Short Notes

Growth of the Submarine Cave-dwelling Micro-bivalve *Carditella iejimensis*

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More than 60 unique cave-dwelling bivalve species have been reported from submarine caves throughout the Japanese Islands, Philippine Islands, Saipan, Palau, and Guam (Kase & Hayami, 1992; Hayami & Kase, 1993, 1996). Kase & Hayami (1992) stated that many of these species share the following characteristics: 1) very small adult size (usually less than 5 mm in length), 2) unusually large prodissoconch I that commonly exceeds 250 μm in length, and 3) the absence of prodissoconch II in many species. The small adult size and large prodissoconch I strongly suggest that the minute bivalve species produce a relatively small number of larvae (Kase & Hayami, 1992). We deduced that such a reproductive strategy appears to be suitable for the oligotrophic conditions experienced in submarine caves, where suspension feeders depend for their survival on the limited phytoplankton brought into the cave from external environments by weak currents. Indeed, Kase & Hayami (1992) predicted that the growth of cave-dwelling micro-bivalves would be slow because nutrition is generally deficient in submarine caves.

However, to the best of our knowledge, no previous study has investigated the life-history characteristics of cave-dwelling micro-bivalve species, although millennia-scale variations in cave-dwelling bivalve assemblages and the larval shell morphology of micro-bivalves have been examined (Kitamura *et al*., 2007; Ubukata *et al*., 2009; Yamamoto *et al*., 2009). To address this shortcoming, we examined the shell growth of *Carditella iejimensis* Hayami & Kase, 1993 (Carditidae), via a mark–release survey in Shodokutsu submarine cave on the fore-reef slope of Ie Island, Okinawa, Japan. According to Hayami & Kase (1993), the most common species of living bivalves within surface sediment in Shodokutsu cave are *C. iejimensis*, *Cosa waikikia*, *Cosa kinjoi*, *Dacrydium zebra*, and *Parvamussium crypticum*. Among these, *C. iejimensis* is the most suitable species for a mark–release survey, because the species is a mobile infaunal suspension feeder, while the others attach to the terminal part of polychaete tubes or small rock fragments above the sediment surface by a byssus (Hayami & Kase, 1993).

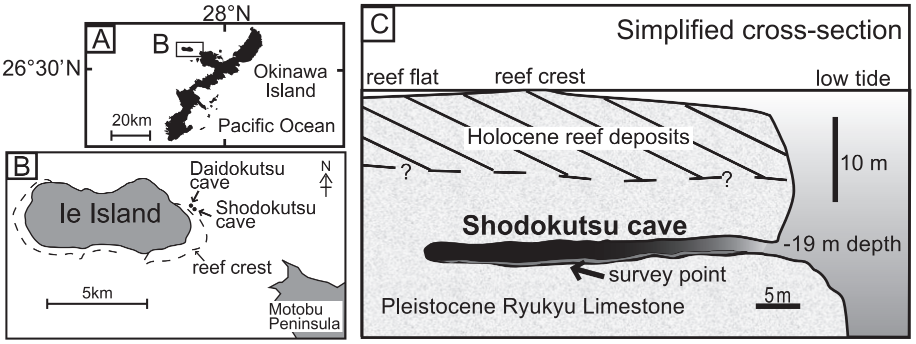

Fig. 1. Location maps of Daidokutsu and Shodokutsu submarine caves at Ie Island, off Okinawa, Japan.

Study Area and Material

The entrance to Shodokutsu cave is approximately 19 m below sea level. The cave is 35 m long, and the interior is straight and horizontal (Fig. 1). Mean monthly water temperature within the cave varies between 20°C (February) and 29°C (September) (Yamamoto *et al*., 2010). Salinity within the cave ranges from 33.5‰ to 34.5‰ (Yamamoto *et al*., 2010).

C. iejimensis has only been found in two caves (Daidokutsu and Shodokutsu) upon Ie Island, Japan (Hayami & Kase, 1993, 1996) (Fig. 1). The species is less than 3.5 mm in height and length even at maturity (Fig. 2). The maximum diameter of prodissoconch I ranges between 130 and 157 μm, while prodissoconch II is not distinguishable (Hayami & Kase, 1993). We inferred from this that *C. iejimensis* has lecithotrophic development. An analysis of sediment cores recovered from Daidokutsu cave reveals that *C. iejimensis* was predominant within the cave during at least the past 7,000 years (Yamamoto *et al*., 2009). Although several species of *Carditella* (*e.g*., *C. hanzawai* (Nomura, 1933), *C. torresi* Smith, 1885 and *C. rugosa* (Sowerby, 1833)) were described from open seas in the low-middle latitudinal regions of the Indo-Pacific, no previous study has investigated their life-history characteristics.

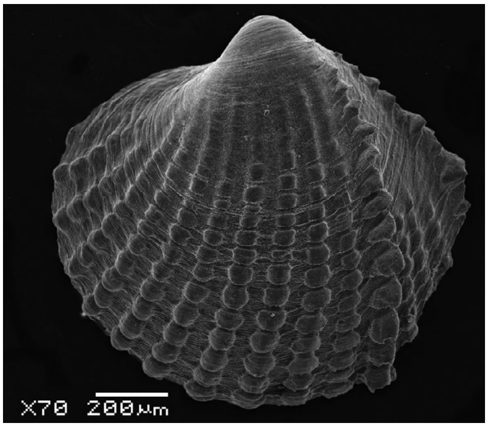

Fig. 2. SEM of *Carditella iejimensis*; left valve, Shodokutsu submarine cave, Ie Island, Okinawa.

Methods

Five mark–release-recapture surveys were carried out, with varying durations (Table 1). For each survey, different individuals were collected, released, and recaptured. Living individuals were picked from the >1.0 mm fraction of surface sediment collected from a plot of 0.25 × 0.25 m^2 in size in the middle part of Shodokutsu cave (Fig. 1). In the laboratory, the very edge of the shell margin was marked using a felt pen with water-insoluble ink. Marked individuals were then released into the sampling plot within 10 hours of their collection. Subsequently, we recaptured the shells from surface sediment of the sampling plot of 0.25 × 0.25 m^2 and measured shell heights of living individuals (Fig. 3). For measurements, a picture of the shell was taken from above with a digital camera connected to a microscope. To estimate the growth rate, the measured increase in shell height was divided by the number of days between release and recapture.

Results and Discussion

We found significant differences among the five surveys in terms of the recapture rates of alive and dead individuals (Table 1). This result may be related to spatial heterogeneity of the environment

Table 1. Results of five sets of mark–release and recapture surveys.

Release day	Recapture day	Days	No. of released individuals	Shell height (mm) of released inds min.–max.	Total number of recaptured individuals (alive + dead)	No. of recaptured individuals (alive)	Shell height (mm) of recaptured living inds min.–max.
29 Jul 2008	29 Jul 2009	365	40	0.81–2.21	35	24	1.13–2.76
	20 Sep 2008	53			3	3	1.67–2.01
3 Jun 2009	29 Jul 2009	56	39	1.39–2.10	7	7	1.47–2.14
29 Jul 2009	21 Apr 2010	266	52	0.81–1.90	17	8	1.40–2.52
18 Apr 2010	12 Jun 2010	56	29	1.40–2.74	9	8	1.40–2.74

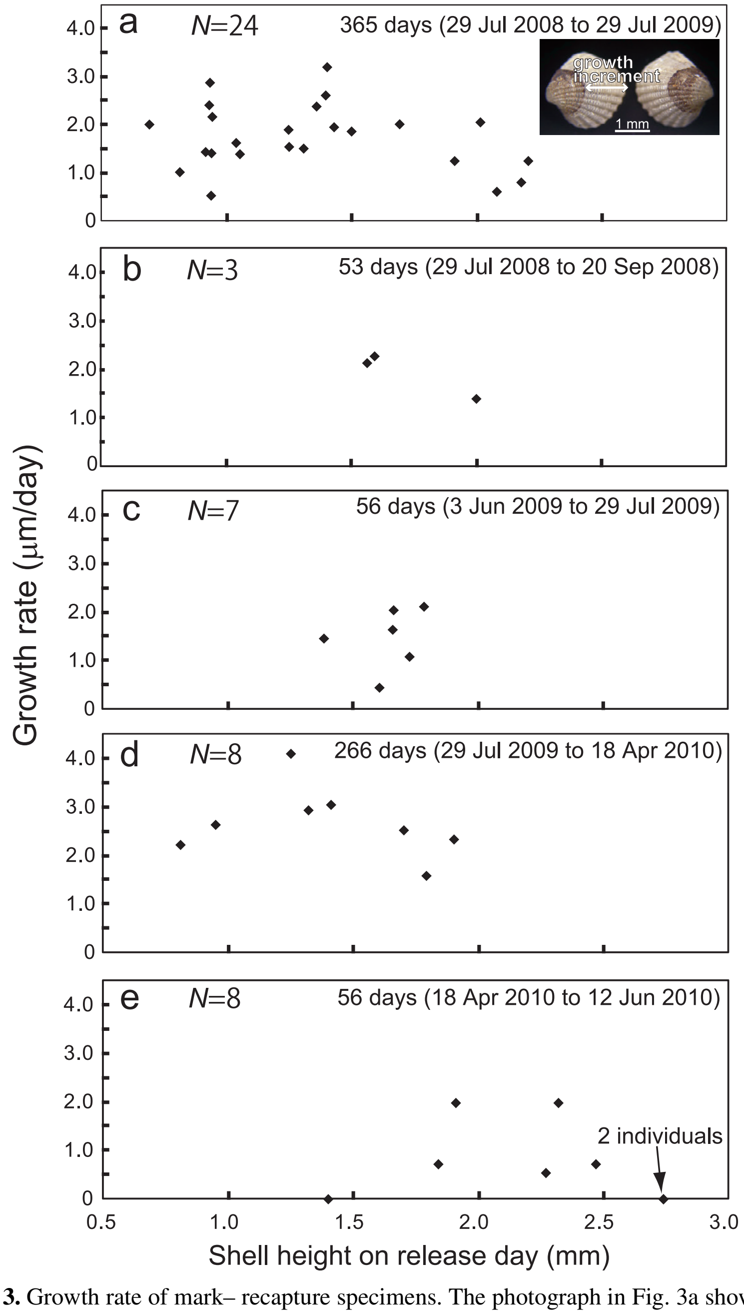

Fig. 3. Growth rate of mark– recapture specimens. The photograph in Fig. 3a shows an individual recaptured 365 days after release.

within the cave, movement of individuals or disturbance of substrata by tourist-diving. We did not perform a detailed examination of changes in growth rate with ontogeny, because we did not recapture living individuals with shell heights greater than 2.8 mm on the day of release (Fig. 3).

The growth rates of the marked specimens were less than 4.1 µm day^{-1} (Fig. 3). Since there is no statistically significant correlation between shell height and growth rate among the five sets of sampled shells (Fig. 3), we estimated the mean growth rates of the five sets in Fig. 4. These values are averaged over released periods. so it is not possible to evaluate changes in the seasonal growth of the shells from these data. However, since evidence of seasonal growth cessation is not discernible from these data, it is possible that the species undergoes year-round continuous growth. If this interpretation is correct, the shell probably requires more than 1 year to reach 1 mm in height, and 4 years to reach 3 mm; consequently, the lifespan for *C. iejimensis* is estimated to be at least 4 years. The growth rate of *C. iejimensis* is much lower than that of bivalves which live in the open sea (Fig. 5). Our data support the previous hypothesis that the growth of cave-dwelling micro-bivalves would be slow (Kase & Hayami, 1992).

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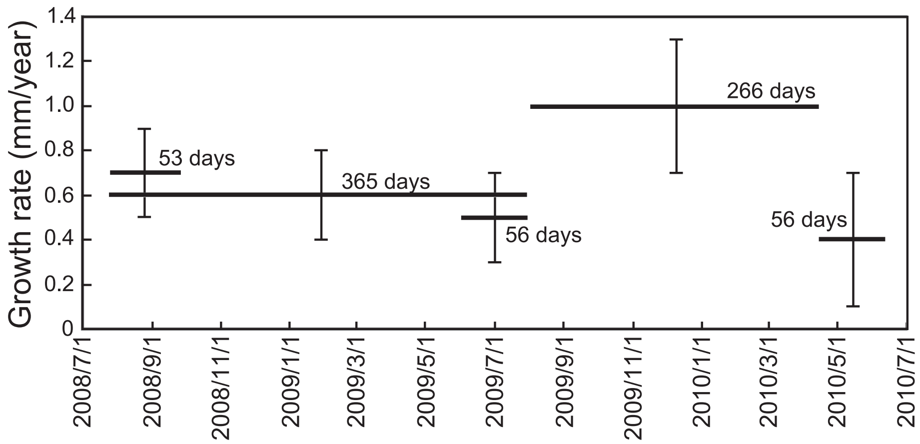

Fig. 4. Mean growth rate of the five surveys. Note that the unit of mean growth rate is mm per year. The vertical lines indicate the interval of ±1 standard deviation.

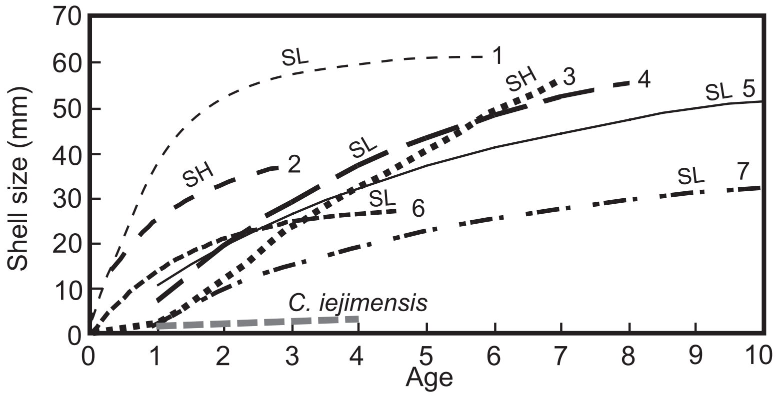

Fig. 5. Shell-growth rate for many bivalve species which live in the open sea. 1, *Mya arenaria oonogai* from Goshima (1982); 2, *Scapharca kagoshimensis* from Yoshida (1964); 3, *Phacosoma japonicum* from Tanabe & Oba (1988); 4, *Pinna nobilis* from Richardson *et al.* (1999); 5, *Modiolus barbatus* from Peharda *et al.* (2006); 6, *Donax dentifer* from Riascos (2006); 7, *Arctica islandica* from Zettler *et al.* (2001). SH, shell height; SL, shell length.

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海底洞窟生微小二枚貝 *Carditella iejimensis* の成長

北村晃寿・山本なぎさ・小林小夏

要　約

沖縄県伊江島沖の海底洞窟“小洞窟”（深度 19 m）に生息する微小二枚貝 *Carditella iejimensis*（殻長・殻高ともに 3.5 mm 以下）について，標識個体の殻成長追跡調査を行った。その結果，同種は 1 年を通じて殻成長を行なう可能性が高いことが分かった。また，殻の成長速度から，殻長 3 mm に達するまでに，少なくとも 4 年間を要するものと推定される。