

First Record of a Sicydiine Goby, *Stiphodon multisquamus* (Actinopterygii: Gobioidae: Gobiidae), from Okinawa Island, Japan

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The morphology of four specimens of *Stiphodon multisquamus* Wu and Ni, 1986, collected from two streams on Okinawa Island in the Ryukyu Archipelago, is described. This is the first record of this species of goby from Japan; it was formerly regarded as endemic to southern China (Hainan and Guangdong Provinces). *Stiphodon multisquamus* is very rare on Okinawa Island and may have arrived as a result of transport of pelagic larvae by ocean currents.

Key Words: *Stiphodon*, Sicydiinae, freshwater fish, amphidromy, colonization, Okinawa Island, Ryukyu Archipelago.

Introduction

The sicydiine gobies of the genus *Stiphodon* Weber, 1895 are distributed in freshwater streams from Sri Lanka and the western coast of Sumatra in the Indian Ocean, to southern Japan, northeastern Australia, and French Polynesia in the Pacific (Watson 1995). This genus comprises both endemic species, known only from a single small island (e.g., *Stiphodon julieni* Keith, Watson and Marquet, 2002 from Rapa, French Polynesia) (Keith *et al.* 2002) or a single river system (e.g., *Stiphodon laron* Watson, 1996 from the Gogol River System, Papua New Guinea) (Watson 1998), and widespread species, such as *Stiphodon semoni* Weber, 1895, which occurs in Indonesia, Papua New Guinea, the Solomon Islands, and northeastern Australia (Maeda and Tan 2013). At present, however, the distributions of most species of *Stiphodon* are not well understood, due to the lack of thorough faunal studies (Maeda and Tan 2013).

In Japan, five species of *Stiphodon*, *S. atropurpureus* (Herre, 1927), *S. surrufus* Watson and Kottelat, 1995, *S. imperorientis* Watson and Chen, 1998, *S. percnopterygionus* Watson and Chen, 1998, and *S. alcedo* Maeda, Mukai and Tachihara, 2012, have been reported (Maeda *et al.* 2012a). In the present study, the occurrence of a sixth species, *Stiphodon multisquamus* Wu and Ni, 1986, on Okinawa Island, the largest island in the Ryukyu Archipelago (Fig. 1), is reported, based on four specimens. Since this species has been described on the basis of only three or four specimens from rivers in the southern part of Hainan Island, China (Wu and Ni 1986; Wu 1991, 2008), and underwater observations in Guangdong Province, China (Nip 2010), the Japanese specimens are described herein in detail.

Materials and Methods

Using a hand net, the first author collected four specimens of *S. multisquamus* (two males and two females) in two streams on the eastern slope of Okinawa Island, Japan (Fig. 1). Detailed localities are not shown here due to the conservation perspective. Specimens were fixed in 10% formalin and then preserved in 70% ethyl alcohol before being deposited at the National Museum of Nature and Science,

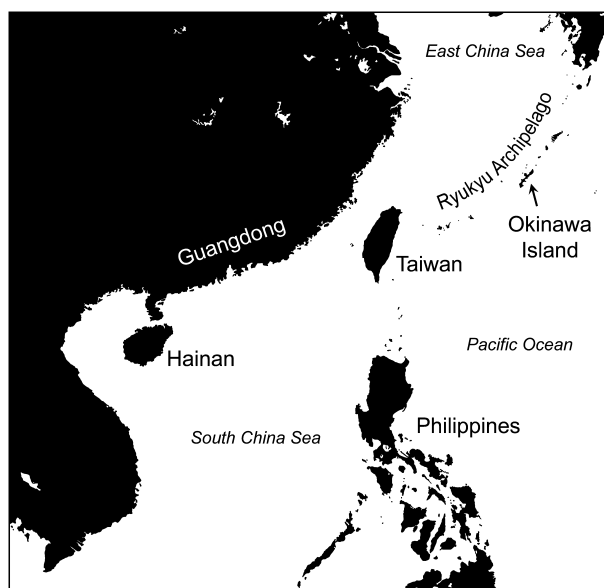


Fig. 1. Map showing the locations of Okinawa Island and Hainan and Guangdong Provinces, China, where *Stiphodon multisquamus* has been reported previously.



Fig. 2. *Stiphodon multisquamus* specimens from Okinawa Island immediately after fixation. A, male (37.7 mm SL, URM-P 46082); B, female (35.6 mm SL, URM-P 46083).

Tsukuba, Ibaraki, Japan (NSMT) and the General Research Center of the Okinawa Churashima Foundation, Motobu, Okinawa, Japan (URM; this collection was transferred from the Faculty of Science, University of the Ryukyus, in 2011).

Measurements and counts were taken from the right side of each fish, except for characters related to the pectoral fin, which were described using the left side, because the right pectoral fin was removed before fixation in formalin for future molecular studies. Measurements were made point-to-point to the nearest 0.1 mm using dial calipers or dividers under a stereomicroscope, and are expressed as a percentage of standard length (SL). Measurements, counts, and abbreviations pertaining to the cephalic sensory pore system follow Nakabo (2002), with the following modifications: SL, head length, snout length, predorsal length, and preanal length were measured to the anteriormost point of the protruding snout; body depth was measured at the anterior origins of the pelvic and anal fins; length of the caudal peduncle was measured from the posterior ends of the second dorsal-fin and anal-fin bases to the midpoint of the caudal-fin base; first and second dorsal- and anal-fin lengths were measured from the anterior origin of each fin to the farthest posterior point when the fin was depressed; caudal-fin length was measured as the length of the longest ray in the central part of the caudal fin; the interval between the first and second dorsal-fin bases was measured from the posterior end of the first dorsal-fin base to the second dorsal-fin's anterior origin; length from anus to anal fin was measured from the center of the anus to the anal-fin origin; scales in a longitudinal row were counted from the middle of the posterior end of the hypurals to behind the pectoral-fin base; scales in a

transverse row were counted along a diagonal line extending posteriorly and ventrally from the first scale anterior to the second dorsal fin, including one scale on the dorsal midline and another scale at the anal-fin base; circum-peduncular scales were counted along the circumference of the narrowest point of the caudal peduncle in a zigzag manner. Tooth counts of the upper and lower jaws were taken from the right side of the symphysis, with dentition terms following Watson (2008). Color in life was described based on underwater observations and photographs taken in streams on Okinawa Island, including those from two individuals observed in 2013 that were not captured.

Stiphodon multisquamus Wu and Ni, 1986
[New Japanese name: Torafu-bouzu-haze]
(Figs 2–4)

Stiphodon elegans multisquamus Wu and Ni, 1986: 422 (type locality: Lingshui River, Hainan, China).

Stiphodon multisquamus: Wu 1991: 495 (Hainan, China); Wu 2008: 729 (Hainan, China); Nip 2010: 1238 (Guangdong, China).

Material examined. NSMT-P 114246, male, 40.6 mm SL, Okinawa Island, Japan, 12 October 2012; NSMT-P 114247, female, 31.7 mm SL, Okinawa Island, Japan, 25 November 2012; URM-P 46082, male, 37.7 mm SL, Okinawa Island, Japan, 6 October 2011; URM-P 46083, female, 35.6 mm SL, Okinawa Island, Japan, 7 October 2011.

Diagnosis. Second dorsal fin with one spine and nine soft rays; pectoral fin with 15 or 16 soft rays; spines of first

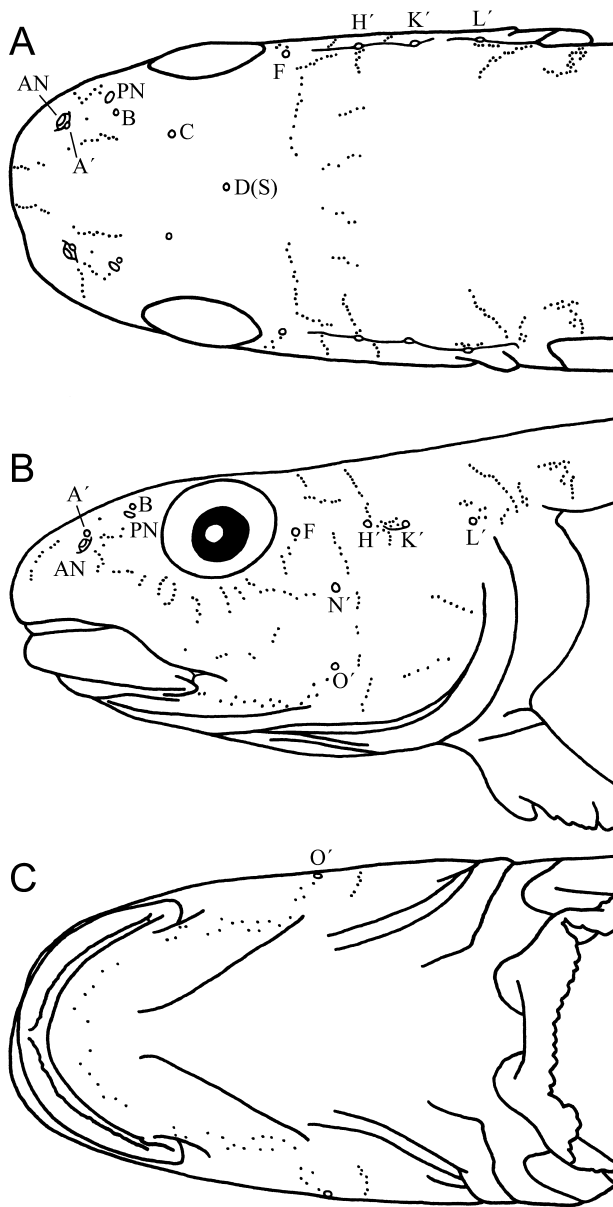


Fig. 3. Diagrammatic illustration of head showing arrangement of cephalic sensory pores (black dots) and cutaneous sensory papillae (A'–O') in *Stiphodon multisquamus* (40.6 mm SL, NSMT-P 114246) from Okinawa Island. A, dorsal view; B, lateral view; C, ventral view. AN, anterior nostril; PN, posterior nostril.

dorsal fin in male elongate, with tip of longest spine extending far beyond second dorsal-fin origin. Premaxillary teeth 40–46; dentary with 39–46 horizontal teeth and one or two canine-like symphyseal teeth even in female. Predorsal midline naked or with a few scales near first dorsal-fin origin, but small cycloid scales extending anteriorly to middle or posterior part of side of occipital region. Nine or ten dusky transverse bars laterally on trunk and tail; two conspicuous light-colored transverse bars on occipital region and nape; pectoral-fin rays with fine black spots. In male, lateral side of head often bluish; distal part of first and second dorsal fins orange in life. In female, second dorsal-fin spine and soft rays each with 2–3 black spots; tips of first and second dorsal fins with reddish markings in life; anal fin with black

line running along transparent margin; caudal fin with black spots forming transverse bars.

Description. Morphometric measurements given in Table 1. Body elongate, cylindrical anteriorly, somewhat compressed posteriorly. Head somewhat depressed with round snout protruding beyond upper lip. Anterior nostril tubular and short, posterior nostril not tubular. Mouth inferior with upper jaw projecting beyond lower jaw. Upper lip thick and smooth with small medial cleft. Premaxillary teeth 40–46, fine and tricuspid. Dentary with canine-like symphyseal teeth (number of teeth two in male, one or two in female) and row of unicuspid horizontal teeth enclosed in fleshy sheath (number of teeth 39–46).

First dorsal fin with six spines, second dorsal fin with one spine and nine soft rays. In female, first dorsal fin almost semicircular and second and/or third spine longest; in male, third to sixth spines elongate (fourth spine longest) and membrane slightly notched between fourth and fifth, and between fifth and sixth spines. Female with relatively larger interval between first and second dorsal-fin bases (6–7% of SL) than male (3–4% of SL). Anal fin with one spine and ten soft rays. In female, first or second and second or third soft rays longest in second dorsal and anal fins, respectively; in male, posterior rays longer than anterior rays (last ray and/or next to last ray longest). Caudal fin rounded, with 17 segmented rays, including 13 branched rays. Pectoral fin with 15 (n=3) or 16 (n=1) rays. Pelvic fin with one spine and five soft rays; pelvic fins joined together to form strong, cup-like disk with fleshy frenum.

Scales in longitudinal row 36 (n=1) or 37 (n=3); scales in transverse row 10 (n=1) or 11 (n=3); circumpeduncular scales 16. Ctenoid scales covering tail and lateral and dorsal sides of posterior trunk. Belly and lateral side of anterior trunk (behind pectoral-fin base) covered by cycloid scales. Scales on nape and occipital region cycloid. Scales extended anteriorly to middle or posterior part of occipital region, but predorsal midline naked (one male) or with a few scales near first dorsal-fin origin (other male and females); anteriormost scales on predorsal midline located around or posterior to midpoint between first dorsal-fin origin and anteriormost scales on occipital region. Cycloid scales also occurring on first and second dorsal-fin bases, anal-fin base, caudal-fin base, and proximal part of caudal fin.

Urogenital papilla in male rounded; that of female rectangular with small projection at each corner of posterior edge.

Cephalic sensory pore system always A', B, C, D(S), F, H', K', L', N', and O' (Fig. 3). Oculoscaphar canal interrupted between pores H and K. Cutaneous sensory papillae developed over dorsal, lateral, and ventral surface of head (Fig. 3).

Color in preservative. Sexual dichromatism well developed. In male, dorsal background dusky, lateral sides light brown, ventral side pale gray; nine dusky transverse bars laterally on trunk and tail; width of bars and intervals between them differing among bars, and number and arrangement of bars often differing between right and left sides of body (one male with ten bars on right side); head and pectoral-fin base dusky; two conspicuous pale-brown transverse bars dorsally on occipital region and nape. First dorsal-fin spines



Fig. 4. Live *Stiphodon multisquamus* in streams on Okinawa Island. A, male (6 October 2011); B, male (1 October 2011); C, female (1 October 2011); D, female (6 June 2013) (A, photo by K. Maeda; B–D, photo by T. Saeki).

black distally and dusky proximally; membranes transparent but proximal part dusky and one black blotch on posterior part. Second dorsal-fin rays dusky; membranes transparent distally and dusky proximally. Anal fin dusky. Caudal fin dusky with translucent spots forming four to six transverse bars on dorsal and middle part, but distal margin of upper part translucent. Pectoral fin translucent with one to 11 black spots along each ray except for lowest two rays. Middle to proximal part of pelvic-fin rays, fin membranes, and frenum dusky or blackish, distal margin translucent except for dusky edge around fifth soft ray.

In female, background of body and head cream-colored; blackish longitudinal band extending from snout and upper lip to below eye and to middle of pectoral-fin base, band continuing from behind pectoral-fin base to posterior end of caudal peduncle through lateral midline, but edge of the band somewhat unclear; nine obscure dusky transverse bars laterally on trunk and tail (one female with ten bars on right side). Dorsum dusky with two conspicuous cream-colored transverse bars on occipital region and nape, and with six cream-colored blotches along dorsal midline from first dorsal-fin base to caudal peduncle. First dorsal-fin membranes almost transparent, but dusky along black spines. Second dorsal fin bordered by narrow transparent mar-

gin; two to three black spots along each spine and soft ray, distalmost spots forming broken line immediately inside transparent margin. Anal fin transparent with black line or broken line running near transparent margin. Blackish blotch at center of proximal part of caudal fin; caudal fin transparent with black spots forming three to four transverse bars on dorsal and middle parts. Pectoral fin transparent with one to five black spots along each ray except for several upper and lower rays. Pelvic fin translucent without pigment.

Color in life. Color of live males variable (Fig. 4A, B). Body and fin markings similar to those of preserved specimens, but background yellowish gray to bluish gray, or sometimes purplish; lateral side of head yellowish gray to gray, often bluish. Distal part of first and second dorsal fins orange; white patch on distal part of membrane between fifth and sixth spines of first dorsal fin; second dorsal and anal fins with narrow bluish-white edge. Distal part of caudal fin orange or yellowish with narrow bluish-white posterior edge. Pectoral-fin rays with white spots between black spots. Margin of pelvic fin white.

Background of body and head of female (Fig. 4C, D) cream to light brown; belly sometimes bluish; body and fin markings similar to those of preserved specimens, but dusky

Table 1. Morphometrics of *Stiphodon multisquamus* from Okinawa Island, expressed as a percentage of standard length.

Sex	Male	Female
Number of specimens measured	2	2
Standard length (mm)	37.7, 40.6	31.7, 35.6
Head length	23.1, 22.9	22.4, 23.0
Snout length	8.5, 8.4	7.9, 8.7
Eye diameter	5.3, 4.9	5.4, 5.3
Postorbital length of head	9.8, 10.3	11.0, 10.1
Upper jaw length	9.5, 9.1	8.5, 9.0
Body depth at P ₂ origin	14.3, 13.5	14.2, 14.9
Body depth at A origin	15.1, 15.8	15.5, 16.3
Depth at caudal peduncle	11.1, 11.1	11.4, 10.7
Length of caudal peduncle from A base	18.6, 17.0	18.6, 19.4
Length of caudal peduncle from D ₂ base	19.9, 19.7	19.9, 21.1
Predorsal length	34.5, 34.5	35.0, 35.1
Length of D ₁ base	17.2, 18.5	14.5, 16.3
D ₁ length	28.6, 28.8	17.0, 17.7
Length of longest spine of D ₁	24.1, 24.4	13.2, 14.3
Interval between D ₁ and D ₂ bases	4.0, 3.4	7.3, 5.6
Length of D ₂ base	25.7, 26.8	24.9, 23.6
D ₂ length	43.0, 43.1	32.2, 30.9
Length of longest ray of D ₂	19.1, 18.5	12.9, 13.8
Preanal length	53.3, 53.0	52.4, 54.2
Length of A base	27.6, 28.6	27.1, 25.3
A length	40.3, 38.9	34.7, 31.5
Length of longest ray of A	15.4, 13.3	12.0, 11.5
Length from anus to A	3.2, 3.4	3.8, 4.2
Length of longest ray of P ₁	21.2, 20.0	20.2, 18.8
C length	24.7, 24.4	23.0, 21.1

D₁, first dorsal fin; D₂, second dorsal fin; A, anal fin; C, caudal fin; P₁, pectoral fin; P₂, pelvic fin.

transverse bars on lateral side of trunk and tail often indistinct; tips of first and second dorsal fins with reddish markings.

Ecology. *Stiphodon multisquamus* was found in two streams on the eastern slope of Okinawa Island and it is very rare there. In addition to four individuals collected in 2011 and 2012, one male and one female were observed in one of these streams in 2013. This species is usually observed in pools that are less than 2.5 m deep with gravel bottoms and exposed bedrock. In addition to *S. multisquamus*, the dominant species *S. percnopterygionus* and several other rare congeners inhabit both streams; *S. alcedo*, *S. atropurpureus*, and *S. imperiorientis* occur syntopically in one stream, while *S. atropurpureus* and an undescribed species are in the other stream.

Discussion

Stiphodon multisquamus was originally described as a new subspecies of *Stiphodon elegans* (Steindachner, 1879) on the basis of a holotype (49 mm SL) collected from the Lingshui River in the southern part of Hainan Island. Although Wu and Ni (1986) did not sex the holotype, it is identifiable as a female, based on shape of the first and

second dorsal and anal fins. Wu (1991) later recognized it as a distinct species, *S. multisquamus*, after noting the remarkable differences between it and *S. elegans*. Wu (1991) redescribed *S. multisquamus* with an additional specimen (55 mm SL) collected from the Taiyang River in southern Hainan Island. This specimen was apparently also a female. Wu (2008) first described the morphology of a male specimen collected from the Lingshui River, as well as a female specimen from the Taiyang River. Although the SLs in the text and figure in Wu (2008) were inconsistent, the male and female seem to have been 45.4 and 54.5 mm SL, respectively, and the female specimen was considered to be same individual with the additional specimen in Wu (1991) based on the collection date and locality. Wu (2008) also stated that the holotype had been lost. In addition to Hainan Island, Nip (2010) reported occurrences of *S. multisquamus* from six streams in Guangdong Province, China, and provided a brief description of this species with some color photographs.

Based on these descriptions, the following characters help to distinguish *S. multisquamus* from congeners, except for *Stiphodon aureorostrum* Chen and Tan, 2005 and *Stiphodon maculidorsalis* Maeda and Tan, 2013 (comparative data from Ryan 1986; Parenti and Maciolek 1993; Watson 1995, 1996, 1998, 1999, 2008; Watson and Kottelat 1995; Watson and Chen 1998; Watson *et al.* 1998, 2005; Keith *et al.* 2002, 2007, 2009, 2010; Keith and Marquet 2007; Suzuki *et al.* 2010; Maeda *et al.* 2012a, 2012b; Maeda and Tan 2013): second dorsal fin with one spine and nine soft rays; pectoral fin with 15 soft rays; spines of first dorsal fin in male elongate and tip of longest spine extending far beyond second dorsal-fin origin; dentary of female with canine-like symphyseal teeth; nape with small cycloid scales but predorsal midline naked or with only a few scales; nine to ten dusky transverse bars laterally on trunk and tail; anal fin in female with black line running along transparent margin; caudal fin with six to ten dusky transverse bars; pectoral-fin ray with fine black spots. Although *S. aureorostrum* and *S. maculidorsalis* share all these characters, the male of *S. multisquamus* has a blue head whereas in *S. aureorostrum* the head of the male is gold, according to Chen and Tan (2005). *Stiphodon multisquamus* differs from *S. maculidorsalis* in having two to three conspicuous light-colored transverse bars on the occipital region and nape (vs. black spots scattering dorsally on the head and trunk in *S. maculidorsalis*; see Maeda and Tan 2013).

The four specimens collected from Okinawa Island are identified as *S. multisquamus* because they present the characters mentioned above. However, a few features of these specimens do not correspond with those in the previous descriptions. The number of scales in a longitudinal row is fewer than those reported by Wu and Ni (1986) and Wu (1991) (36–37 vs. 48 and 43–48, respectively), although it is similar to that in Wu (2008) (34–35). This may be nothing more than a difference in counting methods. Since the scales on the anterior part of the trunk in *Stiphodon* are often irregularly arranged, it is not easy to standardize counting methods. Wu (2008) illustrated a Hainanese male

specimen, showing the third to sixth spines in the first dorsal fin as filamentous and the membranes deeply notched between these filamentous spines. Such a first dorsal fin is not found in any species of *Stiphodon*. This illustration was likely drawn by modifying the illustrations of a female in Wu and Ni (1986) and Wu (1991), and in some respects it is inconsistent with the text. The first dorsal-fin membranes in Okinawan male specimens are slightly notched between the fourth and fifth, and fifth and sixth spines, although the spines are not filamentous. They resemble the first dorsal fins of males figured by Nip (2010). The notched fin morphology may be characteristic of this species, but the illustration of Wu (2008) is probably exaggerated.

All species of *Stiphodon* are believed to be amphidromous (Maeda *et al.* 2012a). Larvae routinely migrate downstream to the sea where they develop for several months. Pelagic larvae potentially may be dispersed to distant islands before migrating into freshwater streams (Maeda *et al.* 2012a). In the Ryukyu Archipelago, there are a number of records of amphidromous gobioid species occurring in very small temporary, isolated populations at great distances from the main species range, *i.e.*, as a sink population (*e.g.*, *Stenogobius ophthalmoporus* (Bleeker, 1853), *Belobranchius belobranchius* (Valenciennes, 1837), and *S. surrufus*, reported by Sakai and Sato (1982), Suzuki *et al.* (1995), and Yonezawa and Iwata (2001), respectively). In some cases, these records may actually involve single individuals, rather than small populations. These species are also rare in Taiwan (Lin 2007a, 2007b). Usually such rare migrants appear to have come from insular streams in low-latitude regions (*e.g.*, the Philippines and Indonesia), and the populations in the Ryukyu Archipelago are believed to have arisen from rare colonization events after pelagic larvae were transported from their main ranges by the Kuroshio Current.

We presume that *S. multisquamis* is yet another example of rare gobioid migrant to the Ryukyu Archipelago, but this case is peculiar in that its previous known range is southern China. Although the larvae could have been transported from southern China to Okinawa Island, this seems dubious, given known ocean currents. Another possible and more plausible explanation is that this species is also distributed in the Philippines or surrounding regions and that larvae were transported to Okinawa Island from there; however, there are presently no data to support such a hypothesis. Although several authors have reported amphidromous gobioid fauna in Southeast Asia (*e.g.*, Herre 1927; Watson and Kottelat 1995; Watson *et al.* 1998 for *Stiphodon*), available information is insufficient for a discussion of the source populations. If future studies produce detailed distribution maps of amphidromous gobioid species in Southeast Asia, their colonization of the Ryukyu Archipelago may become more understandable.

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