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A NEW DICYEMID FROM *OCTOPUS HUBBSORUM* (MOLLUSCA: CEPHALOPODA: OCTOPODA)

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ABSTRACT: A new species of dicyemid mesozoan is described from *Octopus hubbsorum* Berry, 1953, collected in the south of Bahia de La Paz, Baja California Sur, México. *Dicyema guaycurense* n. sp. is a medium-size species that reaches about 1,600 μm in length. It occurs in folds of the renal appendages. The vermiform stages are characterized as having 22 peripheral cells, a conical calotte, and an axial cell that extends to the base of the propolar cells. Infusoriform embryos consist of 39 cells; 1 nucleus is present in each urn cell and the refringent bodies are solid. This is the first of a dicyemid species from a host collected in the Gulf of California.

Dicyemid mesozoans (Phylum Dicyemida) are the most common endosymbionts typically found in the renal sac of benthic cephalopod molluscs. In total, 114 species of dicyemids have so far been reported in at least 43 species of benthic cephalopods. Most of them were found to be host specific (Furuya, 1999). Dicyemids are distributed in a variety of geographical localities, i.e., Okhotsk Sea, Japan Sea, western and northeastern Pacific Ocean, New Zealand, northern Indian Ocean, Mediterranean, northwestern and eastern Atlantic Ocean, and Antarctic Ocean. In Mexico, the dicyemid mesozoan fauna has received little attention. Dicyemids belonging to *Dicyema* and *Dicyemennea* have been described off the Pacific coast of Baja California, Mexico (McConnaughey, 1941, 1949a, 1949b). More recently, *Dicyema shorti* was described from the Gulf of Mexico (Furuya et al., 2002).

In the present article, we describe a new species from *Octopus hubbsorum* Berry, 1953, collected off Bahia de La Paz, Baja California Sur, México. This is the first dicyemid described from the Gulf of California.

MATERIALS AND METHODS

In this study, 53 individuals of *O. hubbsorum* were examined for dicyemids from 2003 to 2004. Host specimens were obtained from fishermen, who collected them in the south of Bahia de La Paz, Gulf of California, Mexico. Small pieces of the renal organ with attached dicyemids were removed and smeared on glass microscope slides. The smears were fixed immediately in Bouin's fluid and then stored. They were stained in Ehrlich's hematoxylin or ferric hematoxylin and counterstained in eosin. Stained smears were mounted with low-viscosity synthetic resin (Citoseal, Kalamazoo, Michigan). Dicyemids were observed with Zeiss and Olympus light microscopes at magnifications up to ×2,000. Measurements and drawings were made with the aid of an ocular micrometer and a drawing tube, respectively.

The terminology for cell names used in the description of infusoriform larvae is based on Nouvel (1948), Short and Damian (1966), Furuya et al. (1992a, 1997), and Furuya (1999).

Specimens of the dicyemids are deposited in the Coleccion Helmintologica del Museo de Historia Natural of the Universidad Autonoma de Baja California Sur (CPMHN-UABCS 250, CPMHN-UABCS 251, CPMHN-UABCS 252), México. The syntypes and host specimen (symbiotype) are deposited in the collection of the Department of Invertebrate Zoology, Santa Barbara Museum of Natural History, Santa Barbara, California (SBMNH 357585, SBMNH 357586).

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DESCRIPTION

Dicyema guaycurense n. sp.
(Figs. 1, 2; Table I)

Diagnosis: Large dicyemid; body lengths to 1,600 μm. Calotte shape conical. Vermiform stages with 22 peripheral cells: 4 propolar cells + 4 metapolar cells + 2 parapolar cells + 12 trunk cells. Infusoriform embryos with 39 cells; refringent bodies solid; and 1 nucleus present in each urn cell.

Nematogens (Figs. 1a, 2a, d): Body lengths 380–1,109 μm, widths 23–70 μm; widest in region of diapolars; trunk width mostly uniform. Peripheral cell number 22 (Table I): 4 propolar cells + 4 metapolar cells + 2 parapolar cells + 10 diapolar cells + 2 uropolar cells. Calotte conical in shape, rounded anteriorly; cilia on calotte about 6 μm long, oriented anteriorly. Propolar cells and their nuclei smaller than metapolar cells and their nuclei, respectively. Propolar cells occupy anterior 35–50% of calotte length when viewed laterally (Figs. 1a, b, 2d, e). Axial cell cylindrical, rounded anteriorly; cell extends forward to middle of metapolar cells. About 20 vermiform embryos present in axial cells of large individuals.

Vermiform embryos (Figs. 1c, 2f, g): Full-grown vermiform embryos range from 56 to 69 μm in length, from 11 to 16 μm in width. Peripheral cell number 22 (Table I); trunk cells arranged in opposed pairs. Anterior end of calotte rounded. Axial cell rounded anteriorly; extends to base of propolar cells; nucleus usually located in center of axial cell. Axial cell of full-grown embryos often with as many as 4 agametes; 2 in each side of axial cell nucleus (Figs. 1c, 2g).

Rhombogens (Figs. 1b, 2b, c, e): Body longer than nematogens, lengths 545–1,600 μm, widths 27–71 μm. Peripheral cell number typically 22 (Table I). Calotte conical, rounded anteriorly. Axial cell shape and anterior extent similar to nematogens. From 1 to 4 infusorigens present in axial cell of each parent individual. About 20 infusoriform embryos present in axial cells of large individuals. Accessory nuclei usually present in trunk cells.

Infusorigens (Fig. 1d; n = 20): Mature infusorigens small sized; composed of 4–15 (mode 9) external cells (oogonia and primary oocytes) + 2–5 (mode 4) internal cells (spermatogonia, primary spermatocytes, and secondary spermatocytes) + 4–13 (mode 7) spermatozoa. Mean diameter of fertilized eggs, 12.6 μm; of spermatozoa, 1.8 μm. Axial cell round or ovoid, diameters 9–25 μm.

Infusoriform embryos (Figs. 1e, f, 2h–j; n = 20): Full-grown embryos large, lengths average 29.6 ± 2.4 μm (excluding cilia; mean ± SD); length:width:height ratio 1.0:0.84:0.80; shape ovoid, bluntly rounded posteriorly; cilia at posterior end 7 μm long. Refringent bodies present, solid; occupy anterior 40% of embryo length when viewed laterally (Fig. 1e). Cilia project from ventral internal cells into urn cavity (Fig. 2j). Capsule cells contain large granules. Mature embryos with 39 cells: 35 somatic + 4 germinal cells. Somatic cells of several types present: external cells cover large part of anterior and lateral surfaces of embryo (2 enveloping cells); external cells with cilia on external surfaces (2 paired dorsal cells + 1 median dorsal cell + 2 dorsal caudal cells + 2 lateral caudal cells + 1 ventral caudal cell + 2 lateral cells + 2 posteroventral lateral cells), external cells with refringent bodies (2 apical cells); external cells without cilia (1 couvercle cell + 2 anterior lateral cells + 2 first ventral cells + 2 second ventral cells + 2 third ventral cells); internal cells with cilia (2

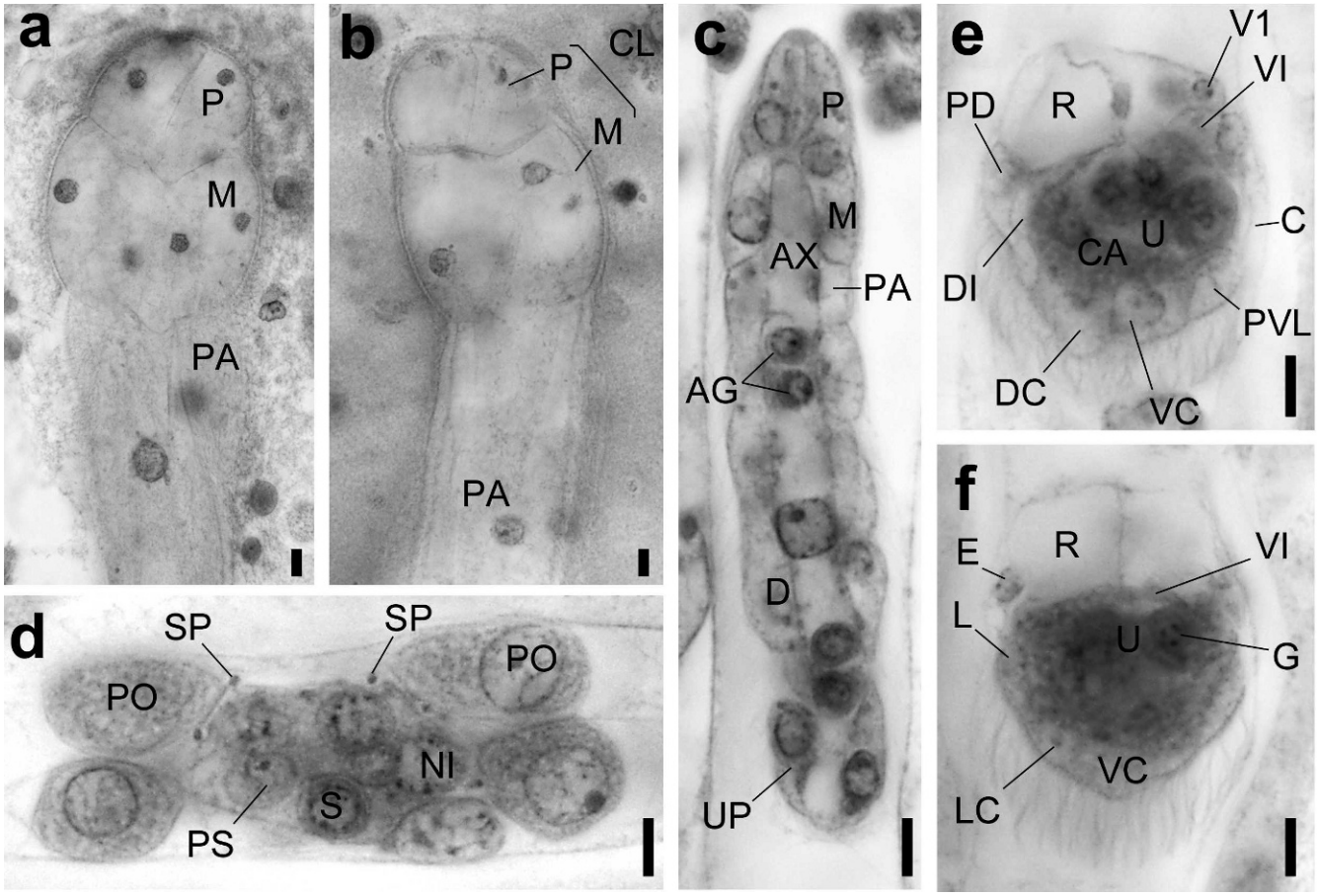

FIGURE 1. *Dicyema guaycurense* n. sp., photographs of specimens on slides in the syntype series (SBMNH 357585 and SBMNH 357586). (**a**) Anterior region of nematogen. (**b**) Anterior region of rhombogen. (**c**) Vermiform embryos within axial cell. (**d**) Infusorigen. (**e, f**) Infusoriform embryos within axial cell: (e) optical sagittal section; (f) optical horizontal section. Scale bars represent 5 μm. Abbreviations: AG, agamete; AX, axial cell; CA, capsule cell; CL, calotte; D, diapolar cell; DC, dorsal caudal cell; E, enveloping cell; L, lateral cell; LC, lateral caudal cell; M, metapolar cell; NI, nucleus of the axial cell of infusorigen; P, propolar cell; PA, parapolar cell; PD, paired dorsal cell; PO, primary oocyte; PS, primary spermatocyte; R, refringent body; S, spermatogonium; SP, sperm; U, urn cell; UP, uropolar cell; VC, ventral caudal cell; VI, ventral internal cell; V1, first ventral cell.

ventral internal cells); and internal cells without cilia (2 dorsal internal cells + 2 capsule cells + 4 urn cells). Each urn cell contains 1 germinal cell and 1 nucleus. All somatic nuclei appear pycnotic in mature infusoriform embryos.

Taxonomic summary

Syntypes: Allocation of type specimens on slides as follows: slides 1, 4, 5, and 16 from SCM host 38 deposited in California (SBMNH 357586); slides 61–63 from SCM host 30 deposited in California (SBMNH 357585). Additional slides deposited in La Paz, Baja California Sur, México (CPMHN-UABCS 250, CPMHN-UABCS 251, CPMHN-UABCS 252).

Type host: Octopus hubbsorum Berry, 1953 (Mollusca: Cephalopoda: Octopodidae).

Symbiotype: Male (mature), 112 mm ML; SBMNH 357586.

Additional host voucher: Male (mature), 80 mm ML; author's collection [SCM-25].

Other hosts: None.

Type locality: México, Gulf of California, Baja California Sur, Bahia de La Paz, El Pulguero, 24°20′53.4″N, 110°16′05.6″W, ~10 m.

Collector and date: Artesinal fisherman, 30 April 2004.

Site of infection: Anterior ends (calottes) inserted into crypts of the renal appendages within the renal sacs.

Prevalence: In 13 of 53 hosts examined (24.5%).

Specimens deposited: Syntype slides deposited in California (SBMNH 357585, SBMNH 357586).

Etymology: The species name refers to the native people "Guaycuras" who lived in the southern region of the peninsula of Baja California, Mexico. It is expressed as a Latinized adjective in the nominative case agreeing in gender with the generic name (neuter).

Remarks

Dicyema guaycurense n. sp. is similar to *Dicyema apollyoni*, Nouvel 1947, *Dicyema awajiense* Furuya, 2006, *Dicyema banyulensis* Furuya and Hochberg, 1999, *Dicyema colurum* Furuya, 1999, *Dicyema leiocephalum* Furuya, 2006, *Dicyema misakiense* Nouvel and Nakao, 1938, and *Dicyema shimantoense* Furuya, 2008, in the number of peripheral cells, the shape of the calotte, and the anterior extent of the axial cell of the vermiform stages.

Dicyema apollyoni was described from *Octopus apollyon* (Berry, 1912) collected off the Marine View Rock in northern California (Nouvel, 1947). The species of the host is now known to be *Octopus rubescens* Berry, 1953 (F. Hochberg, unpubl. obs.). *Dicyema guaycurense* can be distinguished from *D. apollyoni* based on the maximum number of infusorigens (4 vs. 2) and the number of urn-cell nuclei of infusoriform embryos (1 vs. 2) (Nouvel, 1947; Furuya, Hochberg et al., 2004).

Dicyema banyulensis was described from *Octopus salutii* Verany, 1839 collected off the French coast in the western Mediterranean (Furuya and Hochberg, 1999). *Dicyema guaycurense* is easily distinguishable from *D. banyulensis* in the number of urn-cell nuclei of infusoriform embryos (1 vs. 2) and in not having swollen parapolar cells in the vermiform stages.

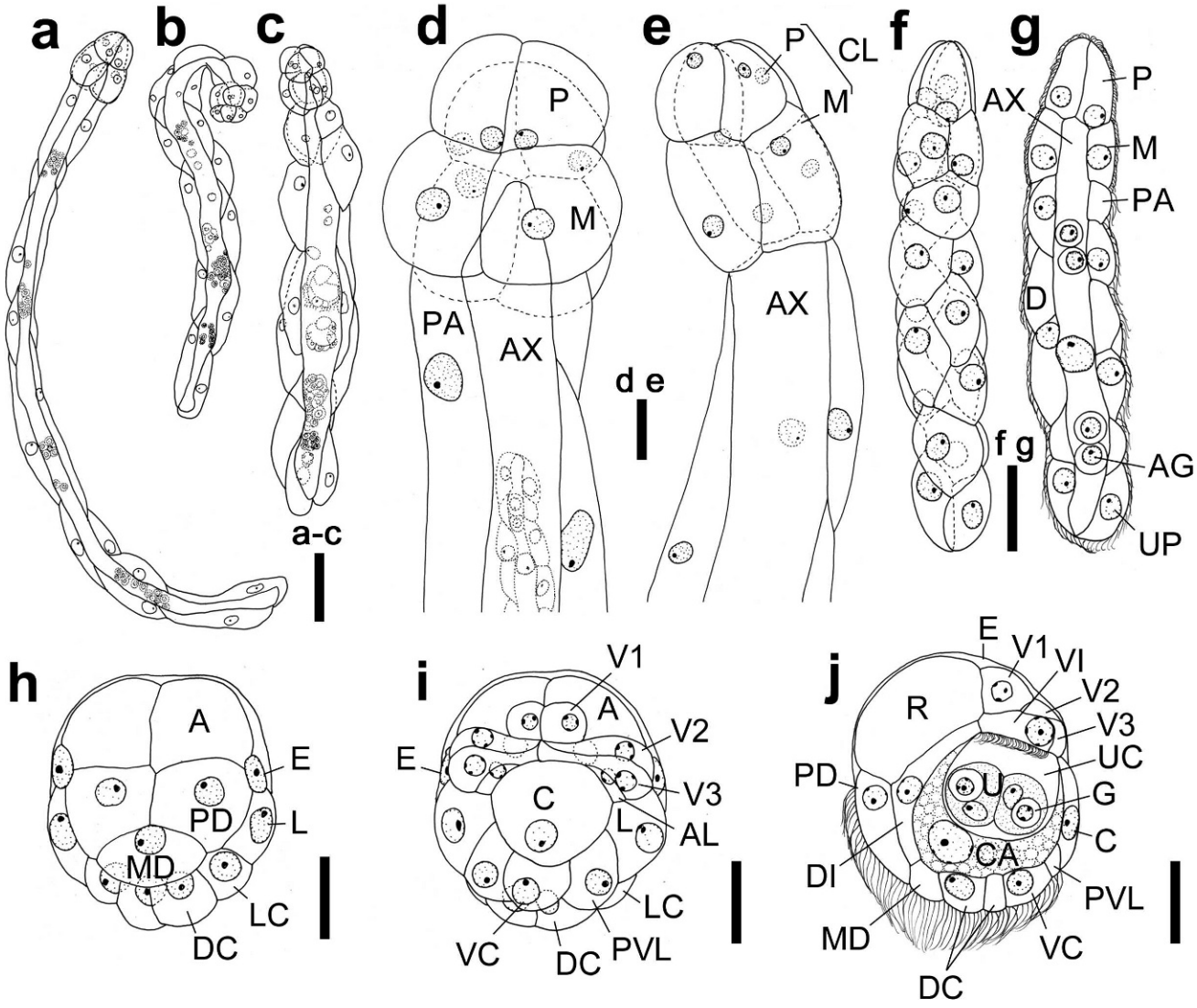

FIGURE 2. *Dicyema guaycurense* n. sp., drawn from specimens on slides in the syntype series (SBMNH 357585 and SBMNH 357586). (**a–c**) Vermiform stages, entire: (a) nematogen, (b, c) rhombogen. (**d**) Anterior region of nematogen. (**e**) Anterior region of rhombogen. (**f, g**) Vermiform embryos within the axial cell: (f) cilia omitted, (g) optical section. (**h–j**) Infusoriform embryos (immature): (h) dorsal view (cilia omitted), (i) ventral view (cilia omitted), (j) sagittal section. Scale bars represent 5 μm in (a–c) and 10 μm in (d–j). Abbreviations: A, apical cell; AG, agamete; AL, anterior lateral cell; AX, axial cell; C, couvercle cell; CA, capsule cell; CL, calotte; D, diapolar cell; DC, dorsal caudal cell; DI, dorsal internal cell; E, enveloping cell; G, germinal cell; L, lateral cell; LC, lateral caudal cell; M, metapolar cell; MD, median dorsal cell; P, propolar cell; PA, parapolar cell; PD, paired dorsal cell; PVL, posteroventral lateral cell; R, refringent body; U, urn cell; UC, urn cavity; UP, uropolar cell; V, vermiform embryo; VC, ventral caudal cell; VI, ventral internal cell; V1, first ventral cell; V2, second ventral cell; V3, third ventral cell.

Dicyema colurum and *D. awajiense* were described from *Amphioctopus fangsiao* (d'Orbigny, 1840) collected off Japan (Furuya, 1999, 2006a). *Dicyema guaycurense* differs from *D. colurum* in the maximum number of agametes at eclosion of vermiform embryos (4 vs. 2) and the number of urn-cell nuclei of infusoriform embryos (1 vs. 2) (Furuya, 1999). *Dicyema guaycurense* can be distinguished from *D. awajiense* based on the maximum number of agametes at eclosion of vermiform embryos (4 vs. 1) and the number of cells in the infusoriform embryos (39 vs. 37) (Furuya, 2006a).

Dicyema misakisense was described from *Octopus vulgaris* Lamarck, 1798 collected in Japanese waters (Nouvel and Nakao, 1938). *Dicyema guaycurense* is distinguishable from *D. misakisense* in the maximum number of agametes at eclosion of vermiform embryos (4 vs. 2) and the number of cells in the infusoriform embryos (39 vs. 37) (Furuya et al., 1992b).

Dicyema leiocephalum was described from *Amphioctopus areolatus* (de Haan, 1840) found off Japan (Furuya, 2006b). In cellular composition of the infusoriform embryos, *D. leiocephalum* is of a particular type that possesses anterior internal cells and lacks dorsal internal cells (Furuya et al., 1997; Furuya, Hochberg et al., 2004; Furuya, 2006b). In this respect, *D. guaycurense* can be separated from *D. leiocephalum.*

Dicyema shimantoense was described from *Octopus sasakii* Taki, 1942 in Japanese waters (Furuya, 2008). *Dicyema guaycurense* is easily distinguishable from *D. shimantoense* in the maximum number of infusorigens (4 vs. 1) and the number of cells in the infusoriform embryos (39 vs. 37) (Furuya, 2008).

Infusorigen size and number are diagnostic characters of dicyemid species (Furuya et al., 1993). There is a negative curvilinear relationship between the number of infusorigens per rhombogen and the number of gametes (egg-line and sperm-line cells) per infusorigen (Furuya et al., 2003; Furuya, 2005, 2006a, 2006b, 2006c). Irrespective of genera, 4 distinct groups of reproductive strategies are classified within the dicyemid species: (1) rhombogens form a relatively small number of medium- to large-sized infusorigens (less than 5) and produce a relatively large number of gametes

TABLE I. Number of peripheral cells in new species of dicyemid.

Cell number	Number of individuals		
	Vermiform embryos	Nematogens	Rhombogens
20	0	0	1
21	0	1	1
22	30	16	10

(more than 20) per infusorigen; (2) rhombogens produce a large number of infusorigens (more than 5), each of which has at most 20 gametes; (3) rhombogens produce large numbers of large-sized infusorigens with a large number of gametes; and (4) rhombogens form a relatively small number of small-sized infusorigens with a few gametes (at most 10) (Furuya et al., 2003; Furuya, 2005, 2006a, 2006b, 2006c). Rhombogens of *D. guaycurense* have a small number of medium-sized infusorigens, and thus this species belongs to the first type. In this respect, *D. guaycurense* differs from *D. apollyoni* (the third type), *D. awajiense*, and *D. leiocephalum* (the fourth type).

DISCUSSION

Octopus hubbsorum is a species with a robust, moderate-size body. It is commonly found in rocky areas from the intertidal to depths of 30 m in the shallow subtidal zone (Hochberg, 1980; Roper et al., 1995). The species ranges from Bahia de Los Angeles in the Gulf of California to Salina Cruz, Oaxaca in México. In the Mexican Pacific, *O. hubbsorum* is the main species that sustains the fishery (López-Uriarte et al., 2005; Alejo-Plata, 2009).

Four species of *Dicyema* have been reported in the region where the Baja Peninsula meets the coast of southern California, namely, *Dicyema acciaccatum* McConnaughey, 1949, *Dicyema acheroni* McConnaughey, 1949, *Dicyema sullivani* McConnaughey, 1941, and *Dicyema apollyoni* Nouvel, 1947 (McConnaughey, 1941, 1949a, 1949b). *Dicyema sullivani* was described in *O. bimaculatus* Verrill, 1883, and *D. acciaccatum* and *D. acheroni* were reported in *O. bimaculoides* Pickford and McConnaughey, 1949. The latter parasite occurs sympatrically along its range with *O. bimaculatus*, and the 2 sister species most likely occupy similar niches (Pickford and McConnaughey, 1949). *Octopus bimaculatus* mixes with populations of *O. hubbsorum* in the Gulf of California (Hochberg, 1980) and probably *O. hubbsorum* has also similar niches to these 2 species. Nevertheless, *O. hubbsorum* harbors only *D. guaycurense*, which has never been found in the other host octopuses. This indicates a host specificity, as Furuya (1999, 2006a) reported in the Japanese dicyemid species.

Species in *Dicyema* sp. commonly are found in small- to medium-sized, shallow water cephalopods (Furuya, 1999). In the present study, the prevalence of dicyemids was 24.5% (13/53), which is relatively low. The host octopus in which dicyemids were not found had a mantle length that measured less than 11 mm. Furuya et al. (1992b) reported a direct relationship between host size and dicyemid occurrences, i.e., smaller or younger cephalopods of a host species generally do not harbor dicyemids. However, there are several exceptions, namely *Amphioctopus fangsiao* (d'Orbigny, 1840), *Amphioctopus kagoshimensis* (Ortmann, 1888), *A. areolatus, Enteroctopus dofleini* (Wülker, 1910), *Octopus sasakii* Taki, 1942, *Sepiella japonica* Sasaki, 1929, and *Sepioteuthis lessoniana* Lesson, 1830 (Furuya, 2005, 2006a, 2006b, 2007, 2008a, 2008b, 2008c; Furuya and Tsuneki, 2005). The absence of dicyemids in them cannot be attributed to host size, but probably to geographical location. In *O. hubbsorum*, the absence of dicyemids may be attributed to host size, because the specimens were sampled in a narrow area. Consequently there is probably a specific size at which the species is infected with dicyemids.

Dicyemids are known to be present in several other species of octopuses in the Gulf of California (F. Hochberg, unpubl. obs.). In addition, several potential cephalopod hosts still remain to be examined in the Gulf. Thus, a number of undescribed species of dicyemids are expected to occur in this region.

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