A new species of *Solemya* (Bivalvia: Protobranchia: Solemyidae) from a hydrothermal vent in the Iheya Ridge in the mid-Okinawa Trough, Japan

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ABSTRACT

A new species, *Solemya* (*Solemya*) *flava*, is described from a hydrothermal vent field located in the Iheya Ridge in the mid Okinawa Trough, Japan. The small-sized new species is characterized by (1) a branched internal ligament attached to the chondrophore, (2) a bright yellowish brown periostracum, and (3) relatively short shell length relative to height (length/height = ca. 2.2) for solemyid bivalves. This species is associated with a vesicomyid clam, *Calyptogena okutanii* Kojima and Ohta, 1997, which is dominant in chemosynthetic environments.

Additional Keywords: taxonomy, *Acharax*, *Calyptogena* site

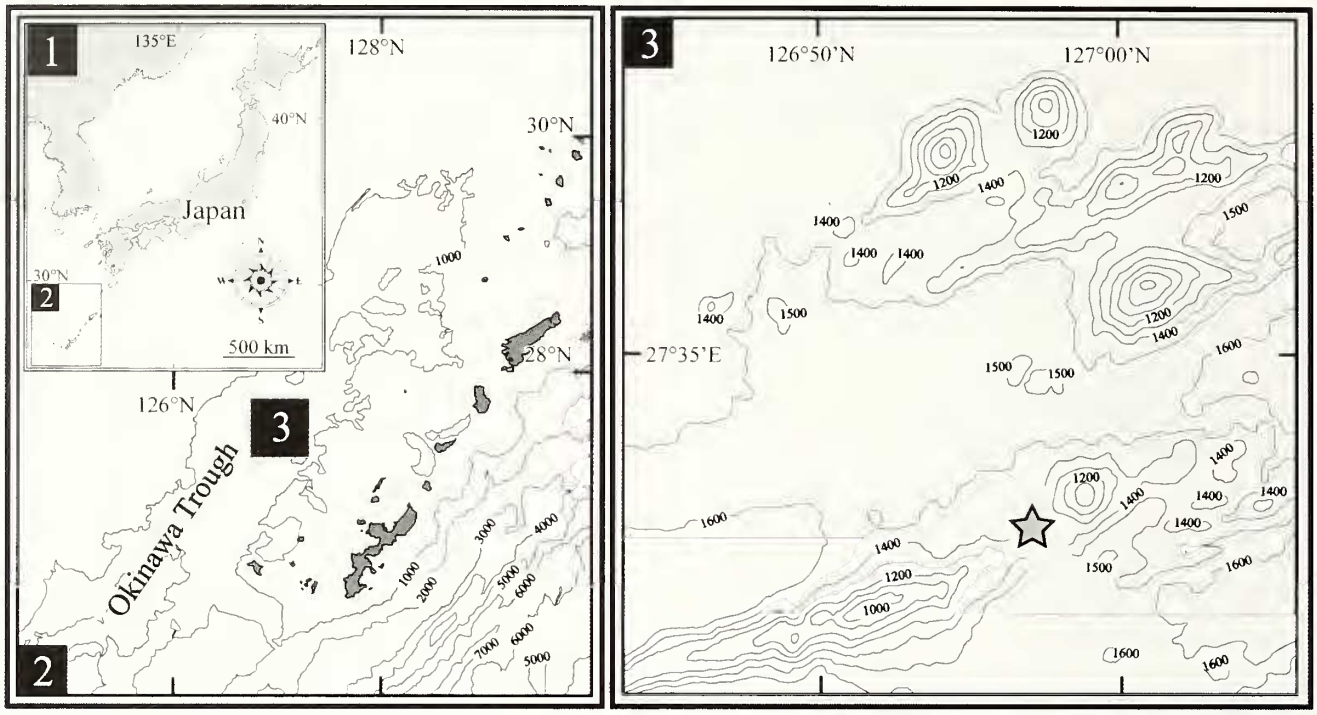
INTRODUCTION

Solemyids are an ancient group of bivalves whose fossil records date back to the Ordovician (Pojeta, 1988; Bailey, 2011). More than 30 Recent species are known (Huber, 2010), and there is also a rich fossil record for the group (e.g. Kiel, 2010; Amano and Ando, 2011; Taviani et al., 2011). They are morphologically characterized by an elongate shell with a thick periostracum, a posteriorly situated and toothless hinge, enlarged ctenidia, and reduced digestive system. The periostracum is much larger than the calcified part of the shell and folded inwards in living-animals. All known species are associated with reduced environments including vents and seeps, and they are one of several groups of chemosynthetic bivalves (Taylor and Glover, 2010), harboring sulfide-oxidizing chemoautotrophic bacteria in the ctenidia (Stewart and Cavanaugh, 2006).

Numerous chemosynthetic-based biological communities have been documented around Japan since 1980s (see review by Sasaki et al., 2005; Watanabe et al., 2010). Okinawa Trough is one of major localities with communities sustained by active hydrothermal vents. During a dive in the Iheya Ridge in mid-Okinawa Trough, an unknown species of the Solemyidae was collected. This was the first record of the family from the Okinawa Trough, and, as a result of morphological comparisons, the specimens were identified as a new species. In this paper we describe this new solemyid species colonizing the *Calyptogena* site.

MATERIALS AND METHODS

Three specimens of the new species were collected from 27°32.994′ N, 126°58.230′ E at a depth of 1402 m (Figures 1–3) with a scoop sampler from ROV Hyper-Dolphin operated by the Japan Agency for Marine-Earth Science and Technology (JAMSTEC). The specimens were collected together with sediments and *Calyptogena okutanii* during Dive #1246, February 10, 2011. The locality has been surveyed since the 1990s, and its fauna and bottom characters were documented by Ohta and Kim (2001). The specimens were preserved during the



Figures 1–3. The type locality of *Solemya (Solemya) flava* new species. **1.** Map of Japan showing location of Okinawa. **2.** Detailed map of Okinawa Trough; bottom contour intervals are 1000 m. **3.** Detailed bathymetrical map of the Iheya Ridge. Star indicates the type locality.

cruise at −30°C in light-shielded conditions, and fixed in 99% ethanol in the laboratory. All specimens used for description were dissected under a binocular microscope. The type specimens were registered in the Department of the Historical Geology and Paleontology, The University of Tokyo (UMUT).

SYSTEMATICS

Family Solemyidae Gray, 1840

Genus *Solemya* Lamarck, 1818

Solemya (Solemya) flava new species
(Figures 4–15)

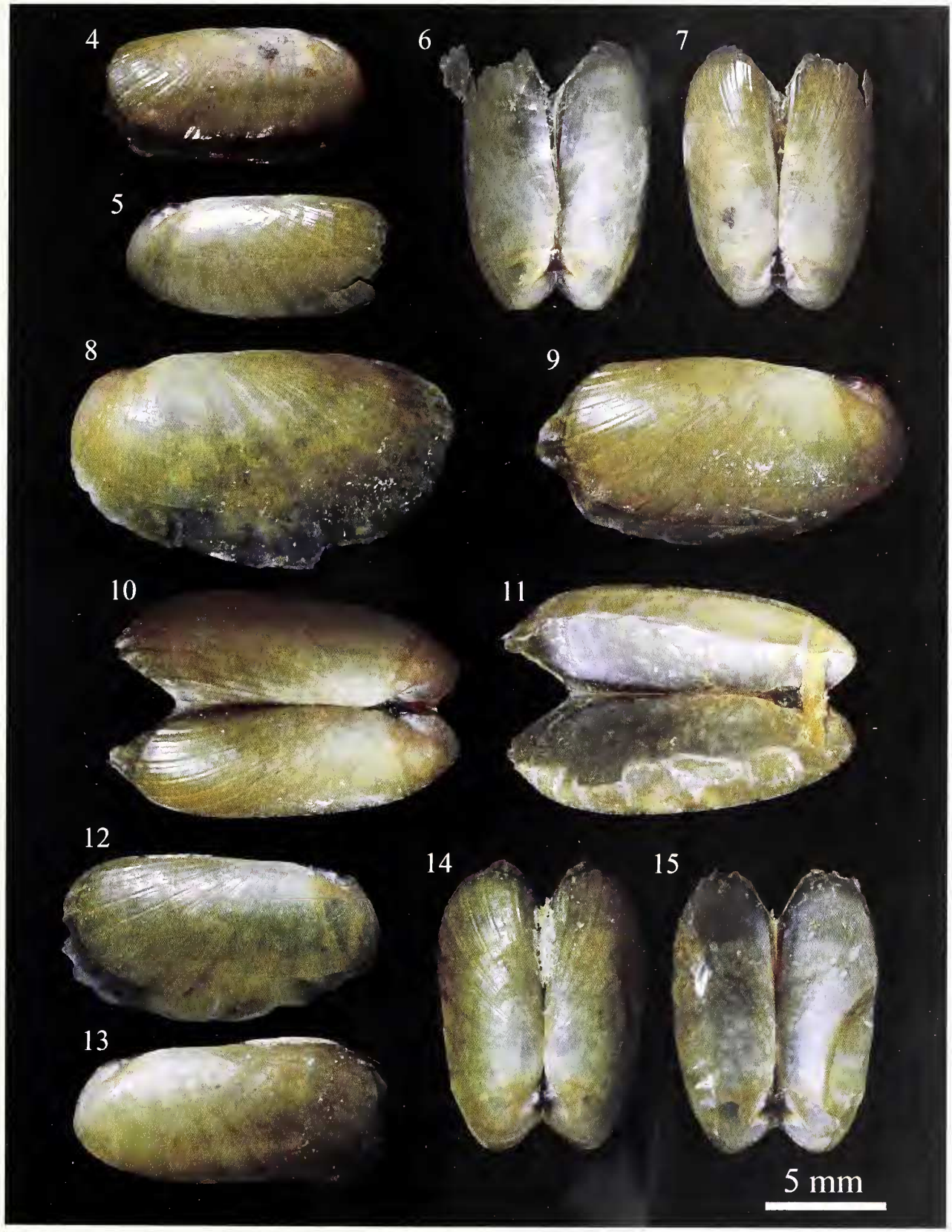
Diagnosis: Branched internal ligament attached to the chondrophore, bright yellowish brown periostracum, and relatively short shell length relative to shell height for solemyid bivalves.

Description: Shell small, up to 14.2 mm in length, elongate oval, laterally compressed, equivalve, inequilateral, thin and flexible. Umbones not prominent, situated at posterior one-fourth of shell length. Lunule and escutcheon absent. Antero-dorsal margin straight, almost parallel to straight ventral margin. Both anterior and posterior margins gently rounded. Postero-dorsal margin slightly convex, positioned slightly below beak, with well-expressed radial, oblique flexure corresponding to attachment of chondrophore to inner shell surface. Shell length small relative to shell height (length/height = ca. 2.2) for solemyid bivalves. Periostracum thick, brownish yellow, extending beyond shell margins and forming frills. Surface with widely spaced weak radial ribs or furrows, especially on anterior and posterior regions. Internal surface dull white. Ligament internal, thin, subtriangular, moderately broad, attached to chondrophore, without expansion in front of chondrophore. Chondrophore weak, narrow, situated behind posterior adductor scar. Internal radial rib anterior to posterior adductor scar inconspicuous, narrow, extended from umbo and located anterior to posterior adductor scar. Anterior adductor scar large, angular-oval, feebly impressed. Posterior scar smaller, oval, not adjoining antero-ventral margin of chondrophore or extending behind chondropore. Pallial line obscure.

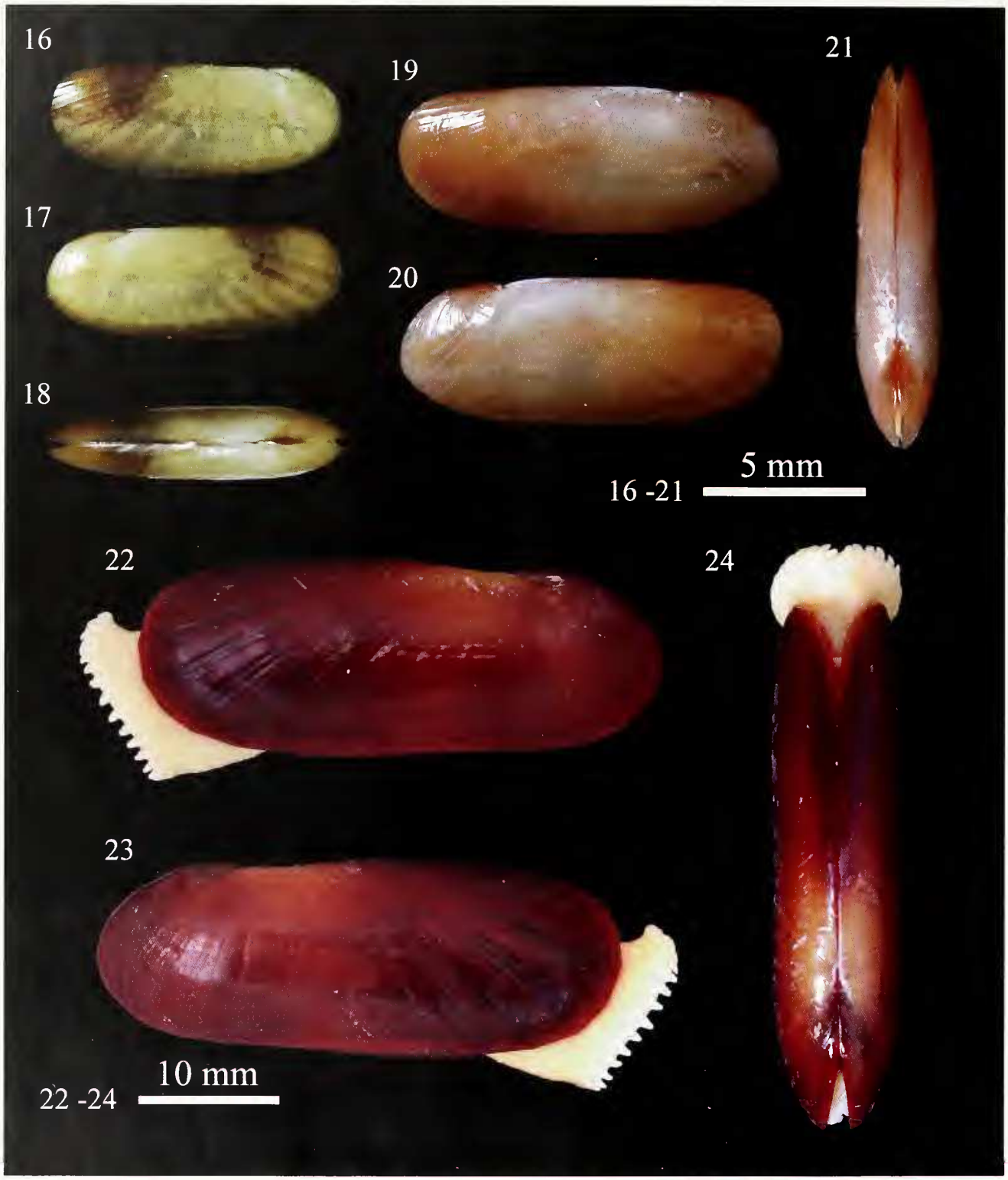
Type Material: Holotype, UMUT RM30147, 11.5 × 5.8 mm with periostracum, 10.7 × 4.6 mm excluding periostracum (Figures 4–7); paratype #1, UMUT RM30148, 15.4 × 9.3 mm with periostracum, 14.2 × 6.9 mm excluding periostracum, (Figures 8–11); paratype #2, UMUT RM30149, 13.1 × 6.9 mm with periostracum, 12.5 × 5.7 mm excluding periostracum (Figures 12–15).

Type Locality: Iheya Ridge in the Okinawa Trough, 27°32.994′ N, 126°58.230′ E, 1402 m deep.

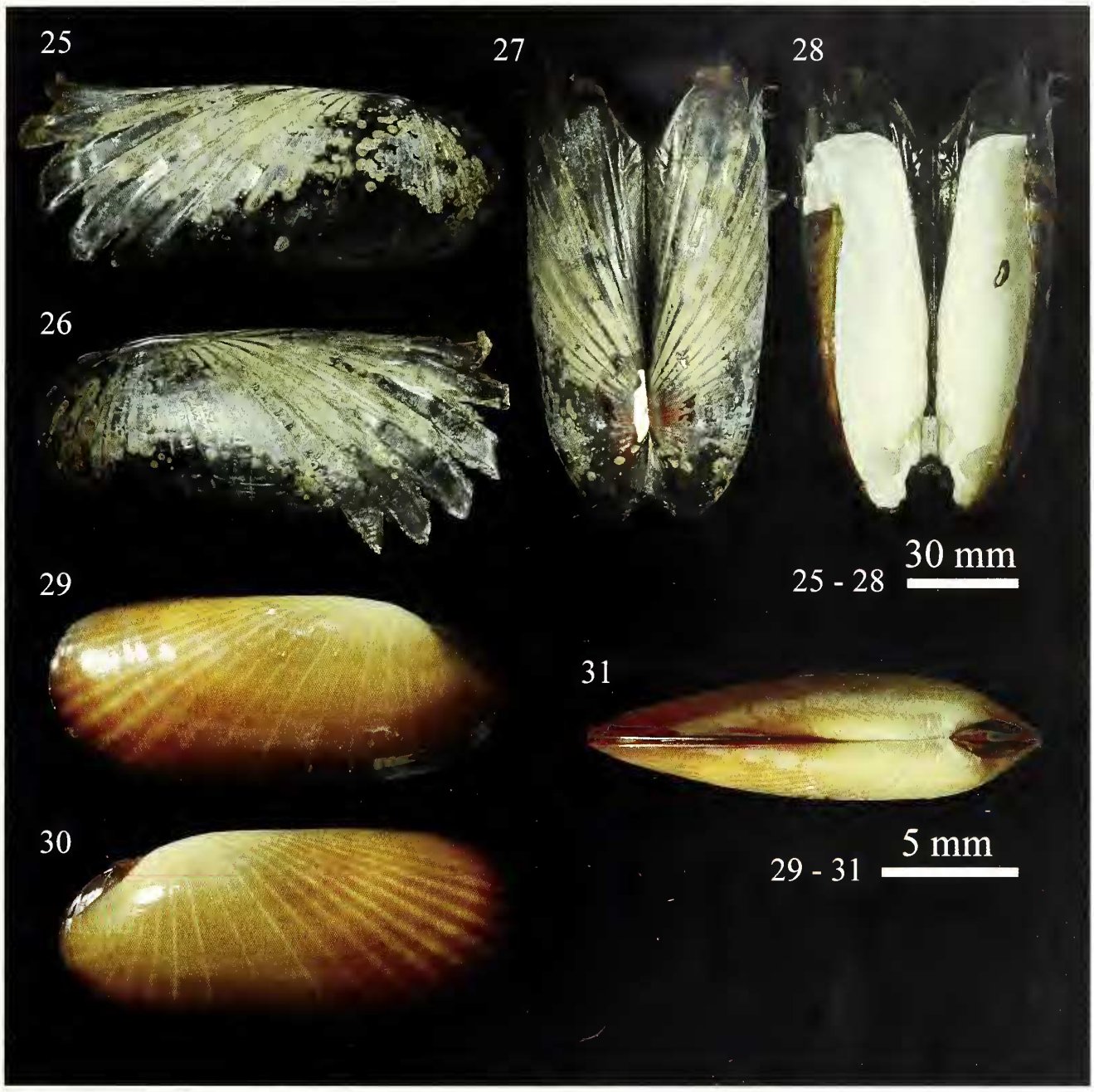
Distribution: Known only from the type locality.



Figures 4–15. *Solemya (Solemya) flava*. **4–7.** Holotype UMUT RM30147. **8–11.** Paratype #1 UMUT RM30148. **12–15.** Paratype #2 UMUT RM30149.



Figures 16–24. Solemyid bivalves for comparison (see also Sato et al., 2013). **16–18.** *Solemya* (*Solemya*) *pusilla* (Gould, 1861) UMUT RM 31050, Okinoshima-Island, Chiba Prefecture, Japan. **19–21.** *Solemya* (*Solemya*) *tagiri* Okutani, Hashimoto and Miura, 2004, one of paratypes JAMSTEC 031588-031594, Kagoshima Bay, Kagoshima Prefecture, Japan. **22–24.** *Solemya* (*Petrasma*) *pervernicosa* (Kuroda, 1948) JAMSTEC 053256, Joetsu Knoll, Niigata Prefecture, Japan.

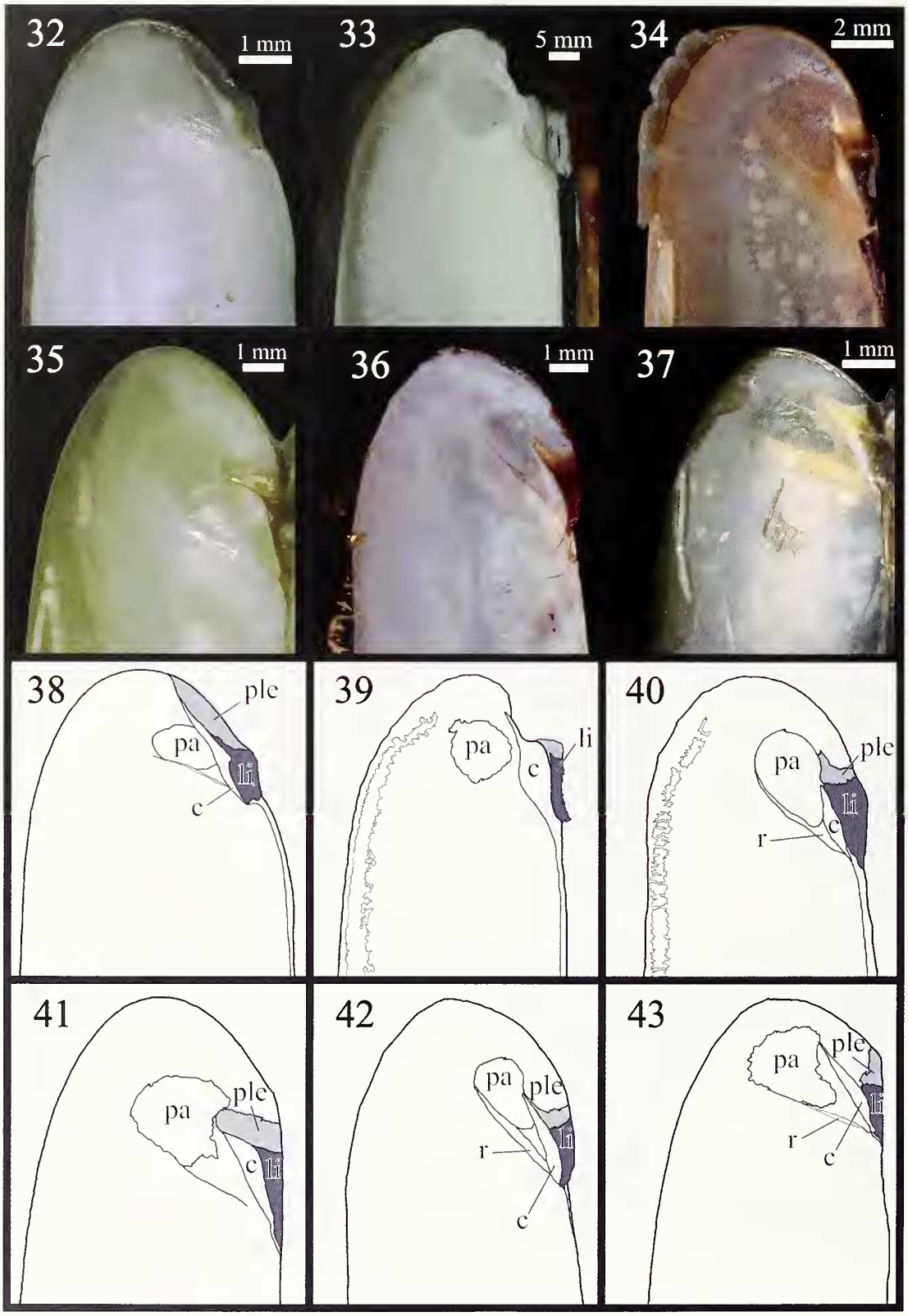


Figures 25–31. Solemyid bivalves for comparison (see also Sato et al., 2013). **25–28.** *Acharax johnsoni* (Dall, 1981) UMUT RM 28724. Off Otsuchi, Iwate Pref., Japan. **29–31.** *Acharax japonica* (Dunker, 1882) UMUT RM 30934. Shimoda Marine Research Center, Shizuoka Pref., Japan.

Etymology: The specific epithet is derived from the Latin word *flavus* meaning yellow.

DISCUSSION

The new species is assigned to *Solemya* (*Solemya*) on the basis of conchological characters. The genus *Solemya* is distinguished from another valid genus of the family, *Acharax* in having internal ligament and a slightly convex postero-dorsal margin (Dall, 1908). *Solemya* is divided into five subgenera: *Solemya*, *Solemyarina*, *Petrasma*, *Zesolemya*, and *Austrosolemya* (Dall, 1908; Cox, 1969; Taylor et al., 2008; Kamenev, 2009) which are diagnosed as follows by features near the umbo such as the posterior adductor muscle scar, internal ligament, chondrophore



Figures 32–43. Internal umbonal areas of six solemyid species around Japan. Images in Figures 32–37 are shown as diagrams in Figures 38–43. **32, 38.** *Acharax japonica*. **33, 39.** *Acharax johnsoni*. **34, 40.** *Solemya (Petrasma) pervernicosa*. **35, 41.** *Solemya (Solemya) pusilla*. **36, 42.** *Solemya (Solemya) tagiri*. **37, 43.** *Solemya (Solemya) flava* new species. Abbreviations: **c**, chondrophore; **li**, ligament; **pa**, posterior sdductor scar; **ple**, posterior outer-layer ligamental extension; **r**, internal radial rib.

Table 1. Comparisons among species of *Solemya* and *Acharax*.

Species	Maximum shell lenght (mm)	Lenght/ Height	Ligament situation	Posterior adductor muscle scar	Chondrophore	Internal radial rib	References
Solemya (Solemya) flava	14.2	2.18 (n=3)	internal	Deached from chondrophore and internal radial rib	Long, thin	Weak, branching from chondrophore at umbo	This study
Solemya (Solemya) pusilla	14.5	2.72 (n=2)	internal	Deached from chondrophore and internal radial rib	Long, thin	Very weak	Okutani (2000), Kamenev (2009)
Solemya (Solemya) tagiri	23.8	2.5 (n=11)	internal	Detached from chondrophore and internal radial rib but contacting with them	Long, thin	Weak, branching from chondrophore at umbo	Okutani et al. (2003)
Solemya (Solemya) valvulus	20.0	3.29 (n=1)	internal	Detached from chondrophore	Long, thin	Absent	Coan et al. (2000), Kamenev (2009)
Solemya (Petrasma) panamensis	47.0	2.88 (n=1)	internal	Attached to chondrophore and internal radial rib	Short, thin	Weak, narrow, supporting chondrophore	Kamenev (2009)
Solemya (Petrasma) pervernicosa	63.1	2.65 (n=4)	internal	Detached from chondrophore and internal radial rib	Short, thick	Strong, supporting chondrophore	Okutani (2000)
Acharax japonica	20.0	2.39 (n=43)	external	Poorly impressed	Absent	Very weak	Okutani (2000)
Acharax johnsoni	150.0	2.45 (n=2)	external	Well impressed	Absent	Absent	Coan et al. (2000)

and internal radial ribs: (1) *Solemya* s.s. has an opisthodetic internal ligament and a short and thin chondrophore; (2) *Solemyarina* has a heart-shaped internal ligament expansion in front of the week and narrow chondrophore. The posterior adductor scar is not impressed into the inner shell surface; (3) In *Petrasma*, the anterior end of the posterior adductor muscle scar is deeply impressed and attached to the anteroventral margin of the chondrophore; (4) *Zesolemya* is characterized by narrow posterior expansions of the ligament, a bifurcated chondrophore around the posterior adductor muscle scar, and prominent anterior linear extensions of the ligament; (5) *Austrosolemya* possesses an internal ligament with lobate anterior extensions, a broad triangular resilium, and strong chondrophoral ridges.

At the species level, the new species from off Okinawa should be compared with known solemyids from Japan and other adjacent regions of the Pacific geographically. Around Japan five species have been recorded (Kuroda et al., 1971; Habe, 1977; Okutani, 2000), namely *Solemya* (*Solemya*) *pusilla* (Gould, 1861) (Figures 16–18); *S.* (*S.*) *tagiri* Okutani, Hashimoto and Miura, 2004 (Figures 19–21); *S.* (*Petrasma*) *pervernicosa* (Kuroda, 1948) (Figures 22–24); *Acharax johnsoni* (Dall, 1981) (Figures 25–28), and *A. japonica* (Dunker, 1882) (Figures 29–31). *Solemya* (*S.*) *flava* is distinct from these species in five characters, viz. maximum shell length, ligament position, configuration of posterior adductor muscle scar, length and thickness of chondrophore, and internal radial ribs (Table 1). Species from other regions of the North Pacific (*Solemya* (*Solemya*) *valvulus*, *Solemya* (*Petrasma*) *panamensis*) are also distinguished by these characters (see also Table 1).

In *Solemya* (*Solemya*), two species, *S.* (*S.*) *pusilla* and *S.* (*S.*) *tagiri*, seem closely related to the new species in shell morphology. *Solemya* (*S.*) *pusilla* is most similar in maximum size to this species but differs in having a much more elongate outline (L/H = 2.72). *Solemya* (*Solemya*) *tagiri* is also similar in shell size and having a narrow and weak internal radial rib. However, the new species is distinguished from these species in having short shell length (L/H = 2.18) relative to shell height and umbo situation. The umbo of *S.* (*S.*) *tagiri* is situated in a more anterior position than that of this species. Internal umbonal areas of six solemyid species are illustrated in Figures 32–43 for comparison.

From an ecological standpoint, the new species might be related to *S.* (*S.*) *tagiri*, since both species are dependent on chemosynthesis-based, hydrothermal vent communities and their habitats are relatively geographically close in Japan. However, the habitat of *S.* (*S.*) *tagiri* is restricted to a narrow site at depth of 94–98 m in Kagoshima Bay which is nearly closed and isolated from the open ocean. In contrast, the locality of *S.* (*S.*) *flava* is isolated in the middle part of Okinawa Trough at a much greater depth (1402 m). Therefore, each species is possibly endemic to Kagoshima Bay and Okinawa Trough, respectively, and their habitats are sharply separated.

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