.2
Interorbital width	0.9 (0.5–0.9)	0.8	0.7	0.6	0.7	0.4	2.0	1.4	1.6	N/A	1.8	1.6
Pectoral-fin length	5.5 (6.2–6.8)	5.8	5.9	6.3	9.9	6.6	6.3	6.0	5.8	N/A	5.9	6.4
Pectoral-fin base	2.7 (2.4–3.0)	2.5	2.5	2.9	3.4	2.3	2.2	2.5	3.1	N/A	2.8	2.4
Pelvic-fin length	0.9 (0.9–1.4)	1.3	1.2	0.8	2.0	1.3	0.6	N/A	N/A	N/A	N/A	N/A
Predorsal length	14.5 (12.5–14.5)	14.9	14.2	14.1	16.8	11.1	13.1	13.1	12.9	N/A	12.8	13.2
Preanal length	31.1 (28.7–30.2)	29.3	29.9	30.5	40.1	26.6	28.5	30.2	31.4	N/A	30.3	29.8
Gill slit length	4.0 (3.1–4.3)	4.2	4.1	4.2	4.8	3.2	3.6	3.6	4.2	N/A	4.2	3.6
Measurements as % HL												
Upper jaw length	51.4 (35.1–48.4)	46.2	47.7	45.0	34.0	33.9	37.2	33.3	36.6	34.1	36.0	33.0
Snout length	30.7 (25.1–27.8)	31.9	31.8	33.1	30.9	26.6	27.9	30.6	28.9	26.1	28.8	27.0
Eye diameter	17.1 (18.4–20.9)	17.3	16.0	18.6	21.5	25.1	22.1	18.3	19.8	19.0	16.1	19.5
Interorbital width	7.4 (4.6–7.1)	5.7	5.2	4.3	4.0	4.2	3.9	4.4	4.3	3.1	4.2	4.0
Pectoral-fin length	44.8 (46.0–53.4)	42.1	42.6	45.5	61.4	62.0	55.4	50.8	44.4	50.0	47.2	56.0
Pelvic-fin length	7.4 (6.9–10.3)	9.6	8.8	5.8	12.2	16.4	5.0	N/A	N/A	N/A	N/A	N/A
Pectoral-fin base/length ratio	49.2 (39.0–44.4)	42.1	42.4	45.7	34.4	27.4	35.0	41.4	53.4	40.1	47.8	37.5

*Data from Kawarada *et al.* (2020)

Discussion

Lycenchelys maculata was only recorded from off Onahama (type locality) before the report in Balushkin *et al.* (2011). A question remains about the photographed specimen (32 cm TL) provided by Toyoshima (1984). Its size does not match any of the specimens in the type series. Consequently, it is more likely that it was another specimen obtained Mr. Hajime Masuda. Mr. Masuda took the photo of the specimen collected during a trip to Onahama (2–8 February 1980), while the type specimens were collected earlier in 10–13 November 1977 (Toyoshima, 1985). Although the specimen of Mr. Masuda appears to be missing (H. Senou and F. Tashiro, personal communications), it is important information for the color of the species when fresh. A photograph of the anterior body of the same fish was discovered in the course of this study (bottom image in Fig. 2B).

Kawarada *et al.* (2020) erroneously added Ibaraki Prefecture as part of the distribution for the species because the latitude for the "Pacific Ocean, off Japan" recorded for ZIN 44945 (see Balushkin *et al.*, 2011: 980) is very close to the prefectural border between Fukushima and Ibaraki. We have found it to be Onahama, Fukushima Prefecture instead.

Compared to Kawarada *et al.* (2020), the additional specimens examined for this study have wider ranges for the following counts: dorsal fin rays 132–139 (vs. 134–139 in Kawarada *et al.*, 2020); caudal fin rays 2 on epural + 4–5 on upper hypural plate + 5–6 on lower hypural plate (vs. 2 + 5 + 5); precaudal vertebrae 29–32 (vs. 28–30); caudal vertebrae 104–115 (vs. 110–112); total vertebrae 136–144 (vs. 137–142); gill rakers 10–13 (vs. 11 based on holotype only); postorbital pores 4–6 (vs. 4). We regard the differences as intraspecific variations for the species.

According to Toyoshima (1985), the length of the holotype is 198.0 mm TL; however, we found it to be 288.0 mm TL, which is more consistent with the 281.1 mm SL reported by Kawarada *et al.* (2020).

Toyoshima (1984ab, 1988ab) described the pelvic fin in the species as having 3 soft rays, but Toyoshima (1985) did not report counts in the original description. Kawarada *et al.* (2020) was unable to count pelvic fin rays for type specimens. We found no pelvic fins in 4 of 11 specimens examined (Table 1). Although the other 7 specimens had pelvic fins, it was hard to count the fin rays with microscopes.

The pale tail in the 4 specimens from Simushir and Urup islands (Fig. 7A–D) is considered to be unrelated to sex as they comprise 2 males and 2 females. The difference in body color (dark brown in the 6 ZIN specimens vs. light brown in the type series and additional specimens in HUMZ and NSMT collections) is unclear.

A revised diagnosis for the species is as follows (new and/or revised characters in italics): *vertebrae 29–32 + 104–115 = 136–144*; *head length 10.7–14.0% SL*; interorbital pore 1; occipital pores 3; *postorbital pores 4–6*; suborbital pores 7 + 1–2; preoperculomandibular pores 8; vomerine teeth 1–6; palatine teeth 4–9, arranged in single row; opercular flap well developed; *pelvic fin with 0–2 rays*, *its base positioned anterior lower edge of gill opening when present*; lateral line incomplete and positioned ventrally, scales present on pectoral fin and absent on its base; body grayish when fresh; blackish irregular blotches on most portions of dorsal fin and dorsal part of body.

Miscellaneous Note

According to ledger records in ZIN, Dr. Vladimir V. Fedorov of the Laboratory of Ichthyology had planned to publish a description of a new species in the 1980s, based on the Russian specimens examined for this study. The new species was intended to be named "*maculata*," which coincidentally is same name chosen by Toyoshima (1985). He had also planned to establish a new genus for it, which he considered to be very close to *Lycenchelys*.

Materials examined. Specimens: HUMZ 71361,

1 specimen (holotype of *Lycenchelys maculata*), 281.1 mm SL, off Onahama, Fukushima Prefecture, depth 200–300 m, 13 Nov. 1977; HUMZ 71362, 1 specimen (paratype of *L. maculata*), 279.5 mm SL, collection locality and date same as the holotype; NSMT-P 10929–10931, 3 specimens, 246.5–294.4 mm SL, 35°45′N, 140°55′E, depth 300 m, off Choshi, Chiba Prefecture, 12 Apr. 1971; NSMT-P 109687, 1 specimen, 150.8 mm SL, off Nakoso, Fukushima Prefecture (36°56.76′N, 141°33.00′E), depth 410 m depth, 5 Nov. 2011; NSMT-P 102466, 1 specimen, 98.5 mm SL, off Kakegawa, Shizuoka Prefecture (34°22.88′N, 137°59.70′E–34°22.24′N, 138°00.10′E), depth 455–486 m, 10 Dec. 1995; ZIN 44945, 1 specimen, 225.3 mm SL, off Onahama (36°58′N, 141°29′E), depth 325 m, 9 Apr. 1973; ZIN 46270, 1 specimen, 306.2 mm SL, off Simushir Island (46°58′N, 152°18′E), depth 360–380 m, 3 Mar. 1982; ZIN 46271, 1 specimen, 213.8 mm SL, off Simushir Island (46°48′N, 152°00′E), depth 340–370 m, 5 Apr. 1982; ZIN 46272, 2 specimens, 172 + (tail broken)–177.6 mm SL, off Simushir Island (47°03′N, 152°19′E), depth 330–380 m, 7 Apr. 1982; ZIN 46273, 1 specimen,175.4 mm SL, off Urup Island (45°27′N, 149°49′E), depth 320 m, 11 Apr. 1982. Photographs: KPM-NR 121359–121360, 32 cm TL, Onahama, Fukushima Prefecture, 8–11 Feb. 1980.

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