

Bulletin of the Mizunami Fossil Museum, no. 47, 21–40, 9 figs.

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Manuscript accepted on March 14, 2020; online published on April 30, 2020

<http://zoobank.org/urn:lsid:zoobank.org:pub:CF4B8D13-86D1-4CDD-BBC8-7C3B128E512C>

## Cenozoic pedunculate barnacles (Cirripedia: Thoracica) deposited in the Mizunami Fossil Museum, Japan

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### Abstract

Cenozoic pedunculate barnacles (Cirripedia, Thoracica) deposited in the paleontological collection of the Mizunami Fossil Museum, Japan, are clarified. Two new species of the scalpellid genus *Arcoscalpellum* Hoek are described: *Arcoscalpellum s.l. isaonishikawai* from the Miocene Bihoku Group and *Arcoscalpellum s.l. joei* from the Miocene Yotsuyaku Formation. *Lepas azuminoensis* Kawase, Koike, and Tanaka is moved to another lepadid genus, *Dosima* Gray. *Smilium scorpio* (Aurivillius) (Calanticidae), *Lepas pectinata* Spengler (Lepadidae), and *Octolasmis orthogonia* (Darwin) (Poecilasmatidae) from the Pleistocene of Japan are first reported in the fossil records. The new records of fossil pedunculate barnacles are as follows: *Calantica* sp. (Calanticidae) from the Pleistocene Ryukyu Group; *Lepas* sp. from the Miocene Katsuta Group; *Oxynaspis* sp. (Oxynaspididae) from the Pleistocene Atsumi and Shimosa Groups; and *Capitulum* sp. (Pollicipidae) from the Miocene Mizunami Group.

*Key words:* Multicrustacea, Calanticidae, Lepadidae, Oxynaspididae, Poecilasmatidae, Pollicipidae, Scalpellidae, fossil

### Introduction

The pedunculate barnacles have been extremely rare in the Japanese fossil record. Takakuwa and Ohta (2019, table 1) summarized these records except for lepadids and listed 16 occurrences during the Jurassic–Middle Pleistocene. Lepadids are represented by only three species; *Lepas kuwayamai* Karasawa, Tanaka, and Okumura, 2004, from the Miocene Mizunami Group; *L. azuminoensis* Kawase, Koike, and Tanaka, 2006, from the Miocene Bessho Formation; and *L. anatifera* Linnaeus, 1758, from the Pleistocene Atsumi Group (Kobayashi et al., 2008). The purpose of this paper is to record the previously described and unrecorded specimens of pedunculate barnacles,

deposited in the Mizunami Fossil Museum (MFM), Japan.

### Taxonomical Accounts

Recent phylogenetic works (Pérez-Losada et al., 2008; Linse et al., 2013; Rees et al., 2014; Lin et al., 2015; Herrera et al., 2015; Ewers-Saucedo et al., 2019; Ewers-Saucedo and Pappalardo, 2019) do not support the monophyly of the currently used orders and suborders to pedunculate barnacles. Therefore, the ordinal-level classifications are not adapted here.

Family Calanticidae Zevina, 1978a

Genus *Calantica* Gray, 1825

*Type species: Calantica hormii* Gray, 1825 (= *Pollicipes villosus* Leach, 1824), by original designation.

*Including fossil species: Calantica juliensis* (Ortmann, 1900) (Miocene, Argentina); *C. miocenica* Withers, 1953 (Miocene, Italy); *C. ? saskatchewanensis* Russell, 1967 (U. Cretaceous, Canada); *C. spinilatera* Foster, 1978 (Miocene, New Zealand; extant); *C. sulci* Withers, 1953 (Miocene, Czech Republic); *C. zancleana* (Seguenza, 1876) (Pliocene–Pleistocene, Italy; extant).

***Calantica* sp.**

(Fig. 1.1)

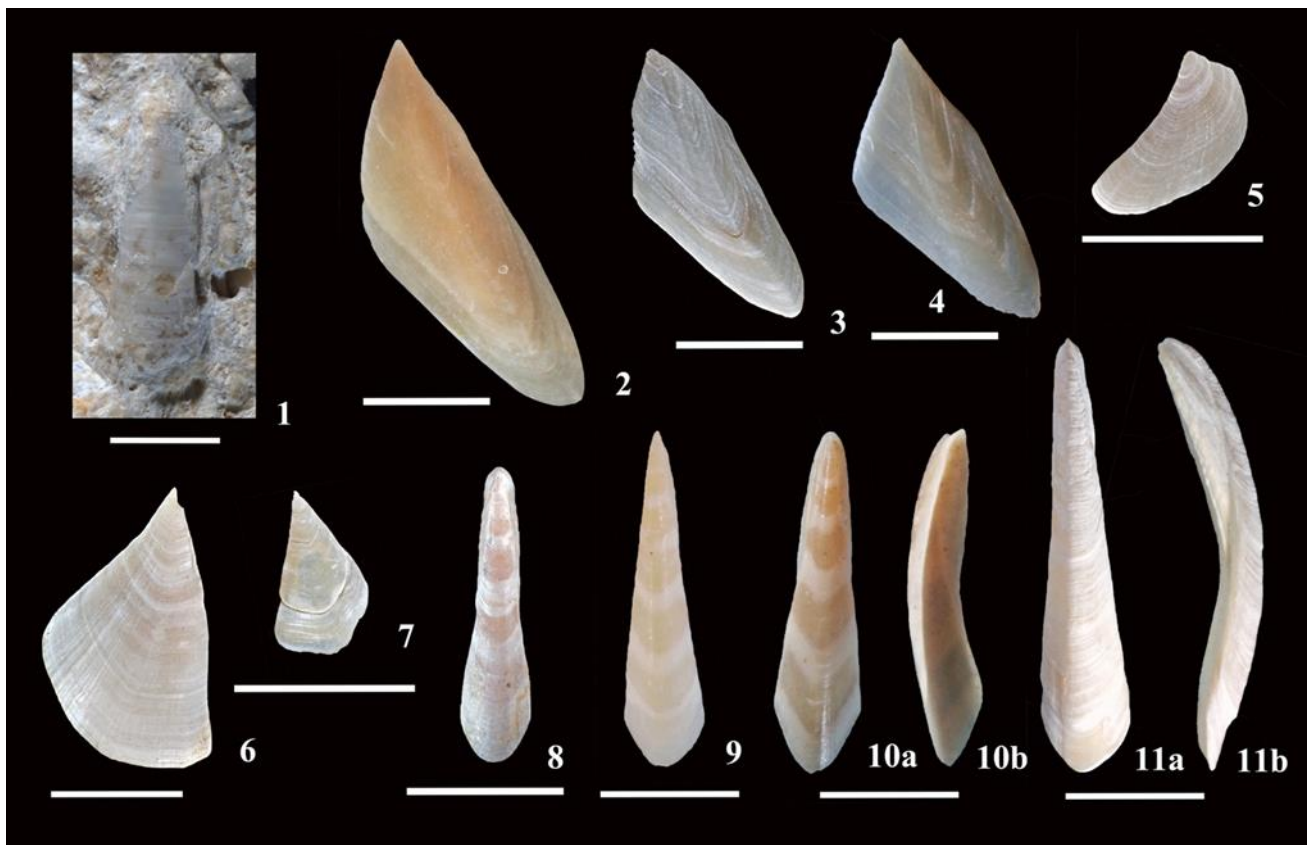
*Remarks:* A single carina was obtained from coral limestone of the Middle Pleistocene Naha Formation. The specific identification of it awaits the discovery of more well-preserved material.

*Material examined:* MFM142692 (1 carina); Sobe (=RK-1 of Karasawa, 2000, p. 168), Yomitan-son, Okinawa Prefecture; coral limestone of the Naha Formation of the Ryukyu Group; Middle Pleistocene, Zone NN20 of Martini's nannozone (Nakamori, 1986); collected by H. Karasawa.

Genus *Smilium* Gray, 1825

*Type species: Smilium peronii* Gray, 1825, by subsequent designation of Pilsbry (1907).

*Including fossil species: Smilium calanticoideum* Buckeridge, 1983 (Paleocene–Eocene, New Zealand); *S. chathecum* Buckeridge, 1984 (Miocene, New Zealand); *S. ? parvulum* (Withers, 1914) (U. Cretaceous, Czech Republic); *S. scorpio* (Aurivillius, 1892) (Pleistocene, Japan; extant); *S. subplanum* Withers, 1913 (Oligocene–Miocene, New Zealand); *S. tortachillense* Buckeridge, 1983 (Eocene, Australia).



**Fig. 1.** 1, *Calantica* sp., MFM142692, carina Naha Formation of the Ryukyu Group, Middle Pleistocene, carinal view. 2–11b, *Smilium scorpio* (Aurivillius, 1892). 2, MFM142685, tergum; 3, MFM142686, tergum; 4, MFM142686-2, tergum; 5, MFM142686-3, upper latus; 6, MFM142685-2, scutum; 7, MFM142686-4, scutum; 8, MFM142685-3, carina; 9, MFM142686-5, carina; 10a, b, MFM142686-6, carina; 11a, b, MFM142686-7, carina. 2, 6, 8, Takamatsu, Toyohashi Formation of the Atsumi Group, Middle Pleistocene; 3–5, 7, 9–11b, Sakurai, Kioroshi Formation of the Shimosa Group, Late Pleistocene. Scale bar = 5 mm. 1, 8, 9, 10a, 11a, carinal view; 2–7, 10b, 11b, lateral view.

***Smilium scorpio* (Aurivillius, 1892)**

(Figs. 1.2–1.11b)

*Scalpellum scorpio* Aurivillius, 1892, p. 126, pl. 3, figs. 6–8.*Smilium scorpio* (Aurivillius); Pilsbry, 1908, p. 107; Zevina, 1981, p. 79, fig. 51 (synonymy).**Diagnosis:** Capitulum quadrilateral, with 13 plates. Tergum the largest plate, scutum triangular; carinal-latus and rostral-latus horn-shaped, bent downwards (Chan et al., 2009, p. 83).**Remarks:** The present specimens represent the first fossil record of *S. scorpio*. This species is recorded from the West Pacific at depth of between 31–140 m (Jones et al., 2000).**Material examined:** MFM142685–142685-3 (1 carina, 3 scutum, 1 terga); Takamatsu (=locality of Karasawa et al., 2014, p. 57, fig. 1), Tahara City, Aichi Prefecture; sandy-silt of the Toyohashi Formation of the Atsumi Group; Middle Pleistocene, Marine Isotope Stage 9 (Nakashima et al., 2008); collected by N. Kobayashi. MFM142686–142686-7 (37 carinae, 40 terga, 1 scutum, 3 upper latera); Sakurai (=Loc. Ko-1 of Kato and Karasawa, 1998, p. 2), Kisarazu City, Chiba Prefecture; sand of the Kioroshi Formation of the Shimosa Group; Late Pleistocene, Marine Isotope Stage 5 (5e) by Okazaki et al. (2018); collected by T. Asada.

Family Lepadidae Darwin, 1852 [1851]

Genus *Dosima* Gray, 1825**Type species:** *Lepas fasciculatus* Ellis and Solander, 1786, by monotypy.**Included fossil species:** *Dosima azuminoensis* (Kawase, Koike, and Tanaka, 2006), new combination (Miocene, Japan); *D. delicatula* (Withers, 1953), new combination (Pliocene, England); *D. laticutis* (Zullo, 1973), new combination (Miocene, USA).**Remarks:** Newman (1996) gave the full genus status to *Dosima* and *Pristinolepas* Buckeridge, 1983, treated as the subgenus of *Lepas* Linnaeus, 1758. I agree with his opinion. Zullo (1973) placed two fossil species, *Lepas rovasendai* De Alessandri, 1895, from the Miocene of Italy and *L. delicatula* Withers, 1953, from the Pliocene of England, under *Lepas* (*Dosima*). However, *L. rovasendai* has the tergum without the

pointed apex and the umbo of the carina at the base; therefore, the systematic status of it is retained.

***Dosima azuminoensis* (Kawase, Koike, and Tanaka, 2006), new combination**

(Figs. 2.1a–2.1d; Figs. 3.1a–3.3b)

*Lepas* sp.; Mizuno and Takeda, 1993, p. 80, pl. 1, figs. 1a–4.*Lepas* sp.; Tokai Fossil Society, 1995, p. 187, 2 figs.*Lepas azuminoensis* Kawase, Koike, and Tanaka, 2006, p. 5, figs. 2.1–2.8.**Revised diagnosis:** Capitulum with thin plates. Scutum broadly triangular, slightly higher than wide to wider than high, with clear growth lines and without radial striations; apicoumbonal ridge absent; occludent margin slightly convex; upper tergolateral margin straight or gently concave; lower tergolateral margin strongly convex; basal margin weakly sinuous. Tergum flattened, subtriangular, without apicobasal ridge; occludent margin weakly sinuous; apex sharply pointed; carinal margin gently concave and scutal margins straight or weakly sinuous. Carina narrow, angularly bent at umbo, with truncated basal margin; umbo not basal, positioned at basal one-fourth–one-fifth (modified from Kawase et al., 2006, p. 5).**Remarks:** Although Karasawa et al. (2004) suggested that *Lepas* sp. from the Morozaki Group (Mizuno and Takeda, 1993) and the Bessho Formation (Tokai Fossil Society, 1995) were conspecific, and possessed plate characters like those of the extant *Dosima fasciculatus*, Kawase et al. (2006) described it as the new species of *Lepas*. However, the present species is assigned to *Dosima* in that a subtriangular tergum has a weakly sinuous occludent margin and sharply pointed apex, and the umbo of the carina is not basal.

The specimen (MFM84034) was collected from the type locality. The type specimens with articulated plates are attached to seaweed (Kawase et al., 2006), whilst the present specimens with numerous articulated and disarticulated plates are attached to driftwood. The specimens (MFM39167, 39168) composed of colonies by articulated plates are not attached to any material.

**Material examined:** MFM84034; Nakatani (=Loc. 1 of Kawase et al., 2006, p. 5, type locality), Toyoshina, Azumino City, Nagano Prefecture; mudstone of the Bessho Formation; Middle Miocene, N9–N11 of the Blow (1969) planktonic foraminiferal zone (Kosaka



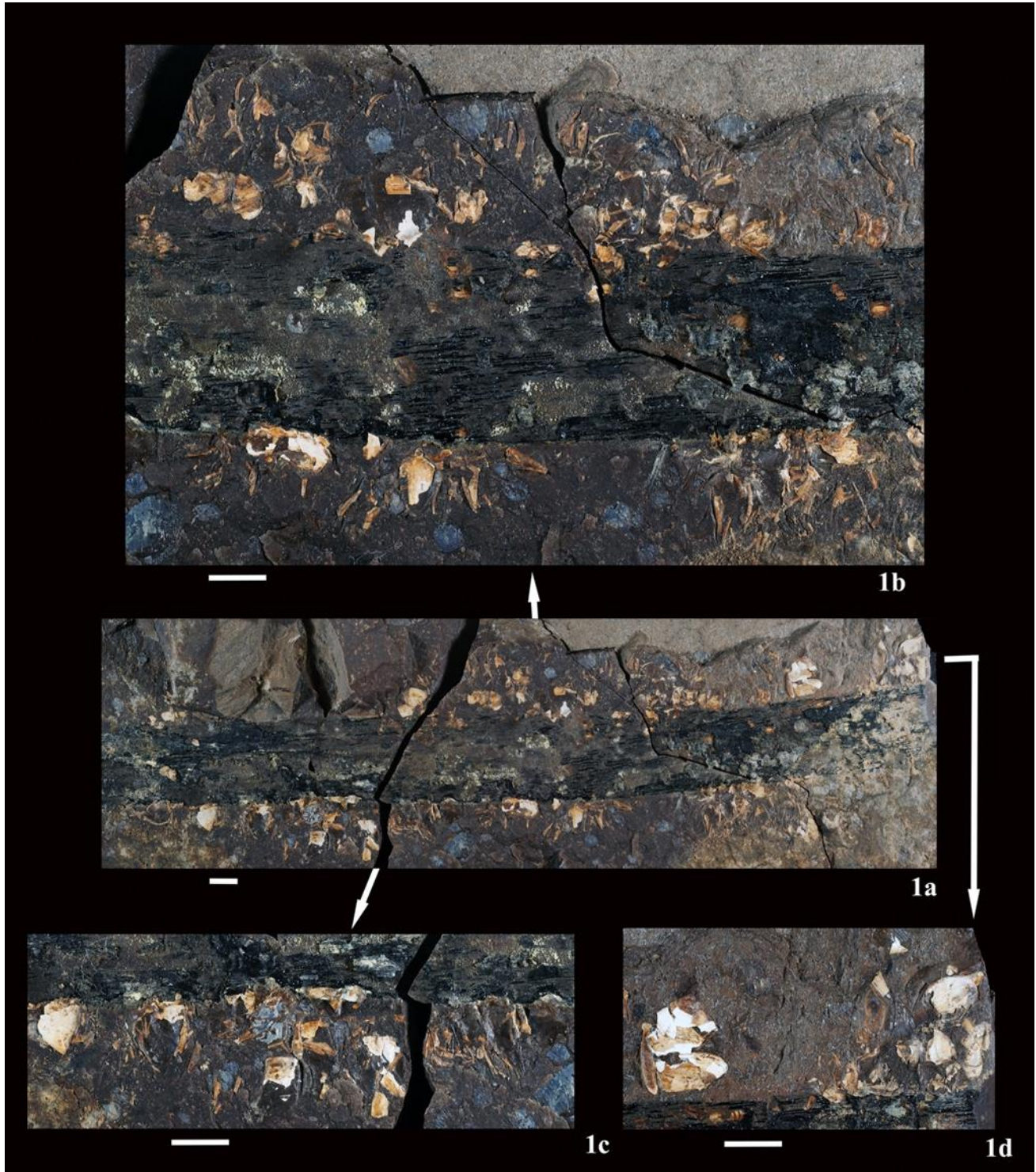


Fig. 2. *Dosima azuminoensis* (Kawase, Koike, and Tanaka, 2006), new combination. 1a–d, MFM84034, Nakatani, Bessho Formation, Middle Miocene. Scale bar = 5 mm.

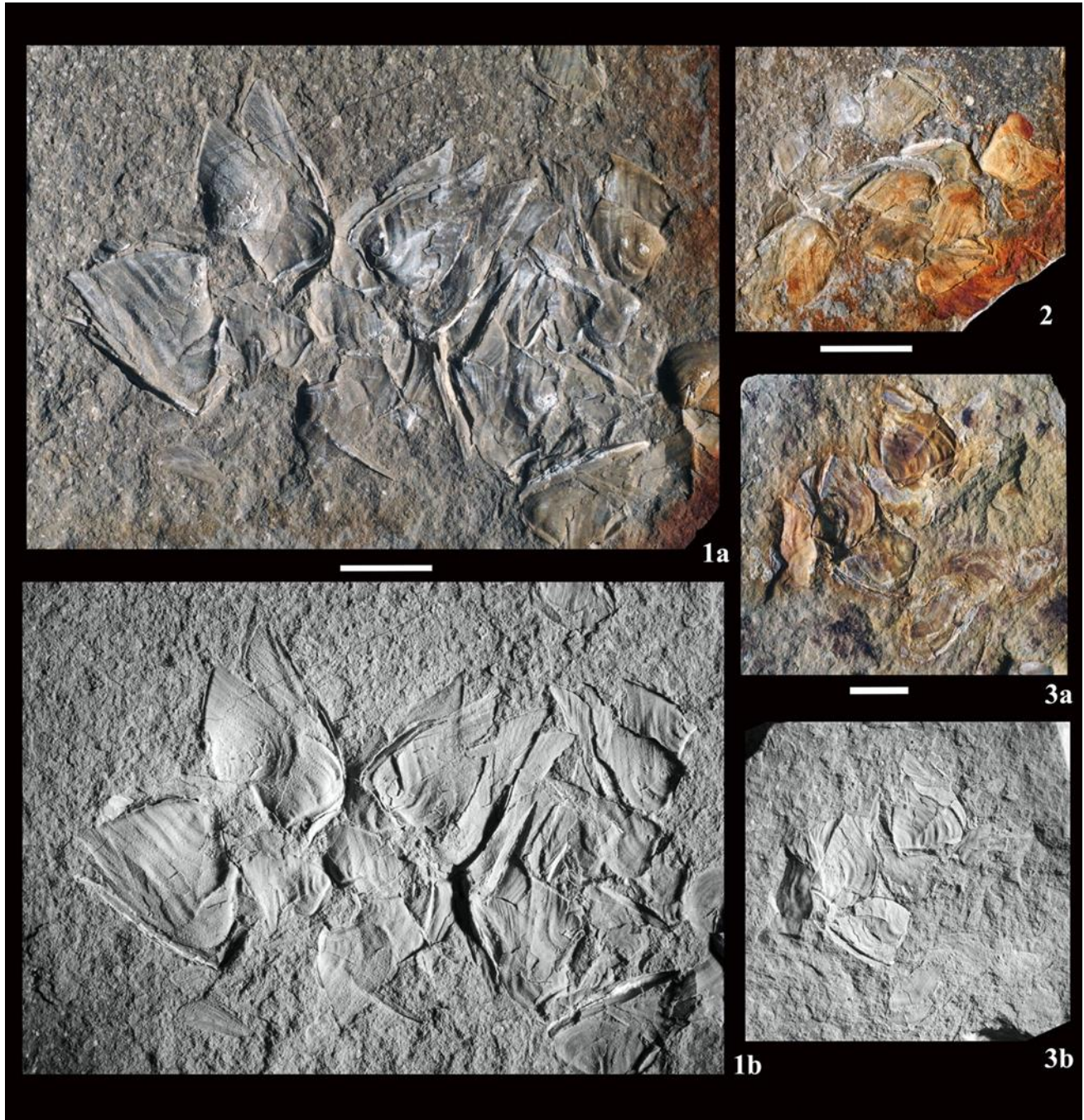
et al., 1992); collected by Y. Mizuno. MFM39167 and MFM39168; Ozagahama (=Loc. MRZ09 of Karasawa et al., 2017, p. 48), Toyohama, Minamichita-cho, Aichi Prefecture; mudstone of the lower-middle part of the Toyohama Formation of the Morozaki Group; Early Miocene, the middle to upper part of *Crucidentricula*

*sawamurae* Zone of diatom zonation by Yanagisawa and Akiba (1998) (Ito et al., 1999); collected by Y. Mizuno and T. Tanaka.

Genus *Lepas* Linnaeus, 1758

Type species: *Lepas anatifera* Linnaeus, 1758, by





**Fig. 3.** *Dosima azuminoensis* (Kawase, Koike, and Tanaka, 2006), new combination, Ozegahama, Toyohama Formation of the Morozaki Group, Early Miocene. **1a–2**, MFM39167; **3a, b**, MFM39168. Scale bar = 5 mm. 1b and 3b are whitening images coated with ammonium chloride sublimate.

subsequent designation of Pilsbry (1907) (ICZN Direction 66).

*Included fossil species:* *Lepas anatifera* Linnaeus, 1758 (Pleistocene, Japan; extant); *L. sp. cf. L. anatifera* Linnaeus, 1758 (Pliocene, Italy); *L. aquiyanica* Fischer, 1886 (Miocene, France); *L. sp. cf. L. australis* Darwin, 1852 [1851] (Miocene, Australia); *L. cliffdenica* Buckeridge, 1983 (Miocene, New Zealand); *L. coplandi* Buckeridge in Buckeridge, Lee, and Robin-

son, 2014 (Oligocene, New Zealand); *L. hillii* (Leach, 1818) (Pliocene, Italy; extant); *L. hyperumbonica* Buckeridge, 1983 (Pliocene–Pleistocene, Australia); *L. kuwayamai* Karasawa, Tanaka, and Okumura, 2004 (Miocene, Japan); *L. mallandriviana* Seguenza, 1876 (Miocene, Italy); *L. moturoaensis* Maxwell, 1968 (Miocene, New Zealand); *Lepas pectinata* Spengler, 1793 (Pleistocene, Japan; extant); *L. orbigny* Fischer, 1886 (Miocene, France); *L. pritchardi* Hall, 1902

(Oligocene, Australia); *L. reflexa* Withers, 1953 (Eocene, England); *L. rovasendai* De Alessandri, 1895 (Miocene, Italy); *L. sattmanni* Harzhauser and Schlögl, 2012 (Miocene, Austria); *L. stenzeli* Withers, 1953 (Eocene, USA).

***Lepas anatifera* Linnaeus, 1758**

(Figs. 4.8a–4.13b)

*Lepas anatifera* Linnaeus, 1758, p. 668.

*Lepas anatifera* Linnaeus; Weisbord, 1979, p. 13, pl. 2, figs. 1, 2 (synonymy).

**Diagnosis:** Capitulum with 5 plates, plates thin, smooth. Right scutum with an internal umbonal tooth; scutum sometimes with dark markings or spots; carina forked below umbo (adapted from Chan et al., 2009, p. 45).

**Remarks:** Kobayashi et al. (2008) reported the carinae and scuta of this species as fossils from the Middle Pleistocene Atsumi Group. The carinae from the Middle Pleistocene Kioroshi Formation and the scuta from the Upper Pleistocene Wan Formation are the subsequent fossil records of *L. anatifera*. This species is cosmopolitan in the present tropical–temperate seas (Jones and Hosie, 2016).

**Material examined:** MFM142473–142473-6 (232 carinae, 259 scuta, 126 tergum); Takamatsu (=locality of Karasawa et al., 2014, p. 57, fig. 1), Tahara City, Aichi Prefecture; sandy-silt of the Toyohashi Formation of the Atsumi Group; Middle Pleistocene, Marine Isotope Stage 9 (Nakashima et al., 2008); collected by N. Kobayashi. MFM142621 (9 carinae); Sakurai (=Ko-1 of Kato and Karasawa, 1998, p. 2), Kisarazu City, Chiba Prefecture; sandstone of the Kioroshi Formation of the Shimosa Group; Late Pleistocene, Marine Isotope Stage 5 (5e) by Okazaki et al. (2018); collected by T. Asada. MFM142679 (2 scuta); Kami-katetsu (=WN-1 of Karasawa, 2000, p. 169), Kikai-cho, Kagoshima Prefecture; detrital limestone of the Wan Formation of the Ryukyu Group; Late Pleistocene, 77–83 ka by  $^{230}\text{Th}/^{234}\text{U}$  ages (Omura, 1988); collected by J. Itoigawa.

***Lepas kuwayamai***

**Karasawa, Tanaka, and Okumura, 2004**

(Figs. 5.1–5.3)

*Lepas kuwayamai* Karasawa, Tanaka, and Okumura,

2004, p. 91, fig. 1.

**Diagnosis:** Plates thick, strongly calcified. Scutum subtriangular, slightly higher than wide, with clear growth lines; very weak radial striae sometimes present; apicoumbonal ridge weak; occludent margin slightly convex; upper tergo-lateral margin straight or gently convex; lower tergo-lateral margin strongly convex; basal margin slightly concave; umbonal tooth absent. Tergum flattened without radial striae; occludent margin convex, rounded; carinal margin gently convex; scutal margin slightly concave. Carina broad, boat-shaped, with rounded apex and wide, triangular basal margin; umbo basal (modified from Karasawa et al., 2004, p. 91).

**Remarks:** The present species has only known from the type locality. One additional carina (MFM9176) is herein figured. The specimens represented by scattered, disarticulated plates were found around driftwood.

**Material examined:** MFM9043 (holotype), 9044–9051 (paratypes), and MFM9176 (1 additional carina); Matsugase (=Loc. MFM54 of Karasawa, 1991, p. 7; type locality), Mizunami City, Gifu Prefecture; siltstone of the Yamanouchi Member of the Akeyo Formation of the Mizunami Group; Early Miocene, NPD2D Zone of Yanagisawa and Akiba's (1998) scale of diatoms (Gladenkoy, 1998); collected by T. Hiramatsu, M. Kuwayama, T. Kaede, and H. Eto.

***Lepas pectinata* Spengler, 1793**

(Figs. 4.1–4.7b)

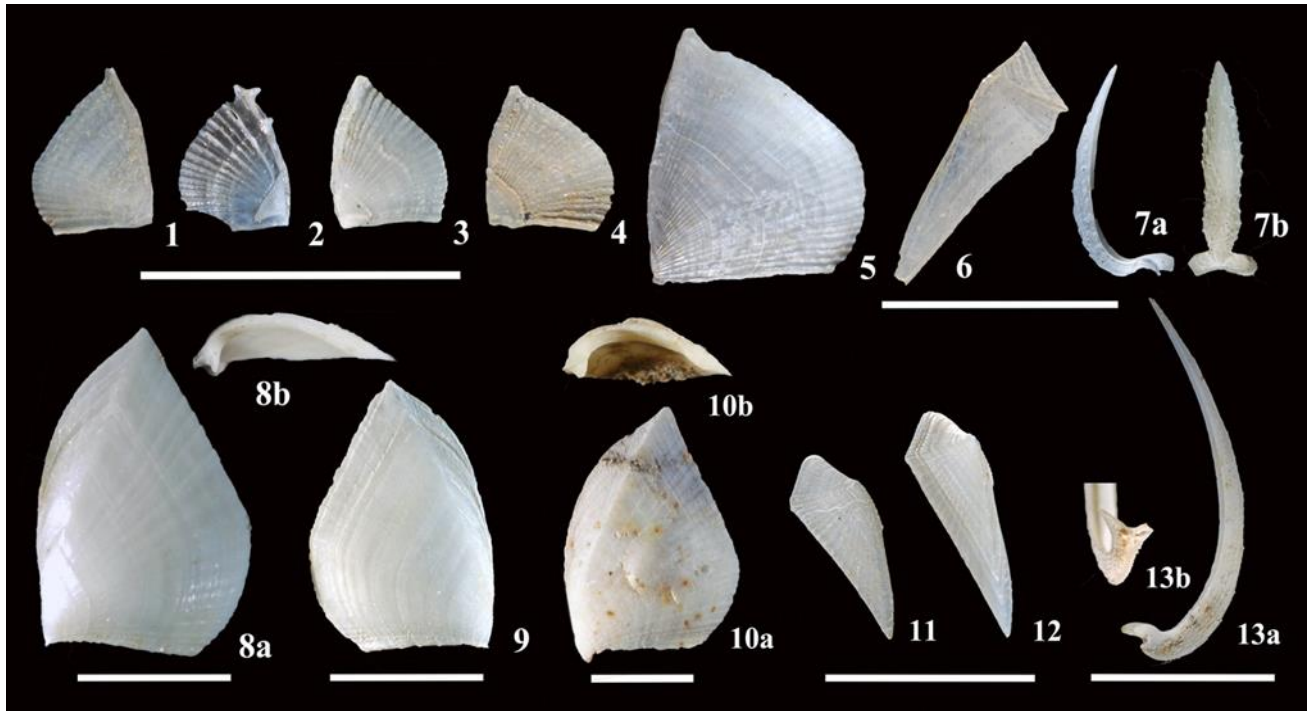
*Lepas pectinata* Spengler, 1793, p. 106, pl. X, fig. 2.

*Lepas pectinata* Spengler, 1793; Weisbord, 1979, p. 25, pl. 2, figs. 7–9 (synonymy).

**Diagnosis:** Plates thick, surfaces striated; carina forked below umbo. Filamentary appendages single-segmented at base of 1st cirrus, anterior and posterior rami of cirrus I–VI counts as I (10, 9), II (10, 11), III (12, 12), IV (12, 13), V (13, 13), VI (13, 13); caudal appendages consisting of elongated triangular projections. Mandible with 3 teeth, lower margin smooth; mandibulatory palps elongated with serrulate setae; labrum with dense large teeth; maxilla spherical with dense setae (from Chan et al., 2009, p. 50).

**Remarks:** The present species from the Middle Pleist-





**Fig. 4.** 1–7b, *Lepas pectinata* Spengler, 1793. 1, MFM142687, scutum; 2, MFM142687-2, scutum; 3, MFM142687-3, scutum; 4, MFM142687-4, scutum; 5, MFM142687-5, scutum; 6, MFM142687-6, tergum; 7a, b, MFM142687-7, carina. 8a–13b, *Lepas anatifera* Linnaeus, 1758. 8a, b, MFM142473, scutum; 9, MFM142473-2, scutum; 10a, b, MFM142679, scutum; 11, MFM142473-3, tergum; 12, MFM142473-4, tergum; 13a, b, MFM142473-5, carina. 1–9, 11–13b, Takamatsu, Toyohashi Formation of the Atsumi Group, Middle Pleistocene; 10a, b, Kamikatetsu, Wan Formation of the Ryukyu Group, Late Pleistocene. Scale bar = 5 mm. 1–7a, 8a, 9, 10a, 11–13a, lateral view; 7b, carinal view; 8b, 10b, 13b, ventral view.

ocene Atsumi Group is first recorded as fossils. This species has a cosmopolitan distribution in tropical and temperate seas (Jones and Hosie, 2016).

*Material examined:* MFM142687–142687-7 (3 carinae, 10 scuta, 1 tergum); Takamatsu (=locality of Karasawa et al., 2014, p. 57, fig. 1), Tahara City, Aichi Prefecture; sandy-silt of the Toyohashi Formation of the Atsumi Group; Middle Pleistocene, Marine Isotope Stage 9 (Nakashima et al., 2008); collected by N. Kobayashi.

#### *Lepas* sp.

(Figs. 6.1a–6.1d)

*Description:* Plates thick, strongly calcified. Scutum subtriangular, slightly higher than wide, gently swollen; umbo at basi-occludent angle; occludent margin gently convex; upper tergo-lateral margin straight; lower tergo-lateral margin strongly convex;

basal margin nearly straight; growth lines clear; radial striae absent; apicoumbonal ridge very weak. Tergum flattened with weak growth lines; radial striae absent; occludent margin convex, rounded; carinal and scutal margins straight. Carina broad, boat-shaped, with axial, median ridge and growth lines; apex sharp; umbo basal.

*Remarks:* The present material consists of numerous scattered, disarticulated plates in juveniles, associated with a small lignite. The juvenile stage of *Lepas kuwayamai*, the other Miocene species has not yet been known, but the scutum without radial striations and the carina with a sharp apex and an axial, median ridge distinguish the present specimens from *L. kuwayamai*.

*Material examined:* MFM84035; Kitazono (=Loc. 20 of Taguchi, 2002, fig. 2), Tsuyama City, Okayama Prefecture; mudstone of the Nokadai Mudstone Member of the Takakura Formation, Katsuta Group; Early–Middle Miocene, NPD3A–NPD3B Zone of Yanagisa-

wa and Akiba's (1998) scale of diatoms (Watanabe et al., 1999); collected by A. Ujihara.

Family Oxynaspididae Gruvel, 1905

Genus *Oxynaspis* Darwin, 1852 [1851]

*Type species: Oxynaspis celata* Darwin, 1852 [1851], by original designation.

*Remarks:* Van Syoc and Dekelboun (2011) moved *Oxynaspis eocenica* (Withers, 1935a), the only known fossil species from the Middle Eocene of England to the monotypic *Archoxynaspis* Van Syoc and Dekelboun, 2011. Therefore, the present unnamed species is only known as a fossil for the genus.

***Oxynaspis* sp.**

(Figs. 7.1a–7.2)

*Remarks:* Four carinae were obtained from the Pleistocene Atsumi and Shimosa Groups of West Honshu. These specimens possess morphological characters like the carina of *Oxynaspis pacifica* Hiro, 1931, from Japan and Taiwan (Hiro, 1931; Chan et al., 2009). The specific identification must await the discovery of scuta and terga.

*Material examined:* MFM142688–142688-2 (3 carinae); Takamatsu (=locality of Karasawa et al., 2014, p. 57, fig. 1), Tahara City, Aichi Prefecture; sandy-silt of the Toyohashi Formation of the Atsumi Group; Middle Pleistocene, Marine Isotope Stage 9 (Nakashima et al., 2008); collected by N. Kobayashi. MFM142682 (1 carina); Sakurai (=Ko-1 of Kato and Karasawa, 1998, p. 2), Kisarazu City, Chiba Prefecture; sandstone of the Kioroshi Formation of the Shimosa Group; Late Pleistocene, Marine Isotope Stage 5 (5e) by Okazaki et al. (2018); collected by T. Asada.

Family Poecilasmatidae Annandale, 1909

Genus *Octolasmis* Gray, 1825

*Type species: Octolasmis warwicki* Gray, 1825, by original designation.

*Included fossil species: Octolasmis orthogonia* (Darwin, 1852 [1851]) (Pleistocene, Japan; extant).

***Octolasmis orthogonia* (Darwin, 1852 [1851])**

(Figs. 7.3–7.14)

*Dichelaspis orthogonia* Darwin, 1852 [1851], p. 130, pl. II. figs. 10a, b.

*Octolasmis orthogonia* (Darwin); Krüger, 1911, p. 462; Jones and Hosie, 2016, p. 251 (synonymy).

*Diagnosis:* Capitulum oval, with 5 valves, orangish-yellow. Scutum narrow, L-shaped; tergum triangular, with 3 prominent ridges at scutal margin; 3rd ridge longest; carina smooth, base oval (adapted from Chan et al., 2009, p. 19–20).

*Remarks:* The present species is first reported in the fossil record. The scuta, terga, and carinae occurred from the Middle Pleistocene Atsumi Group and the Upper Pleistocene Kioroshi Formation of the Shimosa Group. The species is known attached to hydroids, gorgonians, antipatharians, and sea urchins, and is known from the Indo-West Pacific at depths of between 14–818 m (Chan et al., 2009).

*Material examined:* MFM142680–142680-8 (51 carinae, 61 sucta, 52 tergum; Takamatsu (=locality of Karasawa et al., 2014, p. 57, fig. 1); Tahara City, Aichi Prefecture; sandy-silt of the Toyohashi Formation of the Atsumi Group; Middle Pleistocene, Marine Isotope Stage 9 (Nakashima et al., 2008); collected by N. Kobayashi. MFM142681–142681-4 (32 carinae, 1 scutum); Sakurai (=Ko-1 of Kato and Karasawa, 1998, p. 2), Kisarazu City, Chiba Prefecture; sandstone of the Kioroshi Formation of the Shimosa Group; Late Pleistocene, Marine Isotope Stage 5 (5e) by Okazaki et al. (2018); collected by T. Asada.

Family Pollicipidae Leach, 1817

Genus *Capitulum* Gray, 1825

*Type species: Lepas mitella* Linnaeus, 1758, by original designation.

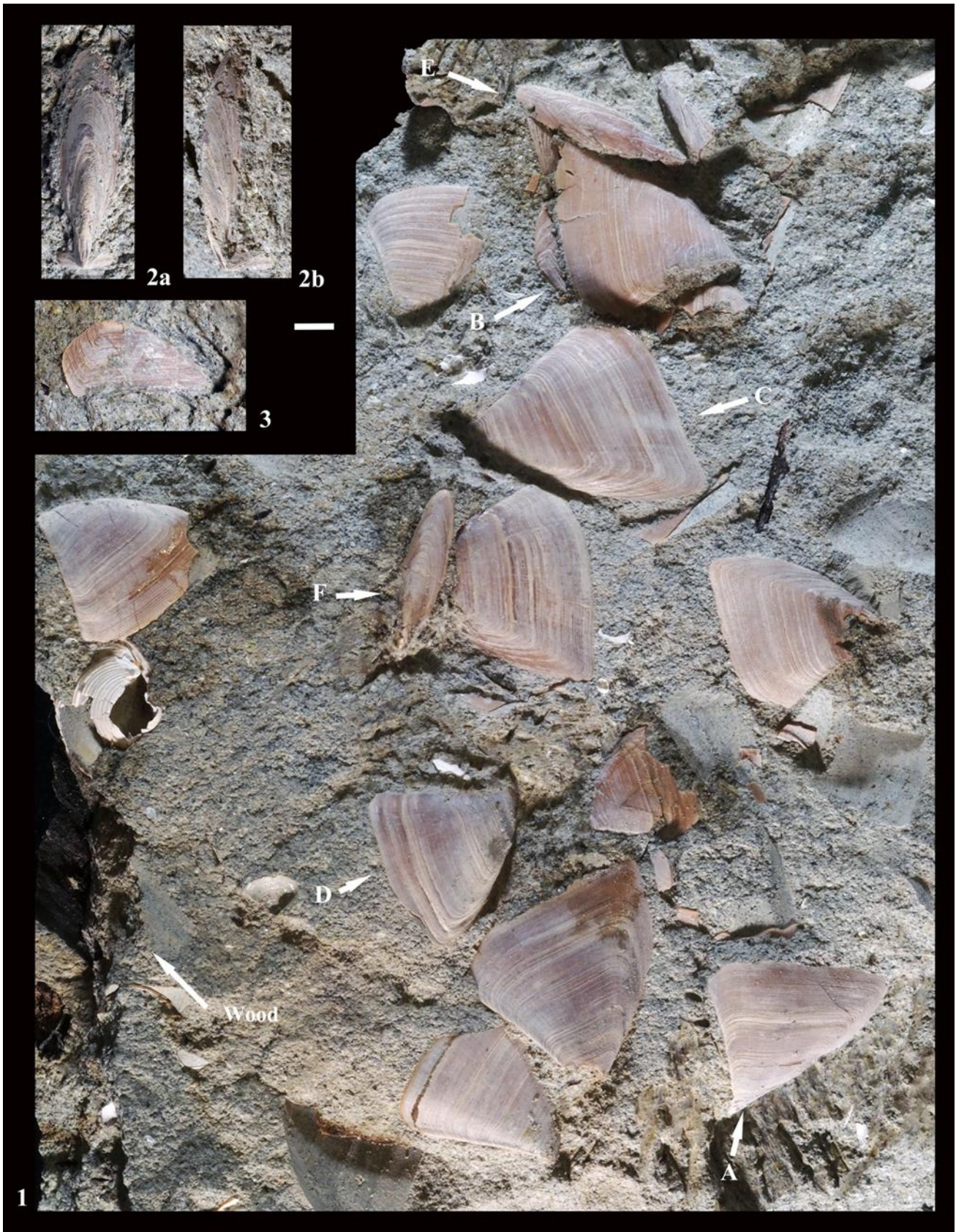
*Included fossil species: Capitulum caelatum* (Withers, 1935b) (U. Cretaceous, Sweden); *C. mitella* (Linnaeus, 1758) (Miocene–Pleistocene, Japan; extant); *C. sklenari* Kočová Veselská, Kočí, Collins, and Gale, 2015 (U. Cretaceous, Czech Republic).

***Capitulum* sp.**

(Fig. 7.15)

*Remarks:* A single scutum from the Miocene Mizunami Group has been deposited in the Mizunami Fossil Museum. The material is similar to the extant





**Fig. 5.** *Lepas kuwayamai* Karasawa, Tanaka, and Okumura, 2004, Matsugase, Akeyo Formation of the Mizunami Group, Early Miocene. **1A**, MFM9043, holotype, scutum; **1B**, MFM9044, paratype, scutum; **1C**, MFM9045, paratype, scutum; **1D**, MFM9046, paratype, scutum; **1E**, MFM9045, paratype, carina; **1F**, MFM9044, paratype, carina; **2a, b**, MFM9176, carina, a, carinal view, b, lateral view; **3**, MFM9050, paratype, tergum. Scale bar = 5 mm.





**Fig. 6.** *Lepas* sp., MFM84035, Kitazono, Takakura Formation of the Katsuta Group, Early–Middle Miocene. *1a*, occurrence of the specimens; *1b*, carina, carinal view; *1c*, tergum, lateral view; *1d*, scutum, lateral view. Scale bar = 5 mm.



**Fig. 7.** 1a–2, *Oxynaspis* sp. 1a, b, MFM142688, carina; 2, MFM142688-2, carina. 3–14, *Octolasmis orthogonia* (Darwin, 1852[1851]). 3, MFM142680, tectum; 4, MFM142680-2, tectum; 5, MFM142680-3, tectum; 6, MFM142680-4, carina; 7, MFM142680-5, carina; 8, MFM142680-6, carina; 9, MFM142680-7, scutum; 10, MFM142680-8, scutum; 11, MFM142681, tectum; 12, MFM142681-2, carina; 13, MFM142681-3, carina; 14, MFM142681-4, carina. 1–10, Takamatsu, Toyohashi Formation of the Atsumi Group, Middle Pleistocene; 11–14, Sakurai, Kioroshi Formation of the Shimosa Group, Late Pleistocene. 15, *Capitulum* sp., MFM9175, scutum; Shukubora, Akeyo Formation of the Mizunami Group; Early Middle Miocene. Scale bar = 5 mm. 1a, 2–8a, 9–15, lateral view; 1b, carinal view; 8b, ventral view.

*Capitulum mitella*, a common intertidal inhabitant of Indo-Pacific (Chan et al., 2009), while the specific identification of it awaits the discovery of more well-preserved material. The fossil records of *Capitulum mitella* has been known from the Upper Miocene Maja Formation of Okinawa Prefecture (Nomura, 2007) and the Middle Pleistocene Hirano Formation of Kochi Prefecture (Mimoto, 1991).

*Material examined:* MFM9175; Shukubora (=Loc. MFM58 of Karasawa, 1991, p. 7), Mizunami City, Gifu Prefecture; sandstone of the Shukunohora Sandstone Facies of the Akeyo Formation of the Mizunami Group; Early Middle Miocene (16.5–16 Ma) (Ujihara et al., 1999); collected by Y. Okumura.

Family Scalpellidae Pilsbry, 1907

Genus *Arcoscalpellum* Hoek, 1907

*Type species:* *Scalpellum velutinum* Hoek, 1883 (= *Scalpellum michelottianum* Seguenza, 1876) by original designation.

*Included fossil species:* *Arcoscalpellum arawakianum* Collins and Donovan, 1996 (Pliocene, Jamaica); *A. bakei* Collins, 1973 (U. Cretaceous, USA); *A. campus* Collins, 1973 (U. Cretaceous, USA); *A. choc-tawensis* Weisbord, 1977 (Eocene, USA); *A. concavitectum* Carriol, 2013 (Pliocene–Pleistocene, France); *A. conradi* (Gabb, 1876) (Paleocene, USA); *A. dortangsi* Collins and Jagt, 1999 (U. Cretaceous, Belgium); *A. floriana* Collins, Moody, and Sandman, 1999 (Eocene, Tunisia); *A. garassinensis* (De Alessandri, 1906) (Eocene, Italy); *A. habanense* Withers, 1953 (Eocene, Cuba); *A. hartleyi* (Withers, 1936) (Miocene, India); *A. hubrichti* Collins, 1973 (U. Cretaceous, USA); *A. jacksonense* Withers, 1953 (Eocene, USA); *A. knapptonensis* Zullo, 1982 (Eocene, USA); *A. michelottianum* Seguenza, 1876 (Pliocene, Italy; extant); *A. mosense* Jagt and Collins, 1999 (U. Cretaceous, Belgium); *A. nanum* Withers, 1953 (Miocene, Italy); *A. okinawanum* Noda, 1975 (Miocene, Japan); *A. palmeri* Withers, 1953 (Miocene, Cuba); *A. principianum* Weisbord, 1980 (Eocene, Cuba); *A. quadratum*



(Dixon, 1850) (Eocene, England); *A. raricostatum* Withers, 1953 (Eocene, Italy); *A. renevieri* (Mayer and Gümbel in Gümbel, 1861) (Oligocene, Austria); *A. scaniensis* Gale and Sørensen, 2015 (U. Cretaceous, Sweden); *A. sistinctum* Grant-Mackie, 1965 (Miocene, New Zealand); *A. subquadratum* (Mayer and Aldrich, 1886) (Eocene, USA); *A. toulmini* Weisbord, 1977 (Paleocene, USA); *A. turinensis* Withers, 1953 (Miocene, Italy); *A. venablesi* Withers, 1953 (Eocene, England); *A. withersi* Collins, 1973 (U. Cretaceous, USA).

*Remarks:* The above list was made by Withers (1953), Grant-Mackie (1965), Collins (1973), Noda (1975), Weisbord (1977; 1980), Zullo (1982), Collins and Donovan (1996), Collins and Jagt (1999), Collins, Moody, and Sandman (1999), Jagt and Collins (1999), Carriol (2013), and Gale and Sørensen (2015). The species excluded from *Arcoscalpellum* by Buckeridge (1983) and Gale (2016) were not included here.

In major revisions of Scalpellidae (Zevina, 1978a, b, 1981; Young, 2007), many extant species previously assigned to *Arcoscalpellum* were moved to other genera, namely *Abathescalpellum* Newman and Ross, 1971, *Amigdoscalpellum* Zevina, 1978b, *Anguloscalpellum* Zevina, 1978b, *Catherinum* Zevina, 1978b, *Gymnoscalpellum* Zevina, 1978b, *Litoscalpellum* Newman and Ross, 1971, *Pilsbryiscalpellum* Zevina, 1978b, *Planoscalpellum* Zevina, 1978b, *Tarasovium* Zevina, 1978b, *Teloscalpellum* Zevina, 1978b, *Trianguloscalpellum* Zevina, 1978b, *Vertebrosalpellum* Newman and Ross, 1998, *Verum* Zevina, 1978b, and *Weltnerium* Zevina, 1978b. However, Young (1999) suggested, using the morphology-based cladistic analyses, that *Arcoscalpellum*, *Litoscalpellum*, and *Trianguloscalpellum* were polyphyletic. Some scalpellid genera including *Arcoscalpellum* were not monophyletic based upon the subsequent phylogenetic works (Linse et al., 2013; Rees et al., 2014; Lin et al., 2015; Gale, 2016; Ewers-Saucedo et al., 2019; Ewers-Saucedo and Pappalardo, 2019). Therefore, it is considered best to adapt *Arcoscalpellum sensu lato* to the fossil scalpellid species having the carina of which the umbo is apical (i.e., Newman et al., 1969) for the time being.

***Arcoscalpellum s.l. isaonishikawai*, new species**

(Figs. 8.11–8.15b)

*Diagnosis:* Plates rather thin; surface ornamented with fine radial striations extending to apex; growth lines well-developed; scutum subtrapezoidal, much higher than wide, with well-defined apicobasal ridge; tergum flattened, subtriangular, without apicobasal ridge; tectum of carina separated from narrow parietes by weak ridges; upper latus subtriangular, gently convex tergal and basal margins, and gently concave scutal margin.

*Derivation of name:* In honor of the late Isao Nishikawa, a researcher on fossils from the Bihoku Group.

*Description:* Plates rather thin; surface ornamented with fine radial striations extending to apex; growth lines well developed. Scutum subtrapezoidal, much higher than wide, steeply depressed on tergal side, gently curved on occludent side, with well-defined apicobasal ridge gently curved towards occludent margin; apex blunt; tergal margin straight or slightly convex; lateral margin nearly straight; occludent margin slightly convex; basal margin nearly straight. Tergum flattened, subtriangular, about half higher than wide, without apicobasal ridge; apex blunt; carinal margin gently convex; occludent margin gently convex; scutal margin nearly straight, much longer than occludent margin; scutal angle obtuse; basal angle blunt. Carina gently curved inward, widened basally; umbo apical; tectum gently convex transversely, separated from narrow parietes by weak ridges. Upper latus subtriangular, weakly convex, about 1.2 times as high as wide, with apex curved towards scutum; tergal and basal margins gently convex; scutal margin gently concave.

*Remarks:* *Arcoscalpellum okinawanum*, the hitherto known fossil species of *Arcoscalpellum* from Japan, is represented by a single carina from the Upper Miocene Tomigusuku Formation of Okinawa Prefecture (Noda, 1975). The present new species is readily distinguished from *A. okinawanum* by having weak radial striations of the carina. This species is similar to *A. michelottianum* from the Pliocene of Italy and *A. nanum* from the Miocene of Italy (Withers, 1953) within the hitherto described fossil species of *Arcoscalpellum*, but differs in having radial striations on plate surfaces.

*Material examined:* MFM83095 (holotype), MFM83096–83099 (paratypes); Itabashi (=Loc. U-3 of Itoigawa and Nishikawa, 1976, p. 129, fig. 1), Shobara City, Hiroshima

Prefecture; mudstone of the Upper Member of the Bihoku Group; Early–Middle Miocene (17–14.9 Ma) based upon planktonic microfossils (Goto et al., 2013).

***Arcoscalpellum s.l. joei*, new species**

(Figs. 8.1–8.10b)

*Diagnosis:* Plates rather thin; growth lines well-developed; scutum quadrilateral, about twice as high as wide, widest at base, without apicobasal ridge; tergum flattened, subtriangular, without apicobasal ridge; tectum of carina separated from narrow parietes by shallow groove; upper latus flattened, subtrapezoidal.

*Derivation of name:* In honor of the late Joe S. H. Collins, a specialist on fossil decapods and cirripedes.

*Description:* Plates rather thin; growth lines well-developed. Scutum gently convex transversely, quadrilateral, about twice as high as wide, widest at base, without apicobasal ridge; apex sharp; tergal margin gently convex; lateral margin sinuous; occludent margin slightly convex; basal margin nearly straight. Tergum flattened, subtriangular, about twice as high as wide, without apicobasal ridge; apex blunt; carinal, occludent, and scutal margins gently convex, scutal margin much longer than occludent margin. Carina gently curved inward, widened basally; umbo apical; tectum gently convex transversely, separated from narrow parietes by narrow groove. Upper latus flattened, subtrapezoidal, slightly higher than wide, with blunt apex curved towards scutum; apicobasal ridge weakly developed; tergal margin nearly straight, longest followed in length by nearly straight scutal, in-framedian-lateral, carino-lateral, carinal margins. and basal margins.

*Remarks:* *Arcoscalpellum s.l. joei* differs from *A. s.l. isaonishikawai* in that the plate surfaces lack radial striations, the scutum has the apicobasal ridge, the upper latus is subpentagonal in outline, and the tectum of the carina is separated from parietes by narrow grooves. *Arcoscalpellum s.l. joei* has the carina with narrow grooves separating the tectum from the parietes, whilst the carina in *A. okinawanum* lacks these grooves. The carina of the present species is similar to that of *Scalpelliformes*, gen et sp. indet. from the Lower Pleistocene Dainichi Formation, reported by Mimoto (2014), but other plates have not yet been known.

*Material examined:* MFM83085 (holotype), MFM 83086–83094 (paratypes), MFM84024–84027 (48 carinae, 9 scuta, 6 terga, 5 upper-latera); Shiratoritsunagi (=near loc. 6 of Matsubara, 1995, p. 309, fig. 5), Ninohe City, Iwate Prefecture; mudstone of the Koiwai Mudstone, Sandstone, and Conglomerate Member of the Yotsuyaku Formation; Late Early Miocene (20–17 Ma by K-Ar and fission-track dating) (Hoshi and Matsubara, 1998); collected by Y. Okumura and H. Karasawa.

**Scalpellidae, genus and species indeterminate 1**

(Figs. 9.1a, 9.1b)

*Description:* Scutum thick, subtriangular, much higher than wide, about twice as high as wide, steeply depressed on tergal side, gently curved on occludent side, with well-defined apicobasal ridge; apex sharp; tergal and lateral margins nearly straight; occludent margin gently convex; basal margin nearly straight; growth lines well marked.

*Remarks:* The specimen is represented by a single scutum, but other plates will be necessary to confirm identification of the species.

*Material examined:* MFM84028 (1 scutum); Kajio (=Loc. 4 of Shimizu et al., 2000, p. 44, fig. 1), Yatsuo-machi, Toyama City, Toyama Prefecture; mudstone of the Higashibessho Formation; Early–Middle Miocene, NPD3B–NPD4A Zone of Yanagisawa and Akiba's (1998) scale of diatoms (Nakajima et al., 2019); collected by T. Kaede.

**Scalpellidae, genus and species indeterminate 2**

(Figs. 9.2–9.4)

*Description:* Plates thick; growth lines well-developed. Scutum, quadrilateral, about twice as high as wide, steeply depressed on tergal side, gently curved on occludent side, with well-defined apicobasal ridge; tergal margin very weakly concave; lateral margin gently concave; occludent and basal margins slightly convex. Tergum gently curved on scutal and carinal side, subtriangular, about two times as high as wide, with well-developed apicobasal ridge; carinal and scutal margins gently convex; occludent margin nearly straight, scutal margin much longer than occludent margin. Tectum of carina weakly convex transversely, continuous to parietes, with rounded lateral angle.



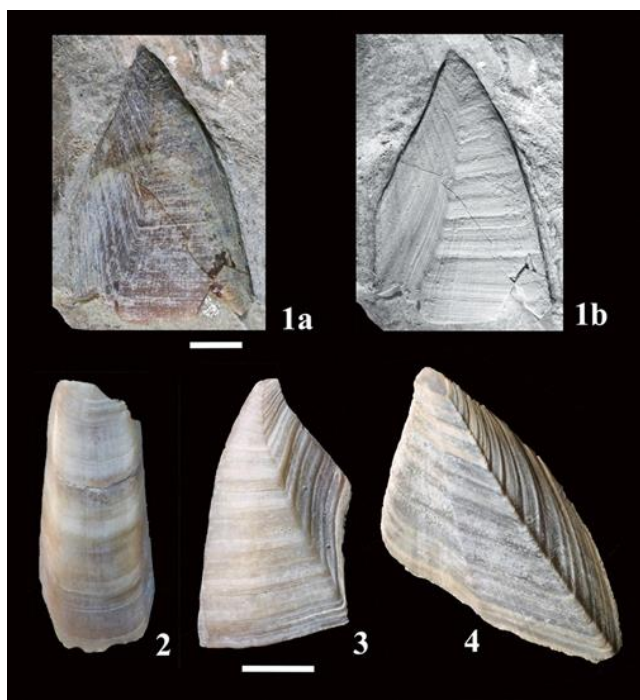


**Fig. 8.** 1–10b, *Arcoscalpellum s.l. joei*, new species, Shiratoritsunagi, Yotsuyaku Formation, Late Early Miocene. 1, MFM83086, paratype; 2, MFM83087, paratype; 3, MFM83088, paratype; 4, MFM83089, paratype; 5, MFM83090, paratype; 6, MFM83091, paratype; 7, MFM83092, paratype; 8a, b, MFM83093, paratype; 9a, b, MFM83085, holotype; 10a, b, MFM83094. 1–7, 8a, 9a, 10a, lateral; 8b, 9b, 10b, carinal view. 11–15b, *Arcoscalpellum s.l. isaonishikawai*, new species, Itabashi, Upper Member of the Bihoku Group, Early–Middle Miocene. 11, MFM83096, paratype; 12, MFM83097, paratype; 13, MFM83098, paratype; 14, MFM83099, paratype; 15a, b, MFM83095, holotype. Scale bar = 5 mm. 15b is a whitening image coated with ammonium chloride sublimate. **Abbreviations:** C, carina; S, scutum; T, tergum; UL, upper latus.



*Remarks:* The specimens consist of the complete tergum and scutum, and an incomplete carina lacking an anterior half. The discovery of a better-preserved carina could make a further identification of them.

*Material examined:* MFM142682–142682-3 (1 scutum, 1 tergum, 1 carina); Toubaru (=locality of Ishikawa and Kase, 2007, fig. 1), Uruma City, Okinawa Prefecture; siltstone of the Shinzato Formation; Late Pliocene–Early Pleistocene, N21 of the Blow (1969)'s planktonic foraminiferal zone (Hanagata, 2004); collected by J. Itoigawa.



**Fig. 9.** *1a, b*, Scalpellidae, genus and species indeterminate 1, MFM84028, scutum, lateral view, Kajio, Higashibesho Formation, Early–Middle Miocene. *2–4*, Scalpellidae, genus and species indeterminate 2, Toubaru, Shinzato Formation, Late Pliocene–Early Pleistocene. *2*, MFM142682, carina, carinal view; *3*, MFM142682-2, scutum, lateral view; *4*, MFM142682-3, tergum, lateral view. Scale bar = 5 mm. *1b* is a whitening image coated with ammonium chloride sublimate.

#### Acknowledgements

I thank T. Kaede (Mizunami), N. Kobayashi (Gama-gori, Aichi), Y. Mizuno (Nagoya, Aichi), A. Ujihara (Nagoya University) for offering the additional specimens

with useful comments for this study. This study is dedicated to Joe S. H. Collins (London), whose advice, support, and kindness helped me in difficult times. The manuscript benefited greatly from the critical review of Professor S. K. Donovan (Taxonomy and Systematics Group, Naturalis Biodiversity Center, Leiden).

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## Appendix

*Arcoscalpellum* s.l. *isaonishikawai* Karasawa, new species LSID: urn:lsid:zoobank.org:act:B7D8ECF4-140A-43DE-8B27-09FF3131DFAA

*Arcoscalpellum* s.l. *joei* Karasawa, new species LSID: urn:lsid:zoobank.org:act:27440F79-3336-4977-B1BB-57662246F826