

First record of the maternal care behavior of a “rhizarian rider,” *Phronimopsis spinifera* Claus, 1879 (Amphipoda, Hyperiidea), in association with *Aulosphaera* sp. (Rhizaria, Cercozoa, Phaeodaria, Aulosphaeridae)

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Rhizaria are a supergroup of unicellular eukaryotes, mainly composed of mineralized skeleton-bearing protists such as Foraminifera, Radiolaria, and Phaeodaria (Nakamura *et al.*, 2019a). Some species of rhizarians (Phaeodaria and Radiolaria) and crustaceans (Amphipoda and Decapoda) show a unique symbiotic relationship (Wakabayashi *et al.*, 2017; Nakamura & Suzuki, 2019), called the “rhizarian rider” phenomenon (Nakamura *et al.*, 2019b). The association between *Phronimopsis spinifera* Claus, 1879 (Amphipoda, Hyperiidea) and *Aulosphaera* sp. (Rhizaria, Phaeodaria) is the most commonly observed combination of rhizarian riders. *Phronimopsis spinifera* is a marine pelagic amphipod species widely distributed in the tropical regions of the Atlantic, Indian, and Pacific oceans, as well as the Mediterranean and Red Seas (Vinogradov *et al.*, 1996). In the “rhizarian rider” phenomenon, *P. spinifera* carries 2–9 individuals of *Aulosphaera* sp. It has been observed that *P. spinifera* holds rhizarians using the chelae of the fifth to seventh pereopods. The rhizarians carried by the amphipod may function as food collectors and floats to keep buoyancy (or to save the swimming energy of *P. spinifera*).

During our field investigation by SCUBA diving, a photograph of *P. spinifera* in association with *Aulosphaera* sp. was captured by one of the authors (A. Kayama) using a digital camera (LUMIX DC-GX7MK3) (Fig. 1) on 3 June 2022 at a water depth of 8 m, 8 km west off the Ani-jima Island (N27°07'21" E142°12'35"), Ogasawara Islands, in the western North Pacific. A mature female of *P. spinifera* (ca.

3 mm in body length) carrying 6 individuals of *Aulosphaera* sp. and 1–2 amphipod juveniles attaching on the surface of or partly inside each rhizarian individual are shown in the photograph. As these juveniles are similar in size and shape, they are likely at the same developmental stage.

In general, mature female amphipods spawn in their brood pouches, wherein the embryos hatch (Irie, 1967). Some species of Hyperiidea raise their juveniles on the surface of or inside gelatinous zooplankton, such as doliolids, salps, and jellyfishes (some of them are known as “barrel”) (Harbison *et al.*, 1977; Madin & Harbison, 1977; Laval, 1980; Gasca & Hadcock, 2004; Aoki *et al.*, 2013; Gasca *et al.*, 2015; Mazda *et al.*, 2019).

In this study, it is revealed for the first time that rhizarian riders have similar maternal care behavior, including demarsupication of their progeny on the symbiont. It is suggested that amphipods utilize rhizarians not only as floats and food collectors but also as breeding beds. It is noteworthy that amphipod juveniles are distributed over the whole rhizarian colony, as if each juvenile holds its own rhizarian individual. This characteristic has never been reported in other amphipods. The observed rhizarian group, Aulosphaeridae, forms a colony of several individuals. After a specific time, rhizarian individuals separate each other, becoming solitary individuals (e.g., Nakamura *et al.*, 2017). For amphipods, a colony of rhizarians is more advantageous than a solitary rhizarian as it prevents competition among amphipod juveniles for rhizarians. Therefore, the mother amphi-

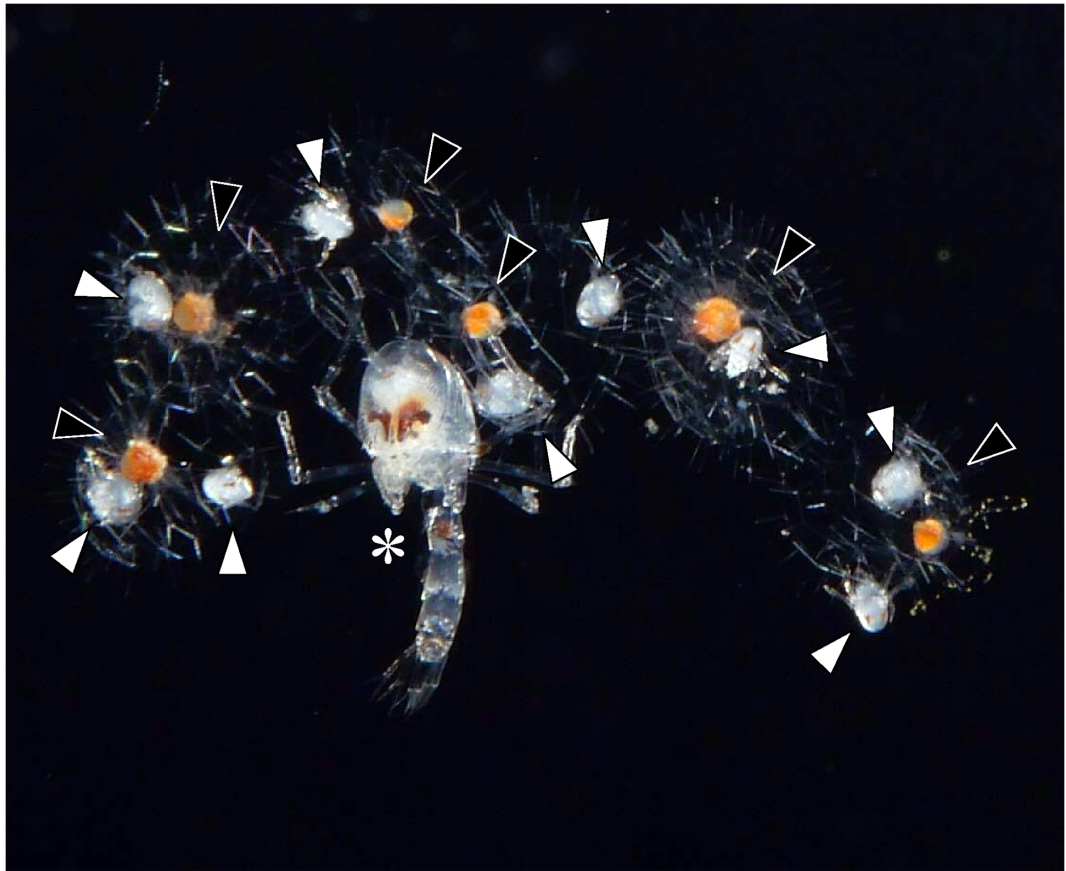


Fig. 1. A photograph of "rhizarian rider," a mature female of *Phronimopsis spinifera* (ca. 3 mm BL) (asterisk) carrying a colony of *Aulosphaera* sp. (filled arrow heads). On the surface or partly inside of each rhizarian individual, 1–2 amphipod juveniles were attached (opened arrow heads). The longest distance of the rhizarian colony was ca. 10 mm. Photo by Aiko Kayama.

pods may choose a colony of rhizarians to increase the survival of its juveniles. Further studies are necessary to clarify the details of the rhizarian rider phenomenon, including maternal care behavior; it needs to be investigated whether juvenile amphipods are identical, rhizarians are controlled (e.g., prevention of their dispersal) by the mother amphipod, and juvenile amphipods feed on rhizarians or other food.

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