

A new pufferfish of the genus *Torquigener* that builds “mystery circles” on sandy bottoms in the Ryukyu Islands, Japan (Actinopterygii: Tetraodontiformes: Tetraodontidae)

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Received: 14 July 2014 / Revised: 20 August 2014 / Accepted: 21 August 2014
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Abstract *Torquigener albomaculosus* sp. nov. is described based on two specimens collected from sandy bottoms at depths of 15 and 18 m along the south coast of Amami-oshima Island in the Ryukyu Islands. This new species is distinguished from all other species of *Torquigener* by the following unique combination of characters: dorsal-fin rays 9 (10); anal-fin rays 6; pectoral-fin rays 16 (dorsalmost ray nubbin-like and rudimentary); vertebrae $8 + 11 = 19$; no solid, dark, longitudinal stripe nor longitudinal rows of dark spots on the mid-side of body from behind pectoral fin to caudal-fin base; no vertical markings on cheek; dorsal half of head and body covered with fine brown reticulations and many white spots; ventral half of head and body silvery white covered by many white spots from chin to above anal-fin origin; dorsal rim of eye light yellow; and many two-rooted spinules on head and body. Males of *T. albomaculosus* build unique circles as spawning nests, these being 2 m in diameter on sandy bottoms at depths from 10 to 30 m at Amami-oshima Island.

Keywords New pufferfish · *Torquigener* · Tetraodontiformes · mystery circles · Ryukyu Islands

Introduction

Strange circles have been found on sandy bottoms at depths from 10 to 27 m along the south coast of Amami-oshima Island of the Ryukyu Islands over the past 20 years. These “mystery circles” on the sea floor are relatively large, being about 2 m in diameter, and characterized by having double edges and radiating troughs giving a spoke-like appearance, which have long been a mystery to local SCUBA divers. How are these mystery circles constructed and who builds them? Three years ago, an underwater photographer, Yoji Okata, observed a pufferfish of the genus *Torquigener* Whitley (1930) building the circles. Following his observation, a team comprising TV staff and ichthyologists including the author visited Amami-oshima Island to record the behavior of this pufferfish for about four weeks in July 2012. This field survey and additional observations resulted in a TV program and a publication on the reproductive behavior of this pufferfish (Kawase et al. 2013). Although specimens were not collected at that time, excellent underwater photographs of the pufferfish taken by Yoji Okata documented that this is a new species clearly distinguished from all other species of *Torquigener* by its color pattern. In May 2014, a research team of the National Museum of Nature and Science visited the south coast of Amami-oshima Island to seek specimens of this new pufferfish. They succeeded in collecting a male and a female of the new pufferfish that is described herein as *Torquigener albomaculosus*.

Materials and methods

The two specimens of *Torquigener albomaculosus* sp. nov. were collected by dip net on the sandy bottom along the

This article was registered in the *Official Register of Zoological Nomenclature* (ZooBank) as [E65AE185-7411-42D3-94A8-7F6A24F662DA](https://doi.org/10.31233/osf.io/662da).

This article was published as an Online First article on the online publication date shown on this page. The article should be cited by using the doi number.

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Fig. 1 Maps showing collection localities of *Torquigener albomaculosus* sp. nov. along the south coast of Amami-oshima Island in the Ryukyu Islands

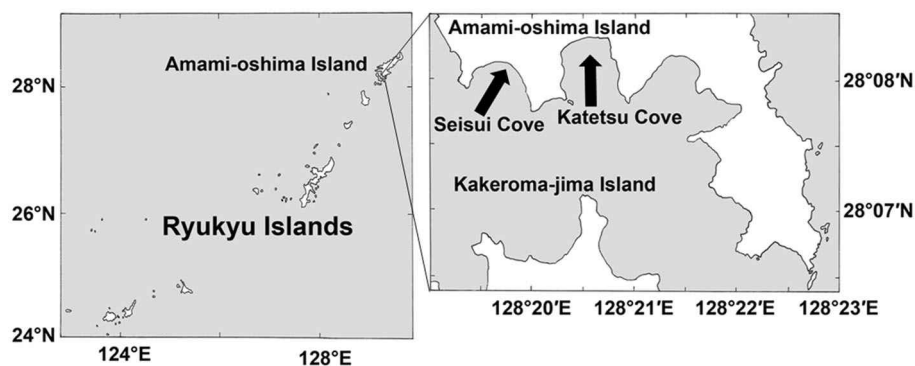
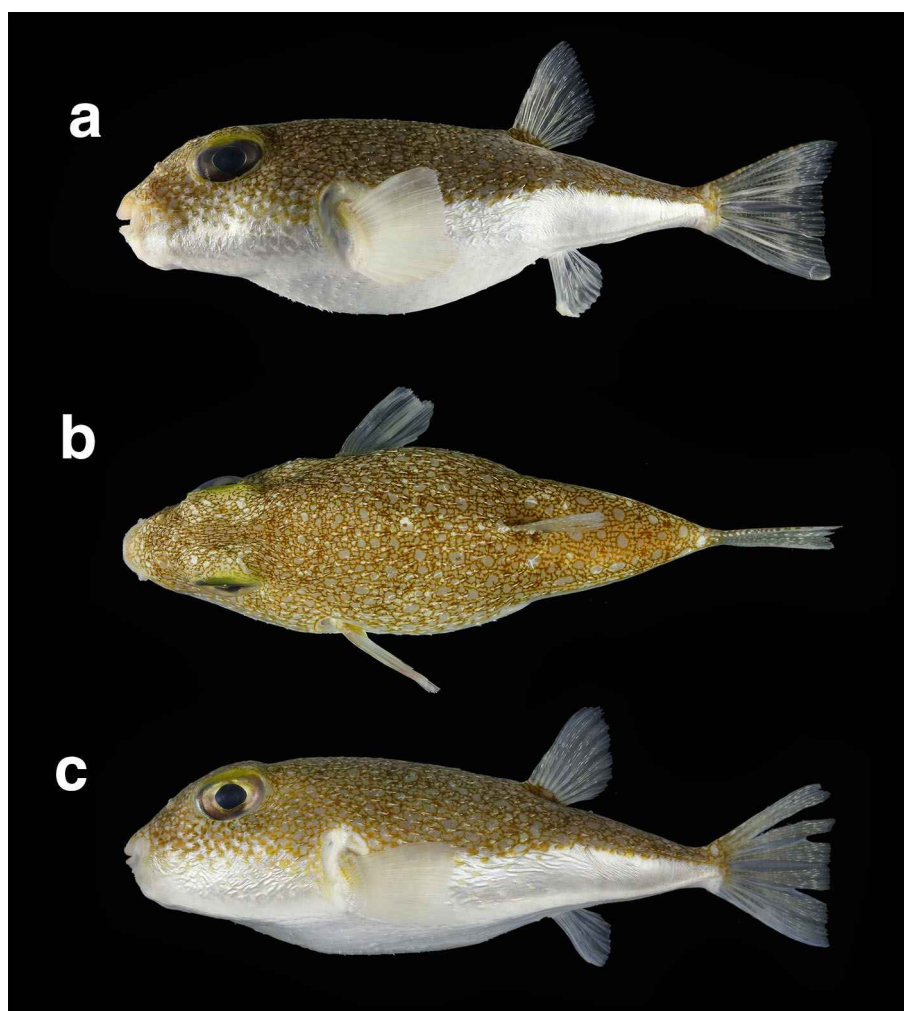


Fig. 2 Type specimens of *Torquigener albomaculosus* sp. nov. **a** Lateral view of holotype, NSMT-P 118118, male, 87.8 mm SL; **b** dorsal view of holotype; **c** lateral view of paratype, KAUM-I. 61100, female, 90.5 mm SL. Photographs by Satoru N. Chiba



south coast of Amami-oshima Island in the northern part of the Ryukyu Islands (Fig. 1). Methods for counts and measurements followed Dekkers (1975). Fin-ray counts include all visible rays, both branched and unbranched, and fin-ray lengths were determined by measurement from the embedded base. Radiographs were used to count the number of vertebrae. The osteological characters of the

skull and associated bones were observed from three-dimensional images constructed from X-ray CT scanning equipment, LCT 100 (Aloka, Tokyo). Paratype data are shown in parentheses when different from those of the holotype. Standard, total and head lengths are abbreviated as SL, TL and HL, respectively. The holotype is deposited at the Department of Zoology, National Museum of Nature

and Science, Tsukuba (NSMT), and the paratype at the Kagoshima University Museum (KAUM).

***Torquigener albomaculosus* sp. nov**

(New English name: White-spotted Pufferfish; New Japanese name: Amami-hoshizora-fugu) (Figs. 2, 3, 4, 5, 6, 7)

Torquigener sp.: Kawase et al. 2013: 1, fig. 1 (Amami-oshima Island, same as the type locality).

Holotype. NSMT-P 118118, male, 87.8 mm SL (109 mm TL), Katetsu Cove, south coast of Amami-oshima Island, Ryukyu Islands, 18 m depth, 21 May 2014.

Paratype. KAUM-I 61100, female, 90.5 mm SL (110 mm TL), same as the holotype but collected at 15 m depth.

Diagnosis. A species of *Torquigener* with the following unique combination of characters: dorsal-fin rays 9 (10); anal-fin rays 6; pectoral-fin rays 16 (dorsalmost ray nubbin-like and rudimentary); vertebrae 8 + 11 = 19; no solid, dark, longitudinal stripe nor longitudinal rows of dark spots on the mid-side of body from behind pectoral fin to caudal-fin base; no vertical markings on cheek; dorsal half of head



Fig. 3 The holotype of *Torquigener albomaculosus* sp. nov. immediately after collection from Katetsu Cove along the south coast of Amami-oshima Island in the Ryukyu Islands. Lateral view. Photograph by Tomohiro Yoshida

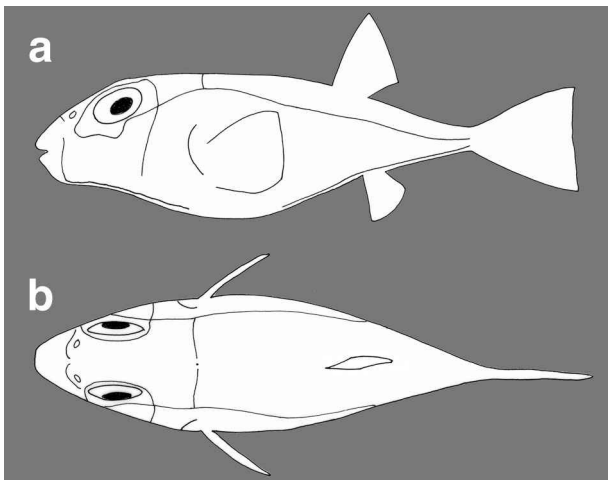


Fig. 4 Schematic illustration of lateral line system of *Torquigener albomaculosus* sp. nov. **a** Lateral view; **b** dorsal view

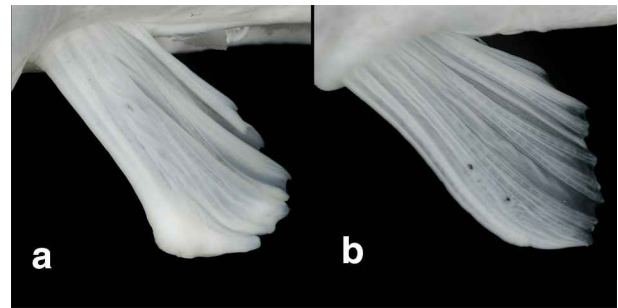


Fig. 5 Anal fin of preserved specimens of *Torquigener albomaculosus* sp. nov. **a** Holotype, NSMT-P 118118, male; **b** paratype, KAUM-I. 61100, female. Two small holes on anterior part of anal fin of the paratype were artificially made when the fin was extended for taking the photograph of Fig. 1. Photographs by Eri Katayama

and body covered with fine brown reticulations and many white spots; ventral half of head and body silvery white covered by many white spots from chin to above anal-fin origin; dorsal rim of eye light yellow; and many two-rooted spinules on head and body.

Description. Body proportions expressed as percentage of SL. Head length 38.4 (35.4), snout length 17.4 (18.2), snout to dorsal-fin origin 67.4 (68.3), snout to anal-fin origin 73.4 (72.4), body width at pectoral-fin base 30.4 (29.5), body depth at end of dorsal fin 15.5 (17.9), body depth at anal-fin origin 16.9 (18.3), depth of caudal peduncle 6.4 (6.9), length of caudal peduncle 23.3 (25.6), gill-opening length 11.7 (9.5), eye diameter 12.6 (12.2), bony interorbital width 7.0 (9.1), snout to anterior edge of nasal organ 11.2 (11.0), posterior edge of nasal organ to anterior edge of eye 5.1 (4.8), length of dorsal-fin base 7.3 (9.6), length of anal-fin base 4.6 (5.0), longest dorsal-fin ray 18.6 (17.9), longest anal-fin ray 12.0 (12.7), longest pectoral-fin ray 17.8 (18.1), caudal-fin length 24.7 (23.2).

Body moderately elongate, rounded dorsally and flattened ventrally in cross-section, tapering posteriorly to laterally compressed caudal peduncle. A longitudinal skin fold extending on ventrolateral corner of body from chin to ventral part of caudal-fin base. Mouth small, terminal; lips thin, covered with many short papillae; chin prominent. Nasal organ a short, erect papilla well before eye, with two well-separated openings, posterior opening much larger than anterior opening, inner surface with several well-developed flaps around circumference. Eye large, 3.0 (2.9) in HL, elliptical, and dorsally adnate, ventral rim at level of dorsal end of gill opening; interorbital region slightly concave. Gill opening a slightly curved slit extending ventrally from level of ventral rim of eye to level of two-thirds down pectoral-fin base.

Dorsal fin slightly rounded, third dorsal-fin ray longest, dorsal-fin origin just behind a vertical through vent; anal fin slightly rounded, much smaller than dorsal fin, second anal-fin ray longest, first and second anal-fin rays of male

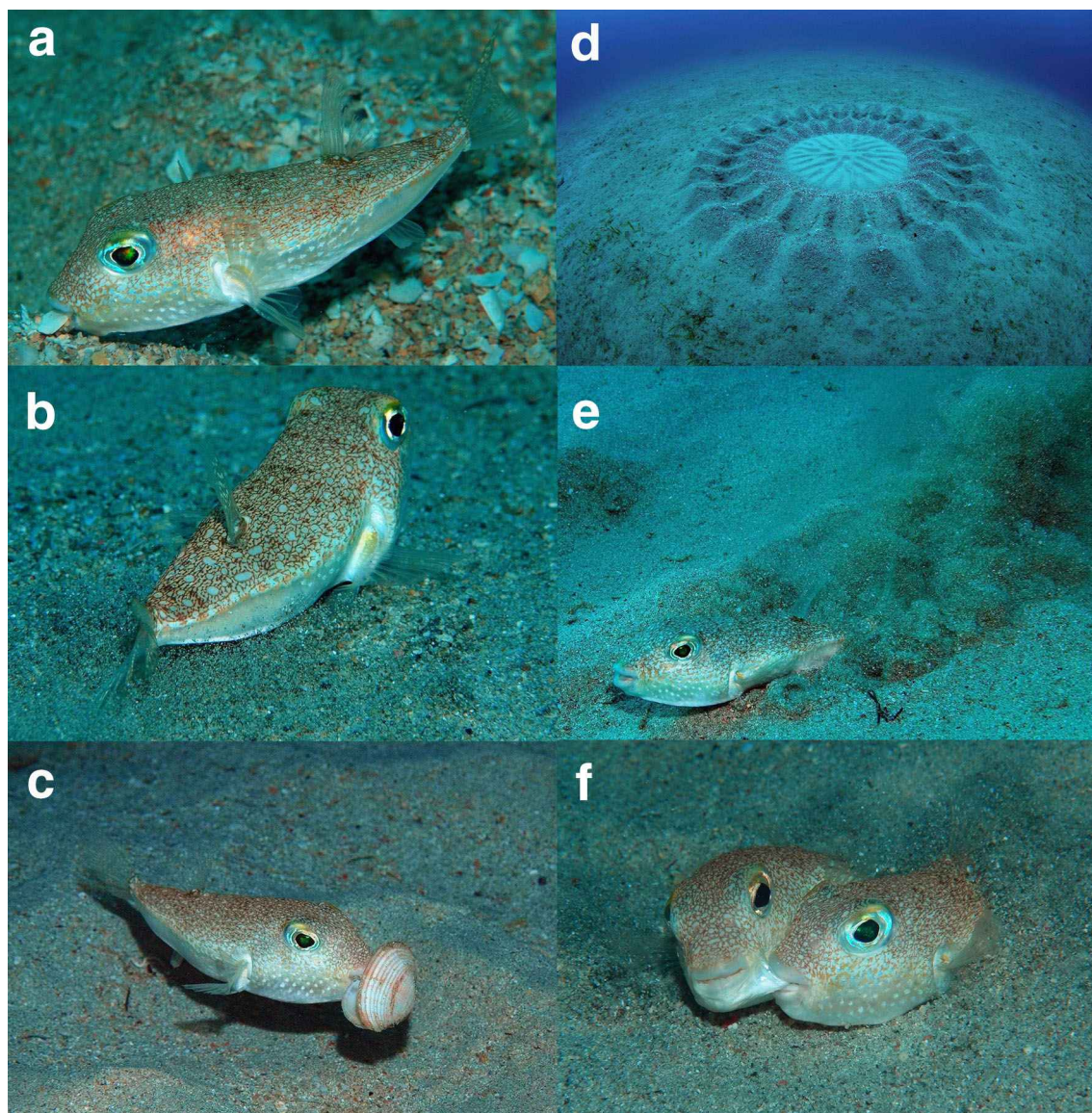


Fig. 6 Underwater photographs of *Torquigener albomaculosus* sp. nov. and its spawning nest. **a** *Torquigener albomaculosus* placing a piece of shell on a ridge of a spawning nest, 11 July 2012; **b** posterior view of a male of *T. albomaculosus* making a trough on a spawning nest, 28 May 2011; **c** a male of *T. albomaculosus* bringing a dead bivalve in a spawning nest; **d** a spawning nest (mystery circle) of *T.*

albomaculosus found at 26 m depth on a sandy bottom along the south coast of Amami-oshima Island in the Ryukyu Islands, 28 May 2011; **e** a male digging a trough by vibrating anal fin and posterior half of body, 28 May 2011; **f** a male (right) biting on the left cheek of a female (left) while they were spawning, 13 July 2012. Photographs by Yoji Okata

thickened and united distally but these rays normal in female (Fig. 5), anal-fin origin just below posterior end of dorsal fin; pectoral fin rounded, first pectoral-fin ray rudimentary and nubbin-like, second pectoral-fin ray longest, dorsal end of pectoral-fin base at level between ventral rim of eye and mouth; caudal fin almost truncate, slightly concave.

Two lateral lines on head and side of body (Fig. 4). The dorsalmost lateral line encircles the eye, with a preopercular branch terminating at level of ventral end of pectoral-fin base and a posteriorly directed branch

coursing along the mid-lateral side of body from just behind ventroposterior part of eye to caudal-fin base, with a dorsally directed branch just above pectoral-fin base almost meeting in midline with its counterpart from the other side of the body. A short transverse element of lateral line in front of nasal organ almost meeting in midline with its counterpart from the other side of the snout. The ventral lateral line originates posterior to the mouth and then courses along the ventrolateral edge of body to caudal-fin base with an interruption ventral to the pectoral fin. Two-rooted spinules present on head and

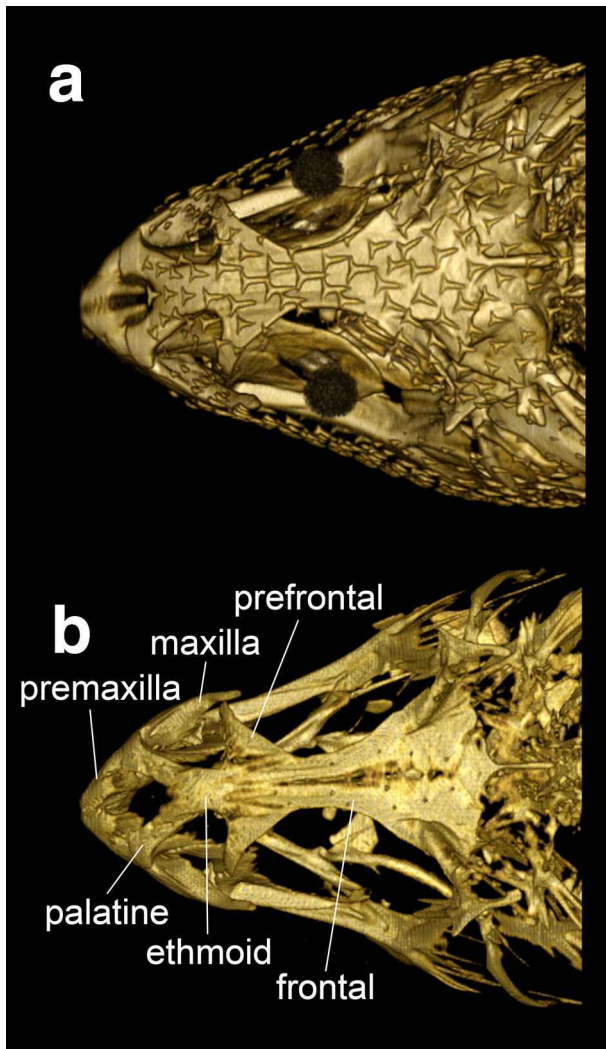


Fig. 7 CT scanning images of skull, associated bones and two-rooted spinules of *Torquigener maculosus* sp. nov. **a** Shallow layer image showing two-rooted spinules scattered over head and body. **b** deeper layer image showing skull and associated bones. Images made by Eri Katayama and Nozomi Kurihara

body (Figs. 2, 3, 7a), projecting from short, normally recessed papillae; extending on dorsal surface from just behind mouth to level of posterior end of dorsal fin and on lateral surface from cheek to level of posterior end of dorsal fin; 9 (10) spinules across dorsum immediately behind mid-dorsal branches of lateral lines; 19 (21) spinules across belly on a line between pectoral-fin bases; smaller spinules making two longitudinal rows along the dorsalmost lateral line from level of posterior end of dorsal fin to caudal peduncle, the dorsal row of spinules just above mid-body lateral line and the ventral row of spinules just below dorsalmost lateral line; two-rooted spinules also densely present on ventral surface from just behind chin to vent.

Color of fresh specimens before preservation (Fig. 2). Dorsal half of head and body covered by fine brown reticulations and many white spots; ventral half of head and body silvery white covered by many white spots from chin to above anal-fin origin; dorsal rim of eye light yellow; dorsal, anal and pectoral fins transparent with slight yellowish tinge; yellow smudge on anterior end of pectoral-fin base and axial part of pectoral fin base also light yellow; caudal fin transparent with yellowish brown dots on rays.

Color when alive (based on color photographs of holotype and paratype when alive, and underwater photographs of non-type individuals: Figs. 3, 6). Color of head, body, and fins almost same as the color of fresh specimens before preservation but network pattern on dorsal half of head and body bright yellowish brown; white spots on ventral half of body distinctive; light yellow spots forming a longitudinal row on mid-lateral body from behind pectoral fin to caudal-fin base.

Distribution. *Torquigener albomaculosus* has been observed by local SCUBA divers at depths from 10 m to 27 m on the sandy bottom along the south coast of Amami-oshima Island of the Ryukyu Islands. According to these SCUBA divers, another population of *T. albomaculosus* has recently been found around 30 m depth in the northern part of Amami-oshima Island. Judging from distributions of other tropical species of *Torquigener*, *T. albomaculosus* will probably be found in the tropical region of the West Pacific.

Etymology. The specific name, *albomaculosus*, refers to many white spots on the body.

Remarks. The new pufferfish is classified in the genus *Torquigener* by having the following combination of characters: eye dorsally adnate only; chin well developed (Fig. 2); two openings on nasal organ; ventrolateral skin fold extending behind pectoral fin to caudal-fin base; frontals elongate and narrow across the orbit, not more than twice the width of the mid-dorsal surface of ethmoid at the posterior margin of prefrontals (Fig. 7b); and the dorsal surface of ethmoid extending well forward of the anterior margin of prefrontals. The revision of 12 Australian species of *Torquigener* (see Hardy 1983a) was followed by descriptions of additional seven new species from various regions of the Indo-Pacific (Hardy, 1983b, 1984, 1989; Hardy and Randall 1983). *Torquigener albomaculosus* brings the total number of species of *Torquigener* to 20. The most helpful characters distinguishing *T. albomaculosus* from all other species of the genus are coloration of the head and body provided in the Diagnosis above.

To the best of our knowledge, *T. albomaculosus* is unique in building large geometric circles on sandy bottoms. Kawase et al. (2013) reported on the reproductive behavior of *T. albomaculosus* showing how this pufferfish builds its circles.

Acknowledgments I thank Kimiaki Ito (Marine Station), Satoru N. Chiba and Eri Katayama (NSMT), Yoji Okata (underwater photographer), Tomohiro Yoshida (KAUM), Hiroyuki Doi and Takayuki Sonoyama (Shimonoseki Aquarium) for collecting the type specimens of *Torquigener albomaculosus*. Yoji Okata provided excellent underwater photographs of *T. albomaculosus* and a spawning nest of this species. Photographs of the holotype and paratype were taken by Satoru N. Chiba and Eri Katayama. Radiographs were taken by Shinpei Ohashi (NSMT). Eri Katayama and Nozomi Kurihara (NSMT) produced three-dimensional images of internal characters of *T. albomaculosus* by using X-ray CT scanning equipment. Masanori Nakae helped in drawing the schematic illustration of the lateral line system of *T. albomaculosus*. My thanks also go to Akira Ida (NHK: Japan Broadcasting Corporation) for providing an opportunity to observe the reproductive behavior of *T. albomaculosus* in July 2012. Edward O. Murdy kindly reviewed the manuscript. This study was partially supported by Grant-in-Aids for Scientific Researches, A (19208019) and B (24370041) from the Japan Society for the Promotion of Science; Grant-in-Aid for Scientific Research on Innovative Areas of the Ministry of Education, Culture, Sports, Science and Technology (MEXT), 24120001; Health Labour Sciences Research Grant (FY2013-2014) of the Ministry of Health, Labour and Welfare, Japan; and the “Biological Properties of Biodiversity Hotspots in Japan” Project of the National Museum of Nature and Science.

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