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Newly discovered habitat of a threatened goby, *Acanthogobius insularis* (Perciformes: Gobiidae), in southern part of Okinawa-jima Island, Japan

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Abstract. *Acanthogobius insularis* Shibukawa and Taki (1996) is a threatened goby species, previously known to be restricted to estuaries on Amami-oshima Island and northern part of Okinawa-jima Island. However, we found this species in two estuaries in the southern part of Okinawa-jima Island (Toyosaki and Manko), which are separated from their habitats in the northern part of the island by approx. 60 km of coral reefs. Morphologies of four specimens collected in Toyosaki and Manko examined in the present study correspond to the original description of *A. insularis*. This study reports that Toyosaki is the southernmost habitat of this species based on specimens. Because it is thought that *A. insularis* move to unknown spawning habitats in winter and because only one individual has been found in Manko, it is necessary to understand the habitats that these newly discovered small populations use, in their entirety.

Key words: *Acanthogobius insularis*, newly discovered habitat, tidal flat, endemic species, Okinawa-jima Island

Introduction

The gobiid genus *Acanthogobius* is composed of six species distributed in estuaries around East Asia. *Acanthogobius insularis* Shibukawa and Taki (1996) is the only species known to inhabit the Ryukyu Archipelago, apart from *A. flavimanus* found on Yaku-shima and Tanega-shima Islands in northernmost of the archipelago (Yoshigou, 2014). This species is endemic to Okinawa-jima and Amami-oshima Islands, in the central part of the Ryukyu Archipelago (Fig. 1; Shibukawa and Taki, 1996). They inhabit mudflats in estuaries; however, their existent habitats are restricted to a few localities. As their habitats are affected by reclamation, dredging, revetment, sediment from urbanized areas, agricultural lands, and construction sites in the river basins (Tachihara,

2005; 2015), *A. insularis* has been ranked as “vulnerable” in the Red List of Threatened Brackish and Fresh Water Fishes of Japan (Ministry of the Environment, 2015). Red Data Book in Okinawa and Kagoshima Prefectures also rank it as “vulnerable” (Tachihara, 2005; Yonezawa and Shinomiya, 2015).

On Okinawa-jima Island, *A. insularis* is known to inhabit the areas around Shioya Bay and Haneji-naikai Inlet, in the northern part of the island (Fig. 2A; Shibukawa and Taki, 1996). However, we recently found two additional habitats of this threatened goby, *A. insularis*, from southern part of Okinawa-jima Island, where this species has never been reported: they are Toyosaki and Manko in Tomigusuku City (Fig. 2B). In the present study, the records of *A. insularis* from these localities are reported with specimens and their morphology is described and compared with that in the original description.

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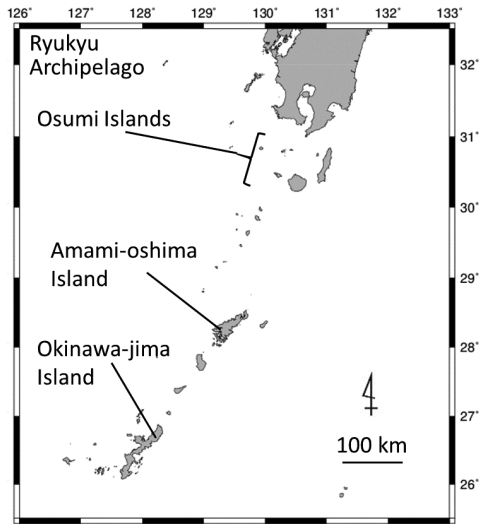


Fig. 1. Map of north and middle parts of the Ryukyu Archipelago.

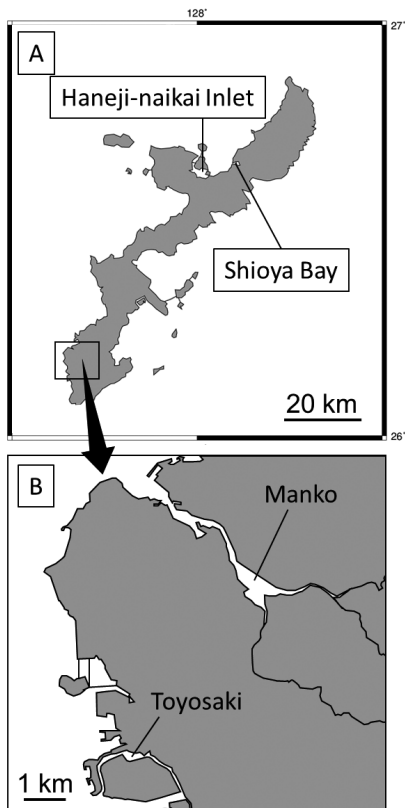


Fig. 2. Map showing habitats of *Acanthogobius insularis* on Okinawa-jima Island (A: Shibukawa and Taki, 1996) and southern part of Okinawa-jima Island (B: the present study).

Materials and methods

Specimens of *A. insularis* were collected from tidal flats in Toyosaki (26°09'37"N–26°09'40"N, 127°39'21"E–127°40'00"E) and Manko (26°11'41"N, 127°40'56"E), in the southern part of Okinawa-jima Island, using hand nets. After being anesthetized with 2-phenoxyethanol, fishes were fixed using 10% formalin and preserved in 70% ethanol. Counts and measurements were taken according to the methods described by Shibukawa and Taki (1996), who modified the methods of Hubbs and Laglar (1958) and Akihito et al. (1984). Measurements were made to the nearest 0.1 mm with a caliper. Cephalic sensory canal pores and papillae were observed after staining with cyanine blue. Vertebrae were counted through a soft X-ray radiography (SOKEN Co., LTD, SOFRON SRO-405A).

Acanthogobius insularis Shibukawa and Taki, 1996

[Japanese name: Minami-ashishiro-haze]

(Figs. 3 and 4)

Materials examined. **Toyosaki:** OCF-P 03503, male, 39.4 mm in standard length (SL), October 11, 2015; OCF-P 03504, female, 38.1 mm SL, January 26, 2016; OCF-P 03505, male, 39.3 mm SL, January 26, 2016. **Manko:** OCF-P 03502, female, 32.8 mm SL, October 10, 2015.

Description. Counts and morphometric measurements are shown in Table 1. Body elongated and subcylindrical anteriorly, somewhat compressed posteriorly. Head cylindrical. Snout blunt and one third of head length. Mouth slightly oblique. Upper jaw protruding a little beyond lower jaw. Anterior nostril tubular and short, posterior nostril not tubular. First dorsal fin triangular with eight spines, without filamentous ones, and second and/or third spine(s) longest. Second dorsal fin with one spine and 11 soft rays. First dorsal fin height equal to second dorsal fin height, and slightly higher than anal fin. Anal fin with one spine and 10 soft rays. Anal-fin base (19.3–22.3% of SL) slightly shorter than second dor-



Fig. 3. *Acanthogobius insularis* immediately after fixation. A, OCF-P 03502, female, 32.8 mm standard length (SL), Manko, Okinawa-jima Island, Japan. B, OCF-P 03505, male, 39.4 mm SL, Toyosaki, Okinawa-jima Island, Japan. Photo by T. Kunishima.

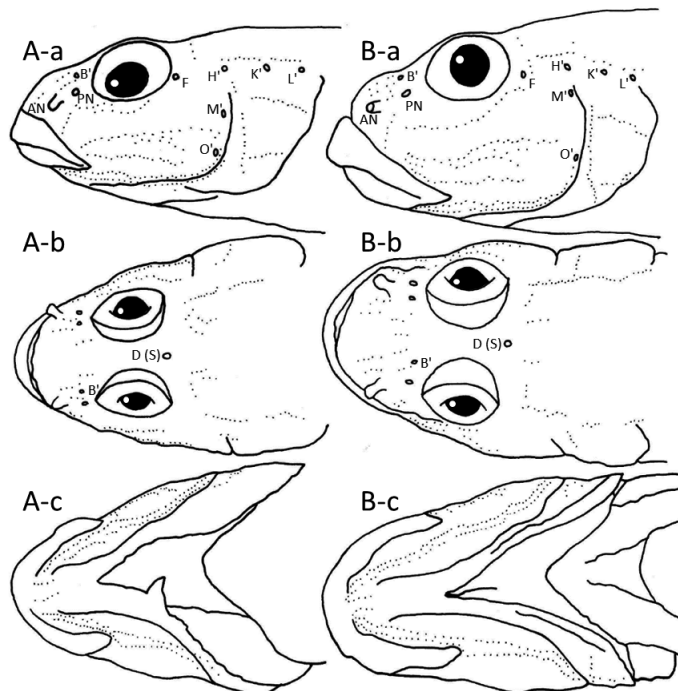


Fig. 4. Diagrammatic illustration of head showing arrangement of cephalic sensory pores and cutaneous sensory papillae in *Acanthogobius insularis* from Manko (A, OCF-P 03502) and Toyosaki (B, OCF-P 03505). a, lateral view; b, dorsal view; c, ventral view. AN, anterior nostril; PN, posterior nostril.

Table 1. Counts and measurements of *Acanthogobius insularis* from Manko and Toyosaki, in the southern part of Okinawa-jima Island, Japan, compared with the original description (Shibukawa and Taki, 1996; type specimens collected from northern part of Okinawa-jima Island and Amami-oshima Island).

	Manko n=1	Toyosaki n=3	Shibukawa and Taki (1996) n=43
Meristic characters			
Dorsal-fin spines	8	8	7 or 8
Dorsal-fin soft rays	11	11	10–12
Anal-fin rays	10	10	9–11
Pectoral-fin rays	18	19	17–20
Lateral scales	35	35–37	33–37
Transverse scales	11	9 or 10	9–11
Predorsal scales	8	6–9	3–10
Precaudal vertebrae	13	13	13
Caudal vertebrae	20	20	19 or 20
Total vertebrae	33	33	31–34
Measurement characters			
Standard length (mm)	32.8	38.1–39.4	30.1–51.4
Total length (mm)	40.9	47.9–49.3	
In % of standard length			
Head length	27.6	27.6–30.2	27.3–31.0
Head width	11.6	12.1–14.4	8.8–12.2
Snout length	9.3	8.0–10.9	8.7–12.0
Eye diameter	6.5	6.6–7.6	6.2–8.7
Interorbital length	2.7	2.2–3.0	1.7–3.5
Maxillary length	9.2	8.3–12.0	7.3–12.5
Body depth	15.2	15.0–17.3	14.8–18.2
Body width	13.1	11.9–13.6	10.8–16.6
Predorsal length	33.7	33.4–36.2	33.2–37.5
Preanal length	51.4	51.5–55.3	49.1–56.6
Caudal peduncle length	23.3	21.4–23.5	22.8–27.6
Caudal peduncle depth	10.0	8.5–9.8	8.1–10.2
Length of 1st dorsal fin base	14.5	16.3–17.6	13.8–18.8
Length of 2nd dorsal fin base	23.2	22.0–24.7	21.5–26.3
Length of anal fin base	19.3	21.2–22.3	17.4–21.3
Pectoral fin length	20.7	19.9–20.2	17.7–24.0
Pelvic fin length	19.3	18.2–22.1	17.2–23.1

sal-fin base (22.0–24.7% of SL). Caudal fin rounded, with 13 or 14 branched rays. Pectoral fin with 18 or 19 rays. All pectoral-fin rays branched, except uppermost and lowermost rays. Pelvic fin with one spine and five soft rays; pelvic fins joined together with a frenum. Pelvic fin not reaching anus. Number of vertebrae 13 + 20 = 33. Lateral scale rows 35–37; transverse scale rows 9–11; pre-dorsal scales 6–9. Cycloid scales covering pre-dorsal, dorsally on trunk to caudal-fin base. Head, pectoral-fin base and pre-pelvic-fin area naked.

Anterior oculoscapular canal with pores B', D (single), F and H'. Posterior oculoscapular canal with pores K' and L'. Pre-opercular canal with pores M' and O'. Transverse row of sensory papillae be-

hind eyes. No transverse papillae row on infraorbital. Papillae line uninterrupted from canal O' to chin, except one individual (OCF-P 03504) with an interrupted row.

When fresh (Fig. 3), body pale yellowish brown, subtranslucent. Belly whitish. Five black blotches aligned along lateral midline from flank to caudal-fin base. Reticulated dusky patterns on dorsal half of the body. Seven or eight whitish, transverse bars laterally on trunk and tail in males. One to four reddish brown spots along each spine and soft ray, and white spots between the reddish brown spots; caudal fin with three to five reddish brown or black vertical stripes and white stripes between them except for lower part of caudal fin, but these fin markings un-

clear in a small specimen (OCF-P 03502). Anal fin grayish brown in males, translucent with white margin in females. Color in preservative similar to that when fresh, but body opaque and white markings indistinct.

Ecology. In Toyosaki and Manko, *A. insularis* were found in creeks and tide pools on the tidal flats in estuaries. Water depths of the sites were shallower than 0.2 m at low tides. When the specimens were caught in Toyosaki in October 2015, we found *A. insularis* in a wide area in the tidal flat and we could observe more than 30 individuals within 30 minutes at one of the areas. However, only two and three individuals were found in January and December 2016, respectively. Only one specimen was caught in Manko in October 2015, although we tried to find this species in Manko several times from October 2015 to December 2016.

Discussion

Morphologies of the specimens observed in this study correspond well to those described by Shibukawa and Taki (1996) based on 88 specimens from northern part of Okinawa-jima Island and Amami-oshima Island, including the following diagnostic characters: Dorsal fins VIII-I, 11; anal fin I, 10; vertebrae 13 + 20 = 33; transverse row of sensory papillae behind eyes; no transverse papillae row on infraorbital; and dark spot on the caudal peduncle not bifurcated posteriorly. The papillae row extending from pore O' of pre-opercular canal to chin was interrupted in one individual observed in the present study, although Shibukawa and Taki (1996) listed uninterrupted papillae line as a diagnosis. However, the interrupted papillae line is not considered to be a unique character of the newly discovered populations, because Akihito et al. (2013) also noted that this papillae line is often interrupted in this species. Therefore, they are identified as *A. insularis*. This study reports the first record of *A. insularis* with the specimens collected from southern part of Okinawa-jima Island. Haneji-okawa Stream, Nago City in northern part

of Okinawa-jima Island had been believed to be the southernmost habitat of this species (Shibukawa and Taki, 1996). However, Toyosaki, located approximately 60 km southwest of Haneji-okawa Stream, is actually the southernmost habitat of this species.

Discovery of the new habitats for this threatened goby species is a significant finding; however, the newly found habitats cannot reverse the "threatened" status. The populations in Toyosaki and Manko are considered to be more threatened than previously known populations, because they are located near the large cities with high human population density. There were once bays and inlets with vast tidal flats along the coastline of Naha, Tomigusuku, and Itoman Cities, southern part of the island. However, approximately 550 ha of the tidal flats in this region had been lost by land reclamations (Fujii, 2001). The tidal flats where *A. insularis* populations were found by the authors are small pieces of the remaining tidal flats. Population sizes of this species in this region must have been reduced significantly by the habitat loss.

In Toyosaki, we found many individuals of *A. insularis* on the tidal flat in the fall; however, only a few individuals were found in the winter. According to observations in Shioya Bay in northern part of Okinawa-jima Island, *A. insularis* move to upper part of the estuary along Taiho-okawa Stream and spawn there from winter to spring (Kunishima et al., unpublished data). They also likely move to the creeks flowing into the tidal flat in winter in Toyosaki.

That only one individual was found in Manko might be due to the insufficiency of our survey, considering that we have explored only a part of wetland around Manko. The collection site may not be the main habitat of this species in Manko. There may have been no barrier to their larval dispersal between Toyosaki and Manko a century ago, but now the larvae have to be transported through open ocean to immigrate from Toyosaki to Manko and vice versa, as there are many artificial lands including Naha Airport between these two estuaries. There is need to in-

investigate whether *A. insularis* are permanent inhabitants in or around Manko, or whether the individual found in Manko was born in Toyosaki or elsewhere and moved to Manko.

Relationships between populations in southern and northern parts of the island are also important. Distance between Manko and Haneji-naikai Inlet is approximately 60 km, and the two locations are separated by coastline mainly composed of coral reefs including the Cape Zanpa and the Motobu Peninsula. There are no inner-bay habitats which harbor *A. insularis*. Considering their endemism and strictly localized distributions, larvae of this species probably cannot move between these two areas. Genetic studies will be required to understand relationships between populations on the southern and northern parts of Okinawa-jima Island.

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