A new species of amphidromous goby, *Stiphodon alcedo*, from the Ryukyu Archipelago (Gobiidae: Sicydiinae)

by

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**ABSTRACT.** - A new goby species, *Stiphodon alcedo*, is described from 27 specimens collected in Okinawa and Iriomote Islands of the Ryukyu Archipelago, Japan. This species can be distinguished from its congeners by having a pointed, but not filamentous, first dorsal fin in males, nine soft-rays in the second dorsal fin, 15-17 rays in the pectoral fin, the number of teeth, and unique sexually dimorphic colouration. The new species is considered to have recently colonised the islands where it has established small populations, and is considered to have originated from regions to the south of the archipelago, with larvae occasionally being transported northward by the Kuroshio Current.

**RÉSUMÉ.** - Une nouvelle espèce de gobie amphidrome de l’archipel des Ryukyu, *Stiphodon alcedo* (Gobiidae : Sicydiinae).

*Stiphodon alcedo* est une nouvelle espèce décrite à partir de 27 spécimens collectés à Okinawa et Iriomote dans l’archipel des Ryukyu au Japon. Elle se distingue des autres espèces du genre par plusieurs caractères dont une première dorsale pointue mais non filamenteuse chez le mâle, 9 rayons mous à la seconde dorsale, 15-17 rayons à la pectorale, un nombre de dents différent et une coloration unique aussi bien chez les mâles que chez les femelles. Il est suggéré que cette nouvelle espèce a récemment colonisé ces îles et y a établi de petites populations. Ces populations sont peut-être plus importantes dans les régions du sud et les larves ont pu occasionnellement être transportées par le courant du Kuroshio.

Key words. - *Stiphodon* - Ryukyu Archipelago - New species - Amphidromy - Larval dispersal - Kuroshio Current.

The sicydiine gobies of the genus *Stiphodon* Weber, 1895 are distributed in tropical and subtropical freshwater streams from Sri Lanka and the western coast of Sumatra in the Indian Ocean to southern Japan, Australia, and French Polynesia (Watson, 1995). Of these gobies, only the life history of *Stiphodon percnopterygionus* Watson & Chen, 1998 from the Ryukyu Archipelago has been studied to date. This species has the following characteristics: it is amphidromous; it produces small pyriform eggs that are laid on the undersurface of stones in freshwater streams (Yamasaki and Tachihara, 2006); newly hatched larvae, which are small (1.2-1.3 mm in notochord length) and poorly developed, migrate downstream to the sea shortly after hatching at dusk where they develop as pelagic larvae for 2.5-5 months; the pelagic larvae may sometimes be dispersed to distant islands before migrating up to freshwater streams at 13-14 mm in standard length (SL) for further growth and reproduction (Yamasaki et al., 2007; Maeda and Tachihara, 2010). Although details of the life histories of the other *Stiphodon* species have not yet been clarified, all sicydiine gobies are generally considered to be amphidromous (Keith et al., 2009).

Watson and Chen (1998) reviewed the taxonomy of the genus *Stiphodon* from the Ryukyu Archipelago in southern Japan to clarify the disarray that previously existed within the genus. They described two new species, *S. imperiortentis* Watson & Chen, 1998 and *S. percnopterygionus* Watson & Chen, 1998, from the Ryukyu Archipelago (with the latter species also found in southern Taiwan and Micronesia), and proved that *S. atropurpureus* (Herre, 1927) also occurs in the Ryukyu Archipelago. Based on a single record from Yaku Island in the northern Ryukyu Archipelago (Fig. 1), Yonezawa and Iwata (2001) added a fourth species, *Stiphodon alcedo*, from the islands of Okinawa and Iriomote in the Ryukyu Archipelago (Fig. 1). The archipelago is located in the northwest Pacific Ocean, along the path of the strong, warm Kuroshio Current which runs from the southwest to the northeast. The dispersal and colonisation of *Stiphodon* larvae along the Kuroshio Current are also discussed, given their role in the occurrence of this new species in the Ryukyu Archipelago.

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MATERIAL AND METHODS

All measurements and counts were taken from the right side of the fish, unless the right side was damaged. For example, characters related to the pectoral fin were described using the left side when the right pectoral fin was removed for mitochondrial DNA analysis. Measurements were made point-to-point with a dial calliper or a divider under a stereomicroscope to the nearest 0.1 mm and expressed as a percentage of SL. The measurements and counts followed Nakabo (2002), with the following modifications: SL, head length, snout length, and predorsal length were measured to the anterior point of the protruding snout; body depths were measured at the origins of the pelvic and the anal fins; length of caudal peduncle was measured from the posterior end of the second dorsal- and also from the anal-fin bases to the midpoint of the caudal-fin base; first and second dorsal- and anal-fin lengths were measured from the origin of each fin to the farthest point when the fin was depressed; 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 origin; preanal length was measured from the snout tip to the anal-fin origin; anus to anal-fin length was measured from the centre of the anus to the anal-fin origin; scales in longitudinal row were counted from the middle of the posterior end of the hypurals to the most anterior scale along the lateral midline; scales in transverse series back 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 small scale at the anal-fin base; scales in transverse series forward were counted along a diagonal line extending anteriorly and ventrally from the first scale anterior to the second dorsal fin to the centre of the belly, and included a scale on the dorsal midline; scales in transverse series in the caudal peduncle were counted along a vertical line around the narrowest point of the caudal peduncle in a zigzag manner, and included scales on the dorsal and ventral midlines. Teeth counts of the upper and lower jaws were taken from the right of the symphysis, with terms used in dentition following Watson (2008). Vertebrae were counted from radiographs. Abbreviations pertaining to the cephalic sensory pore system followed Akihito et al. in Nakabo (2002). Abbreviations used to represent collections and institutions cited follow Leviton et al. (1985), except BLIH (Biological Laboratory, Imperial Household, Tokyo, Japan), CMK (collection of M. Kottelelat, Cornol, Switzerland), KPM-NI (Kanagawa Prefectural Museum of Natural History, Kanagawa, Japan), and ZRC (Raffles Museum of Biodiversity Research, National University of Singapore). Colour in life was described based on underwater observations and photographs taken in streams on Okinawa and Iriomote Islands. The localities were given at the island scale to protect the sites where the new species was discovered from overexploitation by ornamental fish dealers, aquarium hobbyists, and researchers.

Comparative material

The new species was compared to Stiphodon specimens from the Ryukyu Archipelago, Japan (Okinawa, Iriomote, and Yaku Islands; Fig. 1), the Philippines (Cebu, Negros, Leyte, Culion, Busuanga, and Palawan Islands), and Palau (Babelthuap Island). Measurements in brackets are SL (mm).

Stiphodon imperiorientis Watson & Chen, 1998. - NSMT-P 48063 (holotype), male (48.5); Iriomote; 2 Sept. 1986. BLIH 19810202 (paratype), male (43.0); Iriomote; 10 Jul. 1981. BLIH 19860400 (paratype), male (44.1); same data as holotype. BLIH 19950002, 19950028 (paratypes), 2 males (37.9, 43.3); Iriomote; 4 Nov. 1995. URM-P 3205, 3206 (paratypes), 2 males (41.8, 47.5); Iriomote; 4 Jun. 1982. URM-P 4823-4825 (paratypes), 2 males (50.9, 50.9), female (52.0); Iriomote; 13 Sept. 1982. OMNH-P 34657, male (32.0); Okinawa; 29 Jul. 2008. OMNH-P 35471, male (48.2); Iriomote; 28 Jul. 1997. OMNH-P 35472, male (39.5); Iriomote; 29-30 July 1994. URM-P 36457, male (39.4); Iriomote; 20 Aug. 1996. URM-P 46079, male (30.6); Okinawa; 27 Oct. 2006.
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Material examined

Twenty-seven specimens collected on Okinawa and Iriomote Islands, Ryukyu Archipelago, Japan (Fig. 1), by K. Maeda using a hand net, totalling 15 males, 12 females, size range of 26.0–47.9 mm SL, largest male 43.4 mm SL, largest female 47.9 mm SL.

**Holotype.** - NSMT-P 103600, female (30.8); Okinawa; 10 Nov. 2008.

**Paratypes.** - BLIH 20110001, male (29.7); Okinawa; 27 Oct. 2006. BLIH 20110002, female (32.2); Okinawa; 13 Dec. 2006. BLIH 20110003, female (47.9); Iriomote; 20 Oct. 2009. BLIH 20110004, male (40.3); Iriomote; 5 Jul. 2010. NSMT-P 103601-103603, 2 males (27.9, 30.2), female (32.5); same data as holotype. NSMT-P 103604, female (33.5); Okinawa; 5 Nov. 2006. NSMT-P 103605, male (30.1); Okinawa; 13 Dec. 2006. NSMT-P 103606, female (45.6); Iriomote; 20 Oct. 2009. NSMT-P 103607, 103608, male (36.2), female (42.1); Okinawa; 29 Nov. 2009. NSMT-P 103609, male (39.7); Iriomote; 5 Jul. 2010. URMP 46066, male (30.1); Okinawa; 27 Oct. 2006. URMP 46067, female (34.2); Okinawa; 13 Dec. 2006. URMP 46068, 46069, male (29.4), female (29.6); Okinawa; 24 Nov. 2008. URMP 46070, 46071, male (34.4), female (37.2); Okinawa; 27 Sept. 2009. URMP 46072, male (38.8); Okinawa; 7 Nov. 2009. URMP 46073, male (35.4); Iriomote; 9 Nov. 2009. URMP 46074, male (31.7); Iriomote; 10 Nov. 2009. URMP 46075-46078, 2 males (28.5, 43.4), 2 females (26.0, 44.9); Okinawa; 3 Sept. 2010.

Diagnosis

Dorsal fins, usually VI–I, 9. Male having pointed, but not filamentous, first dorsal fin with elongate spines 4 and 5, posterior tip of fin usually extending to base of soft-rays 2-5 of second dorsal fin. Pectoral fin rays 15–17 (mode 16). Premaxillary teeth 32–40. Dentary with 32–45 horizontal teeth. Female having two black longitudinal bands laterally on body arranged with a larger interval between two bands; lower band composed of 8–11 regular blotches, upper band thin and pale. All fins of female usually with faint markings. Non-nuptial coloured male having a dark brown longitudinal band just below lateral midline; nuptial coloured male

Stiphodon alcedo, new species

New Japanese name: Hisui-bouzu-haze

(Tabs I-II, Figs 2-9)
lacking this band, and having blackish or sometimes orange body, metallic turquoise laterally on head, metallic turquoise spot on upper pectoral-fin base when alive. Pectoral-fin rays in male often having 1-6 somewhat obscure black spots.

**Description**

Morphometric measurements are given in table I. Body

elongate, cylindrical anteriorly and somewhat compressed posteriorly. Head somewhat depressed with a round snout

Figure 2. - Number of premaxillary and horizontal dentary teeth of *Stiphodon alcedo* (red circles), *S. imperiorientis* (light blue triangles), *S. pulchellus* (green triangles), *S. pelewensis* (pink squares), *S. atropurpureus* (blue squares), *S. percnopterygionus* (orange squares), and *S. surrufus* (light green squares). Solid and open symbols represent males and females, respectively. A premaxillary tooth count of one *S. percnopterygionus* female (28.2 mm SL) was excluded because the count was exceptionally small (8).

Figure 3. - First dorsal-fin length (% of standard length) of *Stiphodon alcedo* (red circles), *S. imperiorientis* (light blue triangles), *S. pulchellus* (green triangles), *S. pelewensis* (pink squares), *S. atropurpureus* (blue squares), *S. percnopterygionus* (orange squares), and *S. surrufus* (light green squares). Solid and open symbols represent males and females, respectively.

Figure 4. - Interval between first and second dorsal-fin bases (% of standard length) of *Stiphodon alcedo* (red circles), *S. imperiorientis* (light blue triangles), *S. pulchellus* (green triangles), *S. pelewensis* (pink squares), *S. atropurpureus* (blue squares), *S. percnopterygionus* (orange squares), and *S. surrufus* (light green squares). Solid and open symbols represent males and females, respectively.
protruding beyond upper lip. Anterior nostril short tubular, posterior nostril not tubular. Mouth inferior with upper jaw projecting beyond lower jaw. Upper lip thick with small, medial cleft and crenulated with tiny fimbriate projections. Premaxillary teeth 32–40, fine and tricuspid. Dentary with recurved conical to canine-like symphyseal teeth, number of teeth usually 2–3 (range 1–5) in males, usually none in females (1 in a case with teeth); dentary with a row of unicuspoid horizontal teeth enclosed in a fleshy sheath, number of teeth (32–45) similar or slightly more numerous than premaxillary teeth. Larger fish having more premaxillary and horizontal teeth (Fig. 2).

Dorsal fins VI–I, 9 (n = 25) or VI–I, 10 (n = 2); in female, first dorsal fin almost semicircular and spine 3 or 4 longest; in male, first dorsal fin forming parallelogram or triangular with spines 4 and 5 elongate but not filamentous. Most posterior points of first dorsal fin of male extending to base of soft-rays 2–5 of second dorsal fin when depressed, except in a smaller male (28.5 mm SL) having a shorter first dorsal fin extending to base of spine of second dorsal fin; larger males having longer first dorsal fin than smaller males (Fig. 3). Female having larger interval between first and second dorsal-fin bases (4.8–7.8% of SL) than male (3.0–5.6% of SL) (Fig. 4).

Anal fin I, 10, below second dorsal fin. in female, anterior rays (usually soft-ray 2) longest in second dorsal and anal fins; in male, most posterior rays longer than anterior rays. Caudal fin with 13 (n = 4), 14 (n = 17), 15 (n = 6) branched rays within 17 segmented rays, posterior margin rounded or somewhat truncated, male with somewhat larger fin than female (length of longest ray 23.9–28.8% of SL in male, 20.7–25.0% of SL in female; Tab. I).
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Pectoral fin with 15-17 rays (Tab. II), male with somewhat larger fin than female (length of longest ray 21.0-25.8% of SL in male, 18.8-22.0% of SL in female; Tab. I). Pelvic fin I, 5, paired fins joined together to form a strong cup-like disk with fleshy frenum. Number of vertebrae 10+15 (n = 1), 10+16 (n = 25), 10+17 (n = 1).

Scales in longitudinal row 30-33 (Tab. II); scales in transverse series back 10 (n = 2), 11 (n = 25); scales in transverse series forward 13 (n = 4), 14 (n = 19), 15 (n = 3), 16 (n = 1); scales in transverse series in caudal peduncle 9 (n = 23), 10 (n = 4). More predorsal scales in female (9-16) than in male (7-13). Ctenoid scales covering lateral sides of trunk and almost entire tail. Cycloid scales dorsally on trunk and head, posterior to pectoral-fin base, on belly between middle of pelvic fin to origin of anal fin, along second dorsal- and anal-fin base, along dorsal and ventral midline in caudal peduncle (often with ctenoid scales), and caudal-fin base. Pectoral-fin base naked, except in two females with two cycloid scales laterally on pectoral-fin base.

Urogenital papilla in male rectangular or somewhat rounded with two small projections at both sides of tip, often some tiny projections between the two projections; female similar but tip projections more pronounced and posterior edge almost smooth.

Cephalic sensory pore system always A, B, C, D, F, H, K, L, N, and O; pore D singular, all others paired (Fig. 5). Oculoscapular canal separated into anterior and posterior canals between pores H and K. Cutaneous sensory papillae developed over lateral and dorsal surface of head (Fig. 5).

Colour in preservation

Sexual dichromatism well developed with males showing conspicuous nuptial colour during courtship.

Non-nuptial coloured males (Fig. 6A). - Background of body and head pale brown; dark brown longitudinal band extending from behind pectoral-fin base along and just below lateral midline to posterior end of caudal peduncle, band often composed of 9 or 10 obscure blackish blotches at regular intervals along posterior trunk and entire tail. Dorsum somewhat dusky with 1, 3, and 5 whitish blotches on head, trunk, and tail, respectively. Belly whitish. Snout, infraorbital and opercular regions, upper lip blackish; head pale brown ventrally. Black patch on middle and upper part of pectoral-fin base. First dorsal-fin membranes pale grey, first spine with 3-4 black spots, other spines with 0-4 obscure black spots. Second dorsal-fin membranes greyish, spine with 3-4 black spots, soft-rays with 2-5 obscure black spots with translucent spots between each black spot. Anal-fin membranes greyish, spine with 0-3 obscure black spots, soft-rays without spots and paler than fin membranes. Caudal fin dusky with 5-7 translucent transverse bars; distal margin of fin transparent, upper part with wider margin; black blotch at centre of proximal part of fin. Black patch on pectoral-fin base spread to proximal part of rays 6-10 and adjacent membranes; other membranes of pectoral fin transparent; pectoral-fin rays with somewhat obscure black spots, but spots usually invisible in smaller males and sometimes invisible even in larger males, number of spots on longest rays 7 and/or 8 0-6. Black transverse band across middle part of pelvic-fin rays, fin membranes, and frenum, forming a black ring (in ventral view); inside of ring pale brown, outside of ring transparent except around soft-ray 5, which has blackish edge.

Figure 5. - Diagrammatic illustration of head showing arrangement of the cephalic sensory pores and cutaneous sensory papillae in Stiphodon alcedo (BLIH 20110001); A: Dorsal view; B: Lateral view; C: Ventral view.
Nuptial coloured males (Fig. 6B, C). - Head, trunk, and tail blackish, but belly usually whitish grey; 3 and 8 pale grey transverse bars laterally on trunk and tail, respectively (Fig. 6C), but bars sometimes indistinguishable (Fig. 6B); arrangement of whitish blotches along dorsal midline similar to those of non-nuptial coloured males. Dorsal, anal, and caudal fins dusky brown without clear markings. Margin of caudal fin transparent; proximal part of caudal fin of small specimens (< 30 mm SL) sometimes pale brown (Fig. 6C). Colour of pectoral and pelvic fins similar to those in non-nuptial coloured males.

Females (Fig. 6D, E). - Background of body and head pale cream; black longitudinal band extending from snout to below eye and to middle of pectoral-fin base, band continuing from behind pectoral-fin base to posterior end of caudal peduncle through a position somewhat lower than lateral midline (e.g., located on lower half of 6th scale and upper half of 7th scale in transverse series back), band composed of 0-3 obscure black blotches on trunk and 8 black regular spacing blotches on tail (Fig. 6E), but blotches sometimes indistinct and forming disheveled band (Fig. 6D). Another black longitudinal band from behind eye extending dorsola-
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The new species is named from the Latin alcedo, meaning kingfisher, as the metallic turquoise on the head and body of the nuptial coloured male is similar to the plumage of the kingfisher, Alcedo atthis. The new specific name is a noun in apposition.

MtDNA phylogeny

The complete mitochondrial DNA sequence (16,505 bp) of a paratype specimen (NSMT-P 103605) is available from the DNA Data Bank of Japan (DDBJ) (http://www.ddbj.nig.ac.jp/) under the accession number AB613000. Since the genome content, gene order, and L- and h- strand coding of each gene were identical to those obtained for other teleost
fishes reported by Miya et al. (2003), we were able to identify 13 protein-encoding genes, two rRNA-encoding genes, and 22 tRNA-encoding genes, in addition to the control region (D-loop). The gene location data for the mitochondrial genome of *Stiphodon alcedo* has been deposited in the DDBJ.

A total of 1,004 bp for nucleotide sequences of the mitochondrial ND5 gene was determined for 17 *S. alcedo* specimens, 32 specimens belonging to three other *Stiphodon* species, and one *Sicyopterus japonicus* specimen. The nucleotide sequences of two *S. alcedo* specimens (holotype NSMT-P 103600 and paratype NSMT-P 103609) and four
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S. percnopterygionus specimens (URM-P 46049, 46050, 46052, and 46054) had the same haplotypes, respectively (DDBJ accession number AB513050 and AB513064). A neighbour-joining tree showed that all 17 nucleotide sequences of S. alcedo comprised a monophyletic group (Fig. 9). Intraspecific nucleotide sequence differences were small ($p$ distance 0.00-1.00% in S. alcedo, 0.20-1.49% in S. atropurpureus, and 0.00-1.00% in S. percnopterygionus), with those among the four Stiphodon species being remarkably higher ($p$ distance 7.47-12.95%; Tab. III). Among these species, S. alcedo grouped relatively close to S. imperiorientis in the phylogenetic tree.

Figure 9. - Neighbour-joining tree based on genetic distances estimated from partial mitochondrial NADH dehydrogenase subunit 5 (ND5) gene sequences (1,004 bp) in four Stiphodon species including type specimens of S. alcedo and a related genus (Sicyopterus). Distances are based on Kimura's two-parameter model and calculated using PAUP*4.0b10 (Swofford, 2002). Numbers adjacent to internal branches indicate bootstrap probabilities (> 80%) based on 1,000 pseudoreplicates.
Comparison

The morphology of *Stiphodon alcedo* was compared to those of six northwestern Pacific *Stiphodon* species. The second dorsal-fin ray count of *S. alcedo* (usually I, 9) was the same as in other species examined in this study, except for *S. percnopterygionus* (usually I, 10) (Tab. II). While the mode of the pectoral-fin ray count of *S. alcedo* (16) was higher than that observed in all of other species examined in this study, with the range (15-17) almost overlapping with those of *S. imperiorientis*, *S. pulchellus*, *S. pelewensis*, and *S. atropurpureus* (Tab. II). The scale counts in longitudinal row of *S. alcedo* (30-33) were similar to those of *S. imperiorientis*, *S. pulchellus*, and *S. pelewensis* and higher than those of *S. atropurpureus*, *S. percnopterygionus*, and *S. surrufus* (Tab. II). The number of premaxillary teeth and horizontal teeth in the dentary of all species increased with body size (Fig. 2). Teeth counts of *S. alcedo* were lower than those of *S. atropurpureus* and *S. percnopterygionus*, and similar to those of *S. imperiorientis*, *S. pulchellus*, and *S. pelewensis* when compared within the same size class (Fig. 2). Males of *S. alcedo* had a pointed first dorsal fin and differed from the males of *S. atropurpureus* and *S. surrufus*, which had a round first dorsal fin. The first dorsal fins of male *S. imperiorientis*, *S. pulchellus*, *S. pelewensis*, and *S. percnopterygionus* were also pointed, but the first dorsal fin of male *S. alcedo* was longer than that of *S. imperiorientis*, *S. pulchellus*, and *S. pelewensis*, but shorter than that of *S. percnopterygionus* (Fig. 3). The interval between the first and second dorsal-fin bases of *S. alcedo* females was longer than that of *S. imperiorientis*, *S. pulchellus*, and *S. atropurpureus*, but smaller than that of *S. percnopterygionus* (Fig. 4). Taken together, *S. alcedo* can be distinguished from *S. atropurpureus*, *S. percnopterygionus*, and *S. surrufus* through a combination of pectoral-fin ray and teeth counts and the shape of male first dorsal fin, while the ranges of most meristic and morphometric characters in *S. alcedo* generally overlapped with those observed in *S. imperiorientis*, *S. pulchellus*, and *S. pelewensis*. As shown in Fig. 7, a lower band composed of 8-11 regular blotches, and a thin, paler coloured upper band) are unique to this species. The relatively faint fin markings of *S. alcedo* males and females also differed from those in several other species (*S. imperiorientis* males and females, *S. pulchellus* males, and *S. pelewensis* males, which always have distinctive black spots on the pectoral-fin rays; and *S. atropurpureus* females have conspicuous black spots on their dorsal and caudal fins with a black longitudinal band along the distal margin of anal fin).

A combination of pectoral-fin ray count (15-17), second dorsal-fin ray count (I, 9), relatively low premaxillary teeth count (32-40 in specimens measuring 26.0-47.9 mm SL), and pointed but not filamentous first dorsal fin in males distinguishes the new species from all other *Stiphodon* species, except *S. ornatus* Meiniken, 1974, *S. atratus* Watson, 1996, and *S. weberi* Watson, Allen & Kottelat, 1998, as well as *S. imperiorientis*, *S. pulchellus*, and *S. pelewensis*. However, according to descriptions in Watson (1994, 1996) and Watson et al. (1998), *S. alcedo* can be distinguished from *S. ornatus*, *S. atratus*, and *S. weberi* by the unique arrangement and composition of the lateral longitudinal bands in females described above; faint female fin markings (vs. well-defined markings on the second dorsal-, caudal- or pectoral-fin rays); no or 1-6 inconspicuous black spots without clear white spots on male pectoral-fin rays (vs. having alternately arranged rows of black and white spots on rays); uniform intensity of lateral blotches on the tails of males and the caudal peduncle never being whitish (vs. blackish blotches along lateral midline often prominent below second dorsal fin with whitish caudal peduncle in *S. ornatus* and *S. atratus*; often with two broad black bars below first and second dorsal fins in *S. weberi*).

Remarks

The female specimen (OMNH-P 15609) described...
as *Stiphodon atropurpureus* by Suzuki et al. (2001) was a female *S. alcedo*. An illustration of a female *S. atropurpureus* in Nakabo (2002) was based on the same specimen (Y. Ikeda, pers. comm.) and we conclude that this was also *S. alcedo*. That specimen was collected on Iriomote Island in 1999 (T. Suzuki, pers. comm.).

We selected a female specimen as holotype of the new species, although the majority of holotypes in this genus are male. The markings on the body and fins of *S. alcedo* females are unique to this species and stable even after preservation, while some of the characteristics of male colouration, especially nuptial males, disappeared after preservation. Based on these characteristics, we determined that a female specimen would be well suited for use as the holotype for this species.

**Ecology**

Adult and juvenile *Stiphodon alcedo* were observed in freshwater streams where they usually inhabited pools. They often shoaled with conspecific individuals and the congeners *S. percnopterygionus* and *S. atropurpureus*, and occasionally with *S. imperiorientis*. We suppose that the spawning season of the new species is from October to December (autumn and early winter), at least on Okinawa Island, because nuptial coloured males and courtship displays were observed only during these three months. The water temperature decreases during this season, and the males were observed to become inactive and assume non-nuptial colours before the beginning of the coldest season (Jan.-Feb.), retaining the non-nuptial colouration throughout the spring and summer. This spawning season is considerably shorter than that of its sympatric congener, *S. percnopterygionus*, which spawns from spring to early winter (May-December) on Okinawa Island (Yamasaki and Tachihara, 2006). The spawning season of *S. alcedo* is unique among freshwater and estuarine fish species, and that, in doing so, the current facilitates the colonisation of streams on the islands along the current (Maeda et al., 2007, 2011a; Yamasaki et al., 2007; Iida et al., 2010; Shinoda et al., in press). In addition to common migrants (e.g., *Eleotris acanthonoma* and *Sicyopterus japonicus*), it is likely that vagrant species have also colonised the Ryukyu Archipelago, and the discovery of *S. surrufus* on Yaku Island (Yonezawa and Iwata, 2001) is considered to be a typical example of such a colonisation event. The extant populations of *S. alcedo* in the Ryukyu Archipelago may have originated on islands near the origin of the Kuroshio Current. The new species on Okinawa and Iriomote Islands may have established small, local populations either by self-recruitment through local reproduction or by continuous colonisation from regions to the south. The relatively low abundance of this species is likely to be regulated by the environment and/or competition with congeners and other lotic species. For example, the relatively low winter water temperatures on these subtropical islands may be unsuitable, and preferred habitats may be already occupied by *S. percnopterygionus*, a dominant species in streams of the archipelago (Watson and Chen, 1998).

Thus, even though the new goby species has only been found on Okinawa and Iriomote Islands, it may not be endemic to the Ryukyu Archipelago. Indeed, it is possible that this species is well represented in river systems further south, such as those along east coast of Luzon in the Philippines, which is in close geographical proximity to the origin of the Kuroshio Current. The area is likely to have an abundance of suitable habitats and is largely unexplored. Other peripheral regions (e.g., Taiwan, Visayas, Mariana Islands, Palau, and South China) have been surveyed, and only the other *Stiphodon* species have been reported from these regions to date (Herre, 1934, 1936; Watson and Kottelat, 1995; Watson and Chen, 1998; Donaldson and Myers, 2002; Nip, 2010).

The genus *Stiphodon* has undergone considerable diversification in the insular tropical and subtropical streams of
the areas in which it occurs, and species-specific distributions are known to occur (Keith et al., 2009). The speciation events and extant distributions of the species belonging to this genus are considered to be the result of repeated colonization events, of which S. alcedo may be a recent example. The establishment, success, decline, and extinction of local populations are all affected by habitat preference and interspecific competition, as well as by geographic and oceano graphic changes. The distribution of this genus is thus likely to change in the future, particularly if global warming affects the survival of tropical stragglers, such as S. alcedo in the Ryuku Archipelago. It is therefore important to monitor the fluctuations of these populations in the future.

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REFERENCES


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