Somniosus (Rhinoscymnus) cheni sp. nov., A New Species of Sleeper Shark (Squaliformes: Somniosidae) from Eastern Taiwan, with Aspects of Embryo Biology

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A new species of sleeper shark is described based on a 134.0 cm total length pregnant female collected from off Hualien, eastern Taiwan. The species belongs to a small species group (subgenus Rhinoscymnus) and can be distinguished from its congeners in having a smaller second dorsal fin, smaller eyes, more rows of teeth in the upper jaw and fewer in the lower jaw, and a different body proportion. Moreover, the specimen had 33 embryos, which is substantially more than the two other small species in the subgenus. Information on embryo biology are also provided.

Key words: Elasmobranch, Litter size, Morphology, Sex-bias, Taxonomy.

BACKGROUND

The family Somniosidae contains five genera: Centroscymnus, Scymnodalatias, Scymnodon, Somniosus, and Zameus. Most Somniosid sharks inhabit the seabed on continental and insular slopes, but few species are oceanic or semi-oceanic (Ebert et al. 2013a). Somniosus differs from the other genera in having its first dorsal fin situated at the middle of the dorsum, well behind the pectoral fin, but well before the pelvic fin, both dorsal fins without spines, second dorsal fin slightly smaller than first, and paddle-shaped caudal fin with long lower lobe (Compagno 1984; Yano et al. 2004; Ebert et al. 2013a). Yano et al. (2004) divided the genus Somniosus into two subgenera and recognized five nominal species. The total length (TL) of the subgenus Somniosus is over four meters; it is a large species group and comprises the Greenland shark S. (S.) microcephalus (Bloch and Schneider 1801) from the Arctic and North Atlantic; the Antarctic sleeper shark S. (S.) antarcticus Whitley (1939), from the Southern Hemisphere; and the Pacific sleeper shark S. (S.) pacificus Bigelow and Schroeder (1944), from the Arctic and North Pacific. The subgenus Rhinoscymnus is a small species group (< 150 cm TL) comprising the frog shark S. (R.) longus (Tanaka 1912) from the western Pacific, and the little sleeper shark S. (R.) rostratus (Risso 1827) from the eastern North Atlantic and Mediterranean Sea (Compagno 1984; Francis et al. 1988; Yano et al. 2004; Yano et al. 2007; Ebert et al. 2013a).

Cigala Fulgosi and Gandolfi (1983) redescribed S. (R.) rostratus based on the examination of external morphology of eight free-swimmers and 15 embryos; Francis et al. (1988) recorded S. (R.) rostratus that occurred in New Zealand waters of the Southern Hemisphere for the first time, however Roberts et al.
The present specimen were out range of other specimen measurements. Differences in the embryonic sex ratio (male: female) were tested using a chi-square test, and average TL and body weight (non-yolk total weight, BW) between the sexes were tested using t-tests. The holotype and 29 embryos are preserved at the Department of Environmental Biology and Fisheries Science (EBFS), National Taiwan Ocean University, Keelung, Taiwan. The other four embryos are preserved at the National Museum of Marine Biology and Aquarium, Pingtung, Taiwan (NMMB-P33387).

RESULTS

Somniosus (Rhinoscymnus) cheni sp. nov.
Taiwan Sleeper Shark
(Fig. 2, Tables 1, 2)
urn:lsid:zoobank.org:act:F3F4B53B-3970-49CB-B42A-0CE7BAF8020

Holotype: EBFSFSX001, 1340 mm TL, pregnant female, off Hualien, ca. 23°50'N, 121°50'E, eastern Taiwan, northwestern Pacific Ocean, landed at Cheng-Kung fish market, Taitung, long line, 17 March 2017.

Paratypes: NMMB-P33387, 2 males 145.5–147.0 mm TL and 2 females 134.9–135.8 mm TL, embryos taken from EBFSFSX001.

Etymology: The species is named in honor of Mr. Wen-Jong Chen, Taitung Xin Gang District Fisherman’s Association, for his contributions of chondrichthyan fish samples and research assistance with Taiwan and international research for over 30 years.

Diagnosis: A species of Somniosus (Rhinoscymnus) can be distinguished from its congeners by a combination of the following characters: no anal fin; two spineless dorsal fins, first dorsal fin higher and larger than second dorsal fin; a short lateral keels on the caudal peduncle, no precaudal pits; caudal fin asymmetrical and paddle-shaped, with a relatively short upper lobe and long lower lobe; rhomboid-shaped dermal denticles; teeth dissimilar in upper and lower jaws, upper-jaw teeth small with lanceolate, in 72 rows, lower-jaw teeth semioblique with low roots, in 28 rows; precaudal vertebrae 60–61, caudal vertebrae 15–18, and 75–78 in total; number of turns in spiral valve 25–26. In mid-term embryo stage (12.8–15.0 cm TL), body color light brown to yellow-grayish; teeth and dermal denticles absent; sexes identifiable; caudal keel present.

Description: Proportional dimensions in percentage of TL are given in table 1. Body slender, almost cylindrical, no anl fin. Fork length 93.1% TL, precaudal length (PCL) 82.5% TL (Fig. 2). Snout...
Fig. 1. The landing position (Cheng-Kung) and fishing boat’s base (Hualien).

Fig. 2. Holotype of Somniosus (Rhinoscympus) cheni sp. nov. (EBFSFSX001), pregnant female, 1340 mm total length. Photo by C. Y. Lin.
rounded, short and conical (Fig. 3); preoral length 26.2% HL. Head moderately long, HL 25.5% PCL. Gill opening moderately wide, last one about as long as first four, length of fifth gill opening 8.5% HL (Fig. 3). Mouth slightly arched, its width 35.1% HL (Fig. 3). Eye oval, horizontal diameter of eye 21.3% of length from snout tip to eye. Spiracle small, almost circular, maximum diameter of spiracle 6.1% prebranchial length.

Two spineless dorsal fins, first dorsal fin higher than second dorsal fin, height of first dorsal fin 4.9% PCL and height of second dorsal fin 2.9% PCL; overall length of second dorsal fin 88.7% of that of first dorsal fin (Fig. 4). Interdorsal space longer than HL, its length 30.7% PCL. Pectoral fins short, overall length 85.3% of distance between base of pelvic fin and caudal fin (Fig. 4). Distance between base of pectoral fin and pelvic fin 42.3% PCL. Caudal peduncle short, distance between base of second dorsal fin and caudal fin 9.6% PCL; short lateral keels on the caudal peduncle, length of keel 5.1% PCL. No precaudal pits. Caudal fin asymmetrical and paddle-shaped, with a relatively short upper lobe and long lower lobe, and strong subterminal notch; length of lower caudal lobe and 90.2% of length of upper lobe (Fig. 4).

Color uniformly brownish, with narrow but not conspicuous dark brown edges on dorsal, pectoral and pelvic fins, and caudal fin with wider but also not conspicuous dark brown edge (Fig. 2).

Teeth dissimilar in upper and lower jaws, upper small, with lanceolate, arranged in 72 rows; lower with semioblique with low roots, arrange in 28 rows (Fig. 5). Precaudal vertebrae 60 (60–61), caudal vertebrae 17 (15–18), and 77 (75–78) in total; number of turns in spiral valve 25–26 (Table 2).

Dermal denticles of lateral trunk flat basically rounded, sharp, and semioblique. Dermal denticles of lateral trunk flat densely distributed in the rear parts of the body.

Table 1. Proportional dimensions expressed as the percentage of the total length for Somniosus (Rhinocymbus) cheni (Sc) collected from Taiwan (TW); S. (R.) rostratus (Sr) including the holotype of S. bauchotae (Sb) collected from the Mediterranean Sea (MD), New Zealand (NZ) and North Atlantic (NA); and S. (R.) longus (Sl) collected from Japan (JP) and NZ. Data sources: 1. this study; 2. Francis et al. 1988; 3. Barrull and Mate 2001; 4. Yano et al. 2004.

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24 Mouth: width  7.39$  6.0  9.7  6.9  6.0  5.7  5.8  6.0  6.8  6.3  6.2

Gill opening lengths:

25 1st  1.94  1.7  1.8  1.5  1.6  2.0  1.5  1.5  2.0  2.1  1.9
26 2nd  2.01$  1.8  1.7  1.6  1.5  1.5  2.0  1.5  1.5  2.0  1.9
27 3rd  1.64  1.8  1.7  1.8  1.5  1.5  1.5  1.9  1.9  1.9  1.9
28 4th  1.72  1.8  1.9  1.6  1.5  1.5  1.9  1.9  1.9  1.9  1.9
29 5th  1.79  2.4  2.2  2.2  2.6  2.2  2.3  1.8  2.4  2.3  2.7
30 spiracle  0.90$  0.7  0.5  0.8  0.6  0.8  0.4  0.7  

Eye:

31 horizontal diameter  1.19  1.5  2.9  2.2  1.9  1.8  1.7  1.7  1.6  1.5  1.3
32 vertical diameter  1.12  1.4  0.8  1.6  1.2  1.4  0.7  1.5  1.7  1.5  1.7

1st dorsal fin:

33 overall length (from AO)  19.10$  14.7  13.3  14.6  10.4  12.5  13.7  13.7
34 overall length (from PO)  10.60  13.5  
35 length base (from AO)  7.99$  9.0  8.1  8.4  8.4  8.9  7.4  8.6  8.1  7.8
36 length base (from PO)  6.94  6.4  7.5  
37 length posterior margin  5.60  5.1  5.7  6.7  6.6  3.0  4.2  7.6  5.9  
38 height  4.03  4.0  5.5  3.6  4.2  3.7  3.6  3.9  4.4  3.8  4.0  4.0
39 Interorbital width  8.66  9.7  9.0  8.3  7.8  8.8  7.6  8.3  

2nd dorsal fin:

40 overall length  9.40  10.0  11.8  11.8  11.2  10.4  11.3  13.6  13.7  
41 length base  5.97  5.9  5.0  6.1  6.8  5.6  5.9  6.3  7.5  8.8  5.7  4.7
42 length posterior margin  6.27  4.5  7.2  6.7  6.0  5.5  7.3  7.5  6.8  
43 height  2.39  2.2  7.0  2.5  2.1  2.2  2.3  2.4  2.5  2.1  2.5  2.4

Pectoral fin:

44 length base  6.49  5.3  5.5  6.8  4.2  5.6  5.5  5.6  5.4  5.5  6.4  6.9
45 length anterior margin  12.76  12.7  12.0  13.3  11.8  12.7  11.6  11.5  13.5  11.4  12.2  12.4
46 length distal margin  2.84  2.5  6.8  4.8  5.3  4.7  3.8  5.0  4.6
47 length posterior margin  7.99$  6.1  7.3  6.6  5.5  7.3  7.8  6.4  6.6  6.6

Pelvic fin:

48 overall length  9.93  10.0  9.3  9.5  8.8  9.5  11.5  9.6  9.4  9.7
49 length base  7.01$  5.6  5.0  6.8  5.7  6.8  6.4  7.1  6.5  5.7
50 length anterior margin  6.42  5.5  6.5  5.1  6.0  5.2  6.5  6.5  6.1  5.6  6.8
51 length distal margin  5.30$  3.5  3.6  3.9  2.9  2.7  2.5  0.3  0.7
52 length claspers  9.0  7.1  
53 (from pelvic axil)  1.3  1.6  

Caudal fin:

54 length dorsal lobe  15.97  19.90  17.5  19.7  17.6  18.9  18.4  19.6  18.2  17.8  18.9
55 length ventral lobe  14.40  15.5  14.0  14.7  13.3  14.4  14.4  13.1  15.0  14.8  13.6  14.0
56 dorsal tip to notch  7.91  5.7  8.4  7.2  8.1  8.9  9.0  8.3  
57 depth notch  1.64$  7.5  2.9  2.1  2.4  1.7  1.5  1.3  1.5

Trunk at pectoral origin:

58 width  11.34  10.8  11.5  13.0  11.8  11.5  10.1  10.7
59 height  17.01$  9.7  10.3  10.6  11.6  12.5  7.6  11.2
60 Length from snout tip to pectoral end  28.73  36.6  33.7  34.0  30.1  32.1  32.9  32.6
61 Distance between preoral clefts  8.51  
62 Length eye to 1st gill opening  7.84$  8.2  9.5  8.0  9.0  9.0  8.8
63 Keel length  4.18$  4.3  3.6  4.4  4.6  2.2  3.2  3.6  2.8  3.9

Each number of measurements is from figure 1 in Yano et al. 2004. $: significantly different to the mean of Sr and Sb ($P < 0.05$). $: significantly different to the mean of Sl ($P < 0.05$).
rhomboidal in shape with wide crowns and without conspicuous horizontal cusps, giving the skin a smooth texture (Fig. 6).

**Distribution:** Currently known from the holotype collected in canyons surrounded by deep-sea longliner off eastern Taiwan at a depth greater than 500 m.

**Comparison:** According to comparison of length proportional measurements among the present individual and two other *Rhinoscymnus* species, a total of 18 item values are outside of the measurement range of *S. (R.) rostratus*. Of these 18 items, 11 were significantly different to the average length (*P* < 0.05) (Table 1). In addition, a total of 25 item values are outside of the measurement range of *S. (R.) longus*, and 12 of these were significantly different to the average length (*P* < 0.05) (Table 1). In total, 16 item values are outside of the measurement range of both *S. (R.) rostratus* and *S. (R.) longus*, six items of these were significantly different to the average length of both species (*P* < 0.05) (Table 1).

In meristic counts, the number of tooth rows in the upper jaw 72 and number of tooth rows in the lower jaw 28 are clearly different from 53–57 tooth rows in upper jaw and 31–36 in lower jaw in two other *Rhinoscymnus* species (Table 2, Fig. 5). The number of turns in the spiral valve (25–26) is similar to that of *S. (R.) longus* (26–27) but higher than *S. (R.) rostratus* (23) (Table 2). The total vertebral number (77) is similar to those of two other species (77–79), with similar combinations of precaudal and caudal vertebrae.

The arrangement of dermal denticles (Fig. 6) is loose, and there are spaces between denticles, similar to in *S. (R.) longus* (Yano et al. 2004: fig. 8C), but unlike *S. (R.) rostratus* (Cigala Fulgosi and Gandolfi 1983: fig. 8G) whose denticles are arranged closer together with more overlaps. The shape of the dermal denticles without conspicuous horizontal cusps is different from those of two other *Somniosus* (*Rhinoscymnus*) species (Fig. 6; vs. Cigala Fulgosi and Gandolfi 1983: fig. 8G; Yano et al. 2004: fig. 8C).

Moreover, Yano et al. (2004) reported that the overall length of the second dorsal fin and the first dorsal fin and horizontal diameter of eye of length from

### Table 2. Meristic characters of *Somniosus* (*Rhinoscymnus*) *cheni* sp. nov., *S. (R.) rostratus* and *S. (R.) longus*

<table>
<thead>
<tr>
<th>Species</th>
<th><em>Somniosus (R.) cheni</em> sp. nov.</th>
<th><em>S. (R.) rostratus</em></th>
<th><em>S. (R.) longus</em></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Sources</strong></td>
<td>This study</td>
<td>Yano et al. 2004</td>
<td>Yano et al. 2004</td>
</tr>
<tr>
<td>Number of tooth rows</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Upper jaw</td>
<td>72</td>
<td>53</td>
<td>56–57</td>
</tr>
<tr>
<td>Lower jaw</td>
<td>28</td>
<td>31–36</td>
<td>31–32</td>
</tr>
<tr>
<td>Number of spiral valve turns</td>
<td>25–26</td>
<td>23</td>
<td>26–27</td>
</tr>
<tr>
<td>Vertebral count</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Precaudal</td>
<td>60–61</td>
<td>58</td>
<td>58–59</td>
</tr>
<tr>
<td>Caudal</td>
<td>15–18</td>
<td>20</td>
<td>18–21</td>
</tr>
<tr>
<td>Total</td>
<td>75–78</td>
<td>78</td>
<td>77–79</td>
</tr>
</tbody>
</table>
Fig. 4. Closeup of fins of *Somniosus (Rhinoscymnus) cheni* sp. nov., from the holotype. A, right pectoral fin, dorsal view. B, right pelvic fin, dorsal view. C, first dorsal fin, left side, lateral view. D, second dorsal fin, left side, lateral view. E, caudal fin, left side, lateral view. Not to scales, anterior to left.

Fig. 5. Closeup of teeth of *Somniosus (Rhinoscymnus) cheni* sp. nov., from the holotype.

Fig. 6. Dermal denticles on the trunk below first dorsal fin of holotype, *Somniosus (Rhinoscymnus) cheni* sp. nov., anterior to up.
snout tip to eye are diagnostic for distinguishing S. (R.) rostratus and S. (R.) longus. The overall length of the second dorsal fin 49.2% of first dorsal fin is lower than those of S. (R.) rostratus (76–88%) and S. (R.) longus (91–100%); horizontal diameter of the eye of the length from snout tip to eye 21.3% is lower than 33% of S. (R.) rostratus and 46% of S. (R.) longus.

**Key to species of the genus Somniosus**

1a. Small sharks with adults not exceeding 1.5 m in total length; rhomboid-shaped dermal denticles; semioblique cusps teeth on lower jaw, number of tooth rows in the lower jaw 28–36; number of turns in spiral valve less than 28; vertebral counts more than 74 ................................................................. 2

1b. Large sharks (adults about 4 m or more); hook-shaped dermal denticles; strongly oblique cusps lower teeth, number of tooth rows in the lower jaw 45–63; number of turns in spiral valve more than 29; vertebral counts less than 45 ........................................ 4

2a. Number of tooth rows in the upper jaw 72, number of tooth rows in the lower jaw 28 .......... S. (R.) cheni (Eastern Taiwan)

2b. Number of tooth rows in the upper jaw 53–57, number of tooth rows in the lower jaw 31–36 ................................................................. 3

3a. Overall length of second dorsal fin 76-88% of that of first dorsal fin; horizontal diameter of eye 27–37% (mean 33%) of length from snout tip to eye; number of tooth rows in the upper jaw 53; number of turns in spiral valve 23 ................................................................. S. (R.) rostratus (Mediterranean and Atlantic Ocean)

3b. Overall length of second dorsal fin almost equal to first dorsal fin (91–100%); horizontal diameter of eye more than 30–56% (mean 43%) of length from snout tip to eye; number of tooth rows in the upper jaw 56–57; number of turns in spiral valve 26–27 ................... S. (R.) longus (Japan and New Zealand)

4a. Interdorsal space almost equal to length from snout tip to first gill opening (prebranchial length); length from snout to first dorsal origin less than 45% of total length; number of turns in spiral valve 29-34 (mode 31); precaudal vertebral number 31–36 ............... S. (S.) microcephalus (Arctic and North Atlantic)

4b. Interdorsal space less than length from snout to first gill opening; length from snout to first dorsal origin more than about 45% of total length; number of turns in spiral valve more than 32; precaudal vertebral number less than 31 ................................ 5

5a. Interdorsal space about 70% of prebranchial length; height of first dorsal fin about 3.7% of precaudal length (PCL), height of second dorsal fin about 3.4% of PCL; number of turns in spiral valve 32–37 (mode 33); precaudal vertebral number 28–30 (mode 29) ........................................ S. (S.) pacificus (North Pacific)

5b. Interdorsal space about 80% of prebranchial length; height of first dorsal fin about 3.0% of PCL, height of second dorsal fin about 2.9% of PCL; number of turns in spiral valve 36–41 (mode 39); precaudal vertebral number 30-31 (mode 30) .................. S. (S.) antarcticus (South Indo-Pacific, South Atlantic)

**Embryos biology:** A total of 33 mid-term embryos—eight males and 25 females—were found in the specimen and preserved in EBFS and NMMPA (Fig. 7). The sex ratio of 8:25 indicated that there were significantly more female than male embryos ($X^2 = 8.76$, $P = 0.003$). All embryos contained a huge yolk sac, with body pigments deposited as light brown to yellow-grayish, teeth and dermal denticles were totally absent, sexes could be identified, and a caudal keel had developed (Fig. 7). However, only two male and two female embryos with complete yolk sac were preserved, one female remained partial yolk, and others’ yolk sacs were damaged during transportation and dissection (Figs. 7 and 8). Embryonic TLs were 13.7–14.7 cm for males (average 14.3 cm, $n = 8$) and 12.8–15.0 cm for females (average 14.0, $n = 25$), and BWs were 15.70–19.62 g for males (average 17.4 g, $n = 6$) and 13.47–19.54 g for females (average 16.3 g, $n = 22$). The average TL was not significantly different between sexes ($t = 1.54, P > 0.05$), and neither was the average BW ($t = 1.58, P > 0.05$), thus the average TL and BW of embryos were 14.0 cm and 16.55 g, respectively. Total weights of the other four embryos with complete yolks were 90.92–100.00 g, with an average of 95.47 g.

**DISCUSSION**

Before the present specimen, only S. (S.) pacificus of genus Somniosus had been recorded in Taiwan, and most individuals were caught in Hualien by deep-sea longline fishery, a small and localized fishery where very few coastal fishing boats operate. This kind of deep-sea fishery deployed 500–1000 m deep bottom-set longlines in canyons surrounding seamounts in a small region, and the present specimen was also caught by the same fishery in a similar operation area (Wang and Yang 2004).

Small sleeper sharks were found and named in 1827 and 1912; however, there are very few recorded encounters, particular for S. (R.) longus (Risso 1827; Tanaka 1912). The S. (R.) rostratus specimens were also only found from the Mediterranean, the North Atlantic, and New Zealand waters in the Southern Hemisphere (Yano et al. 2004; Ebert et al. 2013a).

In the report from Yano et al. (2004), the ratio of the overall length of two dorsal fins and the proportion of the horizontal diameter of eye of the length from snout tip to eye are two of keys to distinguish S. (R.) longus and S. (R.) rostratus. In S. (R.) cheni, these two values are clearly smaller than in the two other species, although these measurements might be different because they were preserved specimens (Sotola et al. 2019). In addition, at least six morphometric measurements in S. (R.) cheni are significantly different to those of S. (R.) longus and S. (R.) rostratus (Table 1).

The other keys using tooth count and the number of turns in the spiral valve to distinguish S. (R.) longus and S. (R.) rostratus were also used to distinguish S. (R.) cheni (Table 2; Yano et al. 2004). The tooth count in the upper jaw is clearly higher in S. (R.) cheni than in S. (R.) rostratus or S. longus, and the tooth count in
the lower jaw is clearly lower in *S. (R.) cheni* than in *S. (R.) rostratus* or *S. (R.) longus* (Yano et al. 2004). The number of turns in the spiral valve of *S. (R.) cheni* is similar to that of *S. (R.) longus* but clearly higher than that of *S. (R.) rostratus* (Table 2; Yano et al. 2004).

There were some observations on the reproduction of *S. (R.) rostratus* in previous studies. Two pregnant females from the Mediterranean Sea contained nine and eight embryos, one litter of which contained six males and two females (Cigala Fulgosi and Gandolfi 1983; Barrull and Mate 2001). Litter sizes of two *S. (R.) rostratus* individuals were similar (8–9), but relatively

![Fig. 7. Embryos of holotype, Somniosus (Rhinoscymnus) cheni sp. nov., individuals of the first column from the left are males, the others are females.](image)
smaller than those of S. (R.) cheni’s 33 embryos (Cigala Fulgosi and Gandolfi 1983; Barrull and Mate 2001). Embryonic sex-bias with more males occurred in one Mediterranean S. (R.) rostratus, and its status was contrary to S. (R.) cheni, although there was only one specimen with a description of the embryo for both species (Barrull and Mate 2001).

**CONCLUSIONS**

The rows of teeth in the upper and lower jaws distinguished the present specimen from other sleeper shark species. The high degree of variability in morphometric measurements and meristic counts among three small sleeper shark species, and the different reproductive strategy between Somniosus (R.) rostratus and S. (R.) cheni, suggest that S. (R.) cheni is a new sleeper shark species.

**List of abbreviations**

TL, total length.
S. (S.), Somniosus (Somniosus).
S. (R.), Somniosus (Rhinoscyllium).
BW, body weight (non-yolk total weight).
EBFS, Department of Environmental Biology and Fisheries Science.
NMMA, National Museum of Marine Biology and Aquarium.
PCL, precaudal length.
HL, head length.
Sc, Somniosus (R.) cheni sp. nov.
TW, Taiwan.
Sr, S. (R.) rostratus.
Sb, S. bauchotae.
MD, Mediterranean.
NZ, New Zealand.
NA, North Atlantic.

**Fig. 8.** Male A and female B embryos with complete yolk sac. Scale bar = 15 cm.
SI, S. (R.) longus.
JP, Japan.

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Authors' contributions: HHH performed analysis and wrote the manuscript; CYL processed, measured and photographed samples; SJJ processed and measured samples, and reviewed the manuscript.

Competing interests: HHH, CYL, and SJJ declare that they have no conflict of interests.

Availability of data and materials: Holotype measurements and comparing data with other species are all showed as in Table 1. Paratypes and other embryos measurements are available from the corresponding author on reasonable request. Holotype and paratypes are recently stored at the National Museum of Marine Biology and Aquarium, Pingtung, Taiwan, and other embryos of the holotype are stored at the Department of Environmental Biology and Fisheries Science, National Taiwan Ocean University, for comparing and processing the specimens; and Hsuan-Ching Ho, National Museum of Marine Biology & Aquarium, for improving the manuscript and curatorial assistance.

Consent for publication: All the authors consent to the publication of this manuscript.

Ethics approval consent to participate: Not applicable.

REFERENCES

Bloch ME, Schneider IG. 1801. Systema icthyoelogiae iconibus ex illustriatum. Schneider, Berolini, Germany.
Tanaka S. 1912. Figures and descriptions of the fishes of Japan, including the Riukiu Islands, Bonin Islands, Formosa, Kurile Islands, Korea and southern Sakhalin, vol 6. Maruya, Tokyo, Japan.