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**Discovery of living *Chama cerion* Matsukuma, Paulay & Hamada, 2003
(Mollusca: Bivalvia: Chamidae) from submarine caves
in the Ryukyu Islands, southwestern Japan**

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Abstract. The rare chamid bivalve, *Chama cerion* Matsukuma, Paulay & Hamada, 2003, is recorded from submarine caves in Okinawa-jima Island and Ie-jima Island of the Okinawa Island Group, and Shimoji-jima Island of the Miyako Island Group, Ryukyu Islands, southwestern Japan. The specimens examined possessed bent over, overlapping scales that characterize the outer surface of right valve of the holotype of *C. cerion*, and these characteristic scales were also found in the left valve. On the other hand, these characteristic scales were not found in a paratype examined in this study. This indicates that at least one paratype is not conspecific to the holotype and they seem to consist of more than two species, including a potentially undescribed species. All the specimens of *C. cerion* from the Ryukyu Islands have been found in anchialine environments of submarine caves (darkness and low salinity conditions), and these records represent the first definite findings of living individuals of *C. cerion*.

Introduction

The invertebrate biota of submarine caves in the Ryukyu Islands have received substantial attention in recent years, with many new species described and others newly recorded from Japan, especially among Annelida, Crustacea and Echinodermata (Anker & Fujita 2014; Shimomura & Fujita 2017, 2020, 2021; Fujita 2018, 2019; Kakui & Fujita 2018, 2020; Komai & Fujita 2018; Okanishi & Fujita 2018a, b, 2019; Saito & Fujita 2018; Jimi et al. 2020; Worsaae et al. 2021). During these studies listed above, 11 living individuals of *Chama cerion* Matsukuma, Paulay & Hamada, 2003 (Bivalvia: Veneroidea: Chamidae) were collected from three islands; Okinawa-jima Island and Ie-jima Island of

the Okinawa Island Group, and from Shimoji-jima Island of the Miyako Island Group.

Chama cerion was originally described from specimens collected in Melanesia, Polynesia, and southern Japan in the Pacific Ocean, and Aldabra Island in the Indian Ocean (Matsukuma et al. 2003). However, most of the specimens are known only from right valves of evidently dead individuals (Jarrett 2000, Figure 585, as *Chama* sp. ; Matsukuma et al. 2003; Huber 2010; Okutani 2017), and only two complete individuals have been recorded, one from a depth of 9–10 meters in New Caledonia (Matsukuma et al. 2003) and one from an unknown location (Huber 2010). We herein report on this poorly known species based on material from submarine caves of the Ryukyu Islands, with morphological and habitat information.

Materials and methods

The specimens examined were collected by the last author and his field research collaborators using SCUBA in three submarine caves in the Ryukyu Islands: “Hedo-Dome cave” on Okinawa-jima Island, “unnamed” (sometimes called as “Ohoba No.2” or “Sho-doukutsu”) cave on Ie-jima Island, and “Akuma-no-Yakata cave” on Shimoji-jima Island. General characteristics of these cave systems and the location names in the caves (e.g., “main tube”, “entrance hole”, “second slope”) are referred to Osawa & Fujita (2019). All of these specimens are deposited in the collection of the Ryukyu University Museum, Fujikan (RUMF), Nishihara, Okinawa, Japan. For comparative purpose, a paratype of *Chama cerion* from Japan was also examined, which is deposited in the collection of the Kyusyu University Museum (KUM), Fukuoka, Japan as

shown below.

KUM-81, 1 right valve (juvenile), Sumiyoshi, China-cho, Okinoerabu-jima Island, Amami Islands, Kagoshima Prefecture, collected by Osamu Masuda, ex Shinichi Ikebe collection, represented as “KUM” in Matsukuma et al. (2003).

Records of the species

Chama cerion Matsukuma, Paulay & Hamada, 2003

(Figs. 1–4)

Material examined. Okinawa-jima Island, “Hedo Dome” cave: RUMF-ZM-11321, 20–40 m from entrance (“main tube”), 22 May 2017; RUMF-ZM-11322, 0–20 m from entrance (“entrance”), roof, 22 May 2017; RUMF-ZM-11323, 15 Dec. 2017; RUMF-ZM-11324, 5 Dec. 2017. Ie-jima Island, “Unnamed” cave: RUMF-ZM-11325, 8 Sep. 2016; RUMF-ZM-11326, 45 m from entrance (“main tube”), 8 Sep. 2016; RUMF-ZM-11327, 8 Sep. 2016; RUMF-ZM-11328, 5 m from entrance (“entrance hole”), 24 June 2017; RUMF-ZM-11330, 35–45 m

from entrance (“right hall”), 25 June 2017. Shimoji-jima Island, “Akuma-no-Yakata” cave: RUMF-ZM-11331, 100 m from entrance (“second slope”), 4 Feb. 2017; RUMF-ZM-11332, 100 m from entrance (“second slope”), 13 Mar. 2013.

Remarks. The specimens examined in the present study agree well with the illustrations (photographs) of the holotype of *Chama cerion* by Matsukuma et al. (2003, fig. 1A–F) in the following characters of the right valve: (1) oval in shape with a pointed ventral margin (Figs. 1A, 2, Table 1) and (2) bent over, overlapping scales aligned on the top of commarginal lamellae (Figs. 1E, F, 3). Shell sizes of the present specimens are 13.5 ± 2.94 mm in shell length (SL), 13.7 ± 2.90 mm in shell height (SH), and the ratio of SH/SL = 1.03 on average. The right valves of the present specimens have 0–4 dark brown spiral streaks running from the umbo through the posterodorsal area (Fig. 2, Table 1).

The characters of left valves of the newly collected specimens are: (1) oval, but sometimes one side more strongly developed vertically (Fig. 2F, N, U); and (2) bent over, overlapping scales aligned on the top of commarginal lamellae (Fig. 3a–j). The

Table 1. Characteristics of *Chama cerion* valves collected in this study. Abbreviations: SL, shell length; SH, shell height; S.D., standard deviation.

表 1. 本研究で採集されたハチノスキクザルの特徴。略語: SL, 殻長; SH, 殻高; S.D., 標準偏差。

Specimen ID 標本番号	Inner coloration 殻内部の色彩	Number of brown streaks 褐色縞の数	Right valve 右殻			Left valve 左殻		
			SL (mm) 殻長	SH (mm) 殻高	SH/SL 殻高/殻長比	SL (mm) 殻長	SH (mm) 殻高	SH/SL 殻高/殻長比
RUMF-ZM-11321	white 白色	2	11.8	11.4	0.97	12.6	13.1	1.04
RUMF-ZM-11322	white 白色	4	14.8	16.5	1.12	14.8	16.5	1.12
RUMF-ZM-11323	yellow 黄色	2	15.0	13.9	0.92	10.0	15.8	1.58
RUMF-ZM-11324	yellow 黄色	0	13.2	13.6	1.03	15.3	12.7	0.83
RUMF-ZM-11325	brown 褐色	unclear 不明瞭	6.7	8.8	1.32	5.2	10.9	2.08
RUMF-ZM-11326	white 白色	unclear 不明瞭	15.0	12.0	0.80	7.3	15.4	2.11
RUMF-ZM-11327	white 白色	unclear 不明瞭	10.0	10.0	1.00	6.9	10.4	1.51
RUMF-ZM-11328	yellowish brown 黄褐色	0	13.5	14.0	1.04	11.0	18.0	1.64
RUMF-ZM-11330	yellowish brown 黄褐色	0	15.6	16.3	1.04	16.6	18.7	1.13
RUMF-ZM-11331	yellowish brown 黄褐色	2	15.0	15.6	1.04	9.4	17.2	1.83
RUMF-ZM-11332	no data データ無し	no data データ無し	18.0	19.0	1.06	18.0	19.5	1.08
Average 平均			13.5	13.7	1.03	11.6	15.3	1.45
S.D. 標準偏差			2.94	2.90		4.03	2.97	

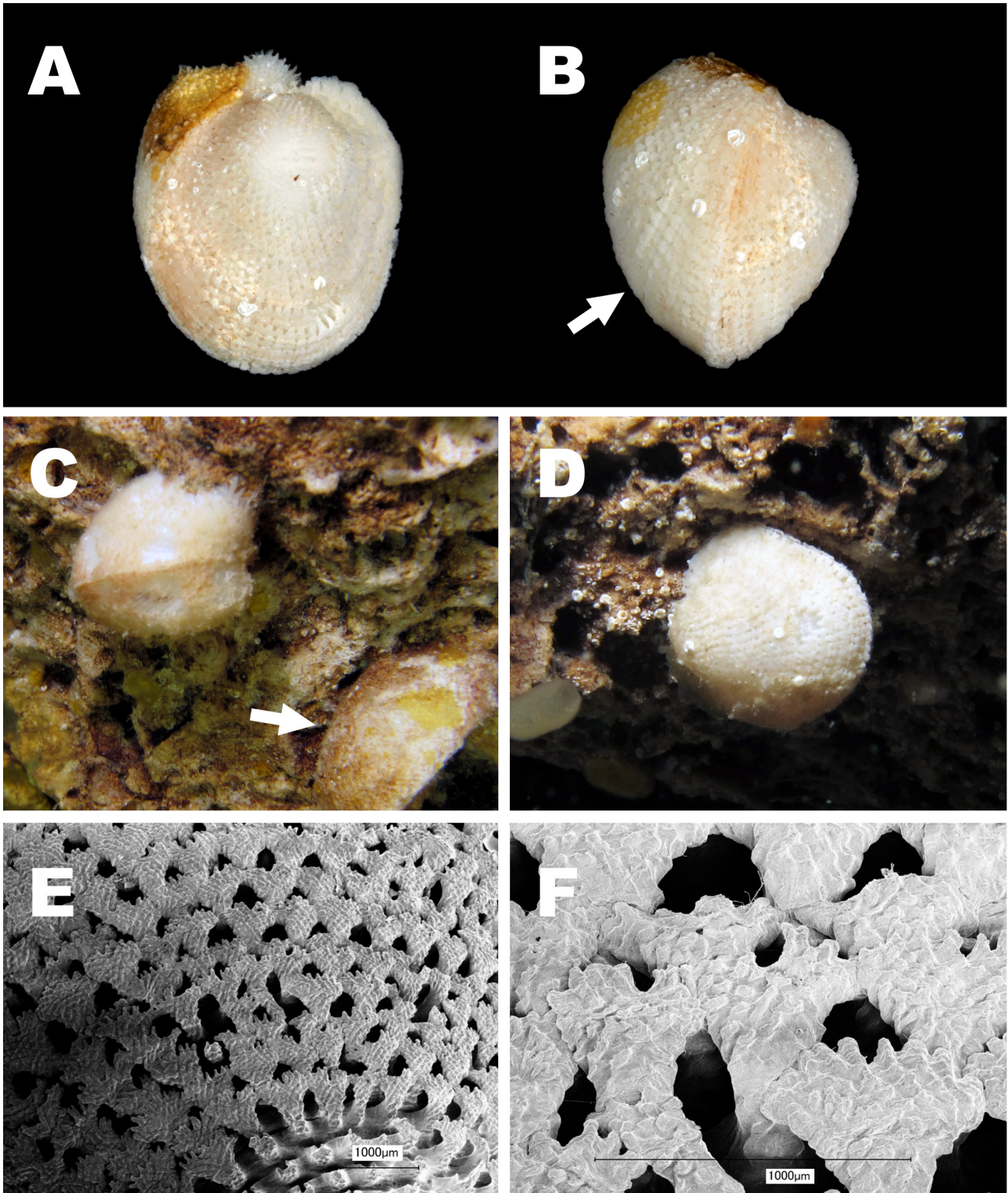
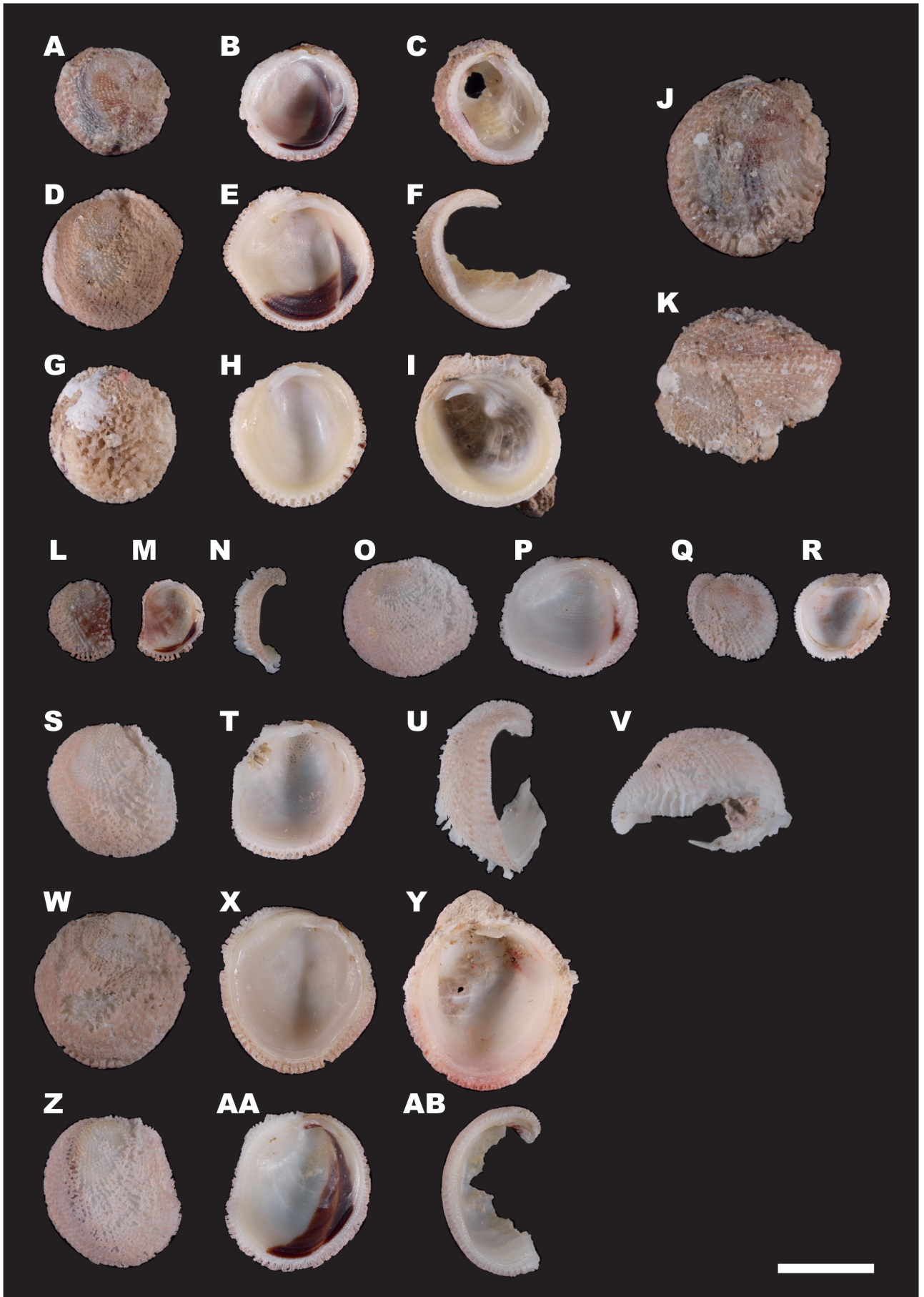


Fig. 1. *Chama cerion* Matsukuma, Paulay & Hamada, 2003, collected from “Akuma-no-Yakata” cave in Shimoji-jima Island, Miyako Island Group. A, right valve of fresh specimen (RUMF-ZM-11332); B, lateral view of fresh specimen (arrow indicating left valve) (RUMF-ZM-11332); C, in situ photographs, lateral view (arrow indicating dead individual, left valve), specimen not collected (photograph taken 17 Mar. 2013); D, same, different individual, right valve, specimen not collected (photograph taken 13 Mar. 2013); E, F, scales of right valve (SEM image) (RUMF-ZM-11332).

図1. 宮古諸島下地島の海底洞窟から採集されたハチノスキクザル *Chama cerion* Matsukuma, Paulay & Hamada, 2003. A, 生貝の右殻表面 (RUMF-ZM-11332); B, 生貝の側面 (矢印は左殻) (RUMF-ZM-11332); C, 生態写真, 側面 (矢印は死貝の左殻), 標本は未採集 (2013年3月17日撮影); D, 同, 別個体, 右殻, 標本は未採集 (2013年3月17日撮影); E, F, 右殻表面の鱗片状突起 (走査型電子顕微鏡画像) (RUMF-ZM-11332).



sizes of left valves of the present specimens are 11.6 ± 4.03 mm in shell length (SL), 15.3 ± 2.97 mm in shell height (SH), and the ratio of SH/SL = 1.45 on average (Table 1). It is notable that even the smallest specimen (RUMF-ZM-11325; SL: right valve, 6.7 mm; left valve, 5.2 mm) has this characteristic scale, and thus this is considered as an extremely stable trait.

Matsukuma et al. (2003) characterized this species as having a “honeycomb-like structure” on the surface of the right valve. In the present study, the “honeycomb-like structure” of one paratype specimen (KUM-81) collected from the Ryukyu Islands (Okinoerabu-jima Island) was observed in detail, and compared with the present specimens. In the present specimens and the holotype of *C. cerion* (Matsukuma et al., 2003: Fig. 1F) have the dense arrangement of the characteristic bent over, overlapping scales, and therefore the gaps between the scales may look “honeycomb-like” to the naked eye. However, in the commarginal lamellae where such scales are broken off, they do not have the “honeycomb-like structure” as in the paratype specimen (KUM-81; Fig. 4).

The present specimens are also different from the original description of *C. cerion* in that the outer surface of the left valve is ornamented by the bent over, overlapping scales as in that of the right valve. In the original description of Matsukuma et al. (2003), the left valve is nearly smooth and ornamented with weak radial striae and distally spaced short commarginal lamellae. Additionally, the left valve is lacking a honeycomb-like structure, but it is unclear if the description of the left valve is based on holotype (MNHN, deposited in Muséum national d’Histoire naturelle, Paris) or a paratype (UF280833, deposited in Florida Museum of Natural History, University of Florida, Gainesville). The

left valve of the holotype might be incomplete, as the characteristic scales were sometimes broken or barely recognizable even in the left valve of our living specimens (Fig. 3a, b, d, g).

These observations suggest that the paratypes of *C. cerion* include at least one potentially undescribed species different from *C. cerion*. To confirm this, further detailed study of the type material is required.

Habitat information. The living animal of *C. cerion* has been hitherto known only by one paratype specimen (UF280833, see Matsukuma et al. 2003) from the intertidal zone of Niue Island, but as mentioned above, it is likely a different species from the holotype of *C. cerion*. Additionally, the holotype was collected at 9–10 meters on the coral reef of New Caledonia (Matsukuma et al. 2003), but it was conjoined as an empty shell. Therefore, this study might represent the first record of living *C. cerion*.

In this study, all living individuals of *C. cerion* were collected from submarine caves, where they were attached by the left valve to the wall surface of the caves, at “entrance” and “main tube” in Hedodome cave on Okinawa-jima Island, at “entrance hole”, “main tube” and “right hall” in Unnamed cave on Ie-jima Island, and at “second slope” in Akumano-Yakata cave on Shimoji-jima Island, respectively (Fig. 1C, D). These habitats are to dark “anchialine” environments, where light does not reach and salinity is somewhat low (approx. 23 ppt to 28 ppt), and the caves all had extremely poor sessile biota compared to surrounding reefs, i.e. only a few sessile attached sponges, tube-dwelling polychaetes and ascidians (Fig. 1C, D). The maximum population density of *C. cerion* in these habitats was approximately five individuals per square meter in all the caves. In addition, many dead shells of the species were observed in the same habitat (the left valves were attached to the walls of the caves: Fig. 1C).

Fig. 2. Specimens of *Chama cerion* Matsukuma, Paulay & Hamada, 2003. A, B, RUMF-ZM-11321, right valve; C, RUMF-ZM-11321, left valve; D, E, RUMF-ZM-11323, right valve; F, RUMF-ZM-11323, left valve; G, H, RUMF-ZM-11324, right valve; I, RUMF-ZM-11324, left valve; J, RUMF-ZM-11322, right valve; K, RUMF-ZM-11322, conjoined valves, lateral view; L, M, RUMF-ZM-11325, right valve; N, RUMF-ZM-11325 left, valve; O, P, RUMF-ZM-11326, right valve; Q, R, RUMF-ZM-11327, right valve; S, T, RUMF-ZM-11328, right valve; U, RUMF-ZM-11328, left valve; V, RUMF-ZM-11328, left valve, lateral view; W, X, RUMF-ZM-11330, right valve; Y, RUMF-ZM-11330, left valve; Z, AA, RUMF-ZM-11331, right valve; AB, RUMF-ZM-11331, left valve. Scale bar represents 1 cm.

図2. ハチノスキクザル *Chama cerion* Matsukuma, Paulay & Hamada, 2003 の標本. A, B, RUMF-ZM-11321, 右殻; C, RUMF-ZM-11321, 左殻; D, E, RUMF-ZM-11323, 右殻; F, RUMF-ZM-11323, 左殻; G, H, RUMF-ZM-11324, 右殻; I, RUMF-ZM-11324, 左殻; J, RUMF-ZM-11322, 右殻; K, RUMF-ZM-11322, 両殻, 側面; L, M, RUMF-ZM-11325, 右殻; N, RUMF-ZM-11325, 左殻; O, P, RUMF-ZM-11326, 右殻; Q, R, RUMF-ZM-11327, 右殻; S, T, RUMF-ZM-11328, 右殻; U, RUMF-ZM-11328, 左殻; V, RUMF-ZM-11328, 左殻, 側面; W, X, RUMF-ZM-11330, 右殻; Y, RUMF-ZM-11330, 左殻; Z, AA, RUMF-ZM-11331, 右殻; AB, RUMF-ZM-11331, 左殻. スケールバー, 1 cm.

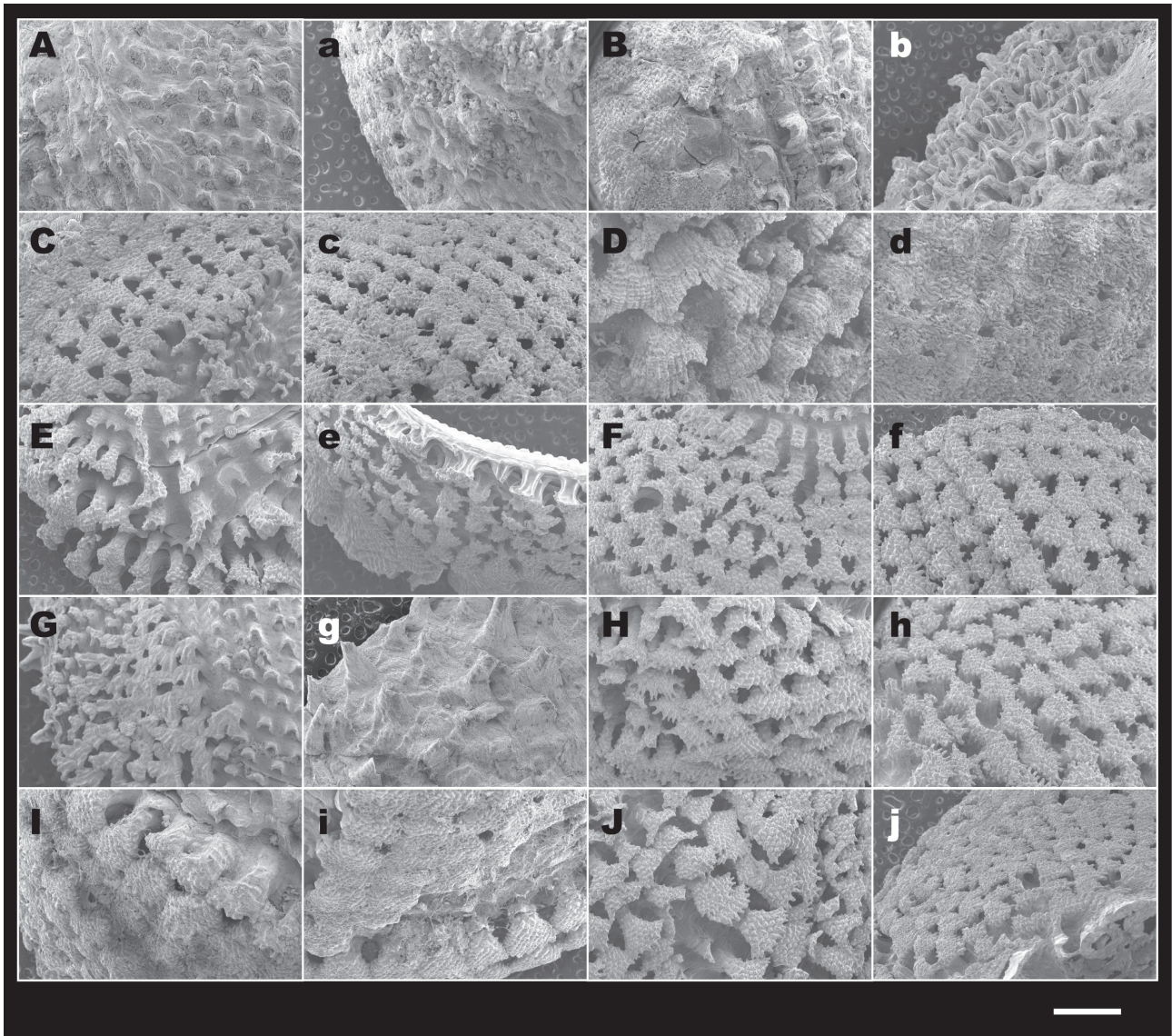


Fig. 3. SEM images of *Chama cerion* Matsukuma, Paulay & Hamada, 2003. Upper and lowercase letters represent right and left valve, respectively. A, a, RUMF-ZM-11321; B, b, RUMF-ZM-11322; C, c, RUMF-ZM-11323; D, d, RUMF-ZM-11324; E, e, RUMF-ZM-11325; F, f, RUMF-ZM-11326; G, g, RUMF-ZM-11327; H, h, RUMF-ZM-11328; I, i, RUMF-ZM-11330; J, j, RUMF-ZM-11331. Scale bar represents 500 μ m.

図3. ハチノスキクザル *Chama cerion* Matsukuma, Paulay & Hamada, 2003 の走査型電子顕微鏡画像。大文字は右殻、小文字は左殻を示す。A, a, RUMF-ZM-11321; B, b, RUMF-ZM-11322; C, c, RUMF-ZM-11323; D, d, RUMF-ZM-11324; E, e, RUMF-ZM-11325; F, f, RUMF-ZM-11326; G, g, RUMF-ZM-11327; H, h, RUMF-ZM-11328; I, i, RUMF-ZM-11330; J, j, RUMF-ZM-11331。スケールバー、500 μ m。

Meanwhile, it is possible that the habitats of *C. cerion* are not necessarily restricted to submarine caves, although the previous habitat information of the species is not clear. One decapod crustacean, *Atoportunus gustavi* Ng & Takeda, 2003 (Decapoda: Brachyura: Portunidae) is known to be distributed across stepping stone islands of the Indo-Western Pacific: in the Indian Ocean, Christmas Island; in the Western Pacific Ocean, Guam Island and Ryukyu Islands including Okinawa-jima Island, Ie-jima Island, Shimoji-jima Island and Yonaguni-jima Island. This crab has been mainly collected from

submarine caves but sometimes has been found among interspaces between dead coral rubble and under boulders (Ng & Takeda 2003; Fujita et al. 2013). Ng & Takeda (2003) pointed out that the cave environments resemble dead coral rubbles zones, in the sense of having a dark environment. In the shallow waters of coral reefs, fresh-water/blackish-water springs (groundwater) often open through fractures of the reef framework (e.g. Silbiger et al. 2020). The observed habitat of *C. cerion* in this study (darkness and low salinity conditions) is likely present not only in submarine caves that are

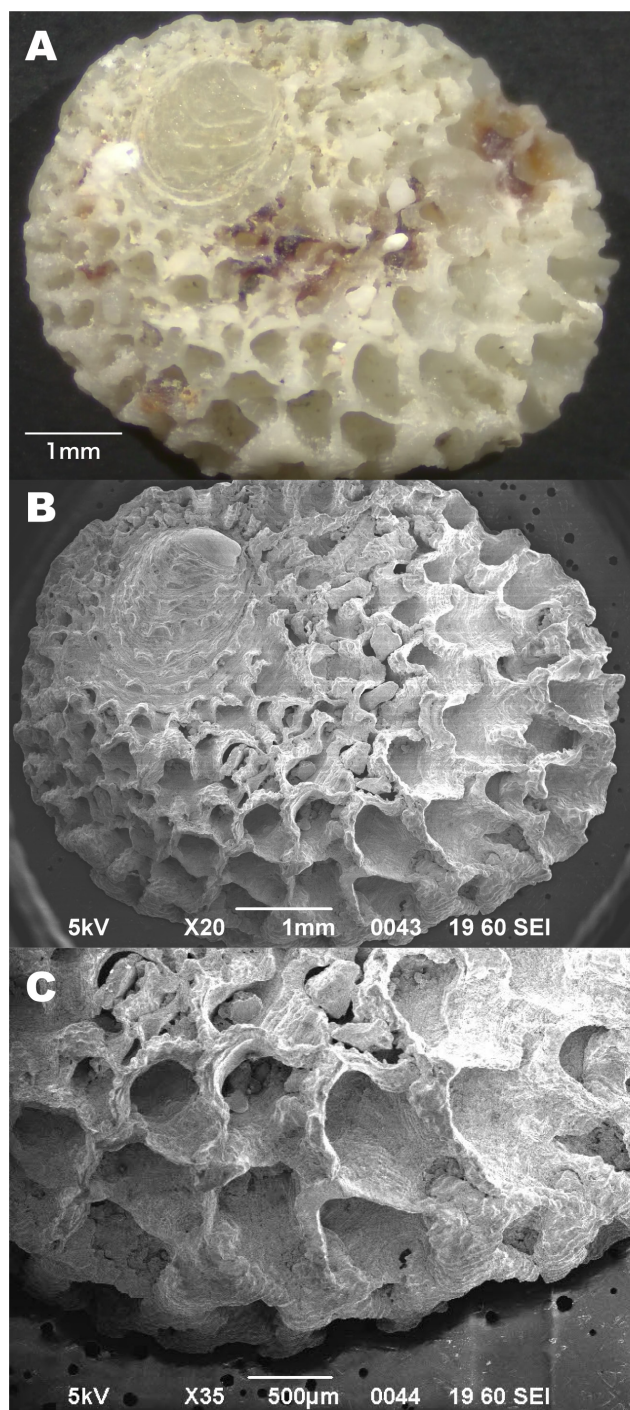


Fig. 4. The paratype of *Chama cerion* Matsukuma, Paulay & Hamada, 2003 (KUM-81). A, right valve; B, right valve (SEM image); C, right valve, “honeycomb-like appearance” (SEM image).

図4. ハチノスキクザル *Chama cerion* Matsukuma, Paulay & Hamada, 2003 のパラタイプ標本 (KUM-81). A, 右殻の外観; B, 右殻 (走査型電子顕微鏡画像); C, 右殻表面の“蜂の巣状構造” (走査型電子顕微鏡画像).

accessible to humans, but also in the shallow waters of coral reefs.

Hayami & Kase (1993) investigated submarine caves in the Ryukyu Islands actively and recorded 48

species of bivalves, but *C. cerion* was not listed. This indicates that the fauna of bivalves in the submarine caves of the Ryukyu Islands is still insufficiently investigated, and further detailed studies are required.

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琉球列島の海底洞窟におけるハチノスキクザル (軟体動物門二枚貝綱キクザルガイ科)の生貝 記録

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要旨．琉球列島の海底洞窟（沖縄諸島の沖縄島
および伊江島，宮古諸島の下地島）からハチノ
スキクザル *Chama cerion* Matsukuma, Paulay &
Hamada, 2003 の生貝を記録した．これらの標本
は，本種のアロタイプ標本と同様に，右殻表面
に折れ曲がって重なり合う特徴的な鱗片状突起
が確認され，また，この突起構造は左殻にも見
られることが明らかとなった．一方，少なくと
も本種のパラタイプ標本の一部には鱗片状突起
が見られない個体が含まれており，*C. cerion* のパ
ラタイプ標本にはアロタイプ標本とは異なる種
（おそらく未記載種）が含まれている可能性が
示唆された．本種の生貝記録は，トンガ王国ニ
ウエ島で採集された一例のみとされてきたが，
このパラタイプ標本は *C. cerion* ではない可能性
があることから，本報告が本種の確実な生貝の
初記録となる．また，本種が海底洞窟内のアン
キアライン環境（暗黒下かつ低塩分環境）に生
息することも明らかとなった．

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