

MARINE RECORD

Open Access



First record of *Protomystides hatsushimaensis* (Annelida: Phyllodocidae) inhabiting vacant tubes of vestimentiferan tubeworms

Genki Kobayashi^{1,2*} and Shigeaki Kojima^{1,2}

Abstract

Background: Vestimentiferan tubeworms (Annelida: Siboglinidae) often play an important role as a foundation species in chemosynthetic ecosystems by providing microhabitats for other organisms. In the present study, we detected a new relationship between phyllodocid worms and tubes of a vestimentiferan *Alaysia* sp.

Methods: Tubes of *Alaysia* sp. were collected from a hydrothermal vent field at a depth of 1052 m on the North Iheya Knoll in the Okinawa Trough on January 17, 2000. The *Alaysia* tubes were fixed with 4.7% neutralized formaldehyde solution and preserved in 70% ethyl alcohol. Phyllodocid worms were later obtained from empty tubes of *Alaysia* sp.

Results: We classified the collected phyllodocid worms as *Protomystides hatsushimaensis* based on the morphology of specialized chaetae. They were observed in thin brownish tubes of mucous, probably secreted by *P. hatsushimaensis*, at approximately 30 and 50 mm from the upper openings of the tubes of *Alaysia* sp.

Conclusions: The phyllodocid worm *P. hatsushimaensis* was found inside the tubes of *Alaysia* sp., a vestimentiferan tubeworm, collected in a hydrothermal vent field on the North Iheya Knoll in the Okinawa Trough of the western Pacific. The present study provides a new record of *P. hatsushimaensis* using empty vestimentiferan tubes as a microhabitat.

Keywords: *Alaysia* sp., Annelida, Hydrothermal vent field, Northwestern Pacific, Okinawa Trough, Siboglinidae

Background

Biological structures, such as annelid tubes, can affect community structuring by facilitating the recruitment of other benthic organisms (Gallagher et al., 1983; Reise, 1983; Trueblood, 1991; Zühlke et al., 1998; Callaway, 2006). Vestimentiferan tubeworms (Annelida: Siboglinidae) often play an important role in chemosynthetic ecosystems by providing microhabitats for other organisms (Govenar et al., 2005). Their chitinous tubes are used as substrata for colonization of sessile organisms, such as actinarians (Desbruyères et al.,

2006), barnacles (Tunnicliffe & Southward, 2004), bivalves (Järnegren et al., 2005), foraminiferans (Sen Gupta et al., 2007), limpets (McLean, 1993), polyps of jellyfishes (Miyake et al., 2004), sponges (Maldonado & Young, 1998), and stoloniferans (Becker et al., 2013). In addition, many organisms aggregate around the vestimentiferan tubes: annelids, cephalopods, zoarcid fishes, pantopods, and shrimps (Desbruyères et al., 2006). An experimental study of habitat provision by vestimentiferans has suggested that the structures made by vestimentiferans are not interchangeable with those made by other habitat-creating invertebrates, such as mussels, for some epifaunal species (Govenar & Fisher, 2007), suggesting a key role of vestimentiferans in generating microhabitats as a foundation species.

* Correspondence: genkikobayashi@s.nenv.ku-tokyo.ac.jp

¹Atmosphere and Ocean Research Institute, The University of Tokyo, 5-1-5 Kashiwanoha, Kashiwa, Chiba 277-8564, Japan

²Graduate School of Frontier Sciences, The University of Tokyo, 5-1-5 Kashiwanoha, Kashiwa, Chiba 277-8561, Japan

Some annelid species endemic to chemosynthetic ecosystems have been collected from the aggregations of vestimentiferans (Govenar et al., 2005; Govenar & Fisher, 2007; Tsurumi & Tunnicliffe, 2003; Govenar et al., 2004). Species of the family Phyllodocidae have also been recorded from the aggregations of vestimentiferans in the western and eastern Pacific (Desbruyères et al., 2006; Martin & Britayev, 1998): *Eulalia papillosa* (Blake, 1985); *Garapagomystides aristata* Blake, 1985; *Protomystides hatsushimaensis* Miura, 1988; *Protomystides verenae* Blake & Hilbig, 1990; and an unidentified species of the genus *Protomystides* inhabiting Gulf of Mexico (Becker, 2010).

Some phyllodocids have been suggested to feed on vestimentiferans (Jenkins et al., 2002), and they were found on the outer surface of vestimentiferan tubes. In contrast, *Protomystides* sp. was obtained from both the outside and inside of a dead tube of a vestimentiferan species (Becker, 2010), although it remains unclear whether this behavior is common or not among phyllodocids aggregating on vestimentiferans. *Protomystides hatsushimaensis* was discovered on the outer surface of a tube of *Lamellibrachia sagami* Kobayashi et al., 2015 in a cold seep area at a depth of 1140 m off Hatsushima Island. Later, additional specimens were obtained from bottom sediments sampled within *Calyptogena* beds with *Nicomache (Loxochona) ohtai* Miura, 1991 (Annelida: Maldanidae) from a site off Hatsushima (Fujikura et al., 2002). In the present study, we show a new record of *P. hatsushimaensis* in a hydrothermal vent field, which was obtained from the inside of empty tubes constructed by a vestimentiferan tubeworm, *Alaysia* sp.

Methods

Tubes of *Alaysia* sp. were collected from a hydrothermal vent field at a depth of 1052 m on the North Iheya Knoll in the Okinawa Trough (27°47.23'N, 126°54.26'E) using the human-occupied vehicle *Shinkai 2000* during the NT00–08 cruise of the research vessel (R/V) *Natsushima* of the Japan Agency for Marine–Earth Science and Technology (JAMSTEC) on January 17, 2000 (Fig. 1). The Okinawa Trough is a representative back-arc basin with hydrothermal vent fields in the western Pacific (Fujikura et al., 2008). The *Alaysia* tubes were fixed with 4.7% neutralized formaldehyde solution and preserved in 70% ethyl alcohol without removing the vestimentiferans from the tubes. The gross morphology of the phyllodocid specimens obtained from the *Alaysia* tubes was observed under a stereomicroscope. The parapodium on the 11th chaetiger was cut for observation under a biological microscope. The phyllodocid specimens are available at JAMSTEC under JAMSTEC No. 2000044404 in the Marine Biological Sample Database (samples available only in Japan).

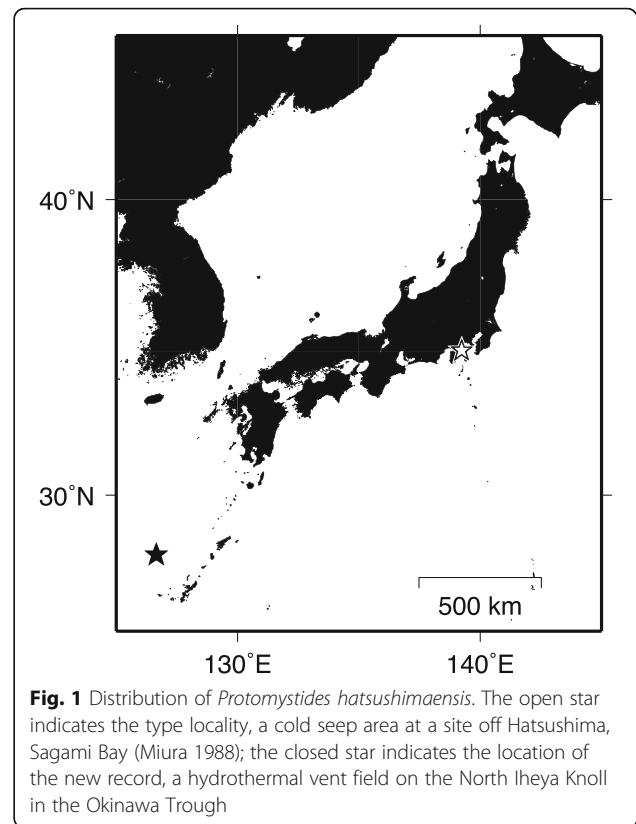


Fig. 1 Distribution of *Protomystides hatsushimaensis*. The open star indicates the type locality, a cold seep area at a site off Hatsushima, Sagami Bay (Miura 1988); the closed star indicates the location of the new record, a hydrothermal vent field on the North Iheya Knoll in the Okinawa Trough

Results

Two phyllodocids were obtained from the inside of 2 of over 30 empty tubes of an *Alaysia* sp., by dissecting the tubes in 2014. They were observed in thin brownish tubes of mucous, probably secreted by phyllodocids, at approximately 30 and 50 mm from the upper openings of the tubes of *Alaysia* sp. (Fig. 2c).

We classified the phyllodocids as *P. hatsushimaensis* (Fig. 2a, b) based on the morphology of the specialized chaetae. Among congeneric species, only *P. hatsushimaensis* and *P. verenae* have very short, aristate-like blades of compound spinigers (Miura, 1988; Blake & Hilbig, 1990). *P. hatsushimaensis* and *P. verenae* were distinguished by the shape of their parapodia, having a single type of spinigers in the former and two types in the latter (Blake & Hilbig, 1990). The trapezoidal shape of the prostomium slightly differed from the original description (hexagonal prostomium) probably because of a variation in the degree of modifications when they were fixed in the tubes.

Discussion

Some studies have suggested that certain species of phyllodocids feed on vestimentiferans. For example, the blood feeding of *G. aristata* on *Riftia pachyptila* Jones, 1981 has been suggested at the 9°N vent site on the East Pacific Rise (Jenkins et al., 2002). However, it was

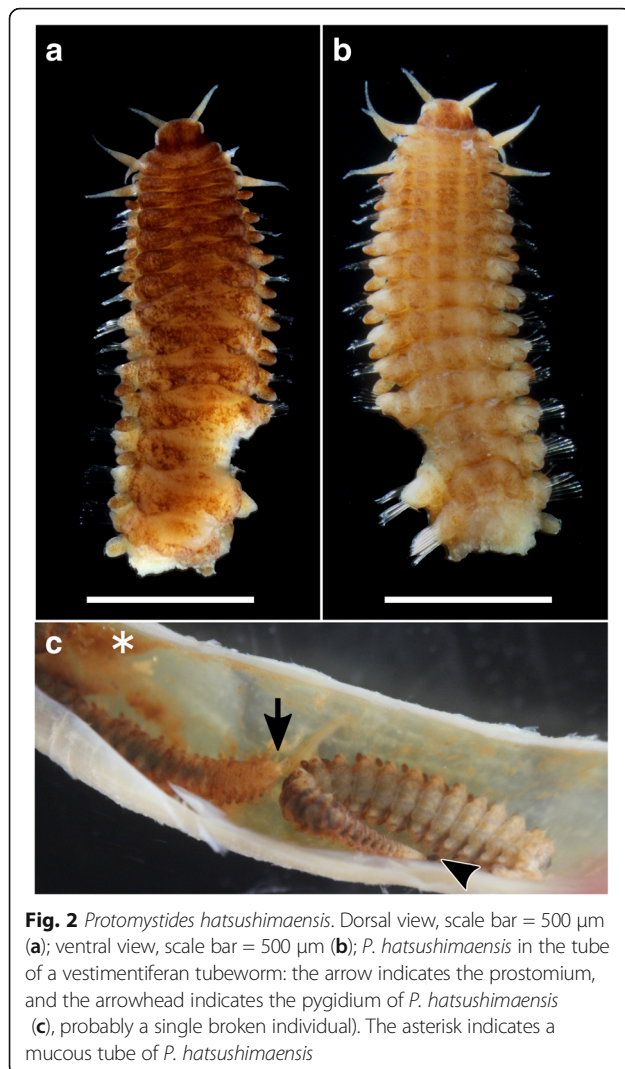


Fig. 2 *Protomystides hatsushimaensis*. Dorsal view, scale bar = 500 μ m (**a**); ventral view, scale bar = 500 μ m (**b**); *P. hatsushimaensis* in the tube of a vestimentiferan tubeworm: the arrow indicates the prostomium, and the arrowhead indicates the pygidium of *P. hatsushimaensis* (**c**), probably a single broken individual). The asterisk indicates a mucous tube of *P. hatsushimaensis*

suggested that *P. hatsushimaensis* utilizes tubes as a habitat because the worms were collected from vacant vestimentiferan tubes. The behavior of occupying tubes constructed by other species appears to be uncommon among annelids, as well as benthic organisms. Indeed, no other organisms were obtained from the inside of more than 30 tubes of *Alaysia* sp., although at least five epifaunal annelid species inhabit vent fields on the North Iheya Knoll (Yamamoto et al., 1999). *Protomystides* sp. in the eastern Pacific has been reported from the dead tubes of the vestimentiferan *Escarpiia laminata* Jones, 1985 (Becker, 2010); therefore, our observation suggests that this occupying behavior may be common among species of *Protomystides*.

Annelid tubes provide small annelids with shelters from predators, waves, and thermal or chemical extremes (Zbinden et al., 2003; Stewart et al., 2004; Vinn & Kupriyanova, 2011). Tube production, however, can be the largest energy expenditure of such organisms:

tube production energy expenditure exceeds that for somatic growth and gamete production in serpulid species (Dixon, 1980). Thus, the occupying behavior of *P. hatsushimaensis* may be advantageous in saving the production energy cost for hard tubes. Physiological and ecological characteristics would provide further insights into the benefits of the occupying behavior of *P. hatsushimaensis*.

Conclusions

Tubes of vestimentiferans provide habitats for other organisms (Desbruyères et al., 2006). This new record of *P. hatsushimaensis* using vestimentiferan tubes as a microhabitat provides a new association between phyllococids and vestimentiferans. This is also the first record of *P. hatsushimaensis* from a hydrothermal vent, providing one of relatively few examples of species inhabiting both seep and vent sites.

Abbreviation

JAMSTEC: Japan Agency for Marine-Earth Science and Technology

Acknowledgements

We are grateful to Tsuyoshi Takano for his valuable comments on the earlier draft. A special note of thanks goes to the crew of the R/V *Natsushima* NT00-08 cruise for their help in sampling materials. We also thank Marika Ichiyanagi, Tohru Iseto, and other staff of JAMSTEC for their support for using phyllococid specimens.

Funding

Not applicable.

Availability of data and materials

The phyllococid specimens are available at JAMSTEC under JAMSTEC No. 2000044404 in the Marine Biological Sample Database (samples available only in Japan).

Authors' contributions

GK examined specimens. GK and SK drafted the manuscript. Both authors gave the final approval for publication.

Ethics approval and consent to participate

All applicable international, national, and/or institutional guidelines for the care and use of organisms were followed. No permissions were required for the collection of invertebrates in the study sites. No experiments concerning live animals were conducted in the present study.

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

Publisher's Note

Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Received: 17 July 2017 Accepted: 12 September 2017

Published online: 20 September 2017

References

- Becker EL. Food web ecology in Gulf of Mexico hydrocarbon seep communities, PhD thesis. Pennsylvania: Pennsylvania State University; 2010.
- Becker EL, Cordes EE, Macko SA, Lee RW, Fisher CR. Using stable isotope compositions of animal tissues to infer trophic interactions in Gulf of Mexico lower slope seep communities. *PLoS One*. 2013;8:e74459.

- Blake, JA. Polychaeta from the vicinity of deep-sea geothermal vents in the eastern Pacific. I. Euprosinidae, Phyllococidae, Hesionidae, Nereididae, Glyceridae, Dorvilleidae, Orbinidae, and Maldanidae. *Bull Biol Soc Wash.* 1985;6:67–101.
- Blake JA, Hilbig B. Polychaeta from the vicinity of deep-sea hydrothermal vents in the eastern Pacific. II. New species and records from the Juan de Fuca and explorer ridge systems. *Pac Sci.* 1990;44:219–53.
- Callaway R. Tube worms promote community change. *Mar Ecol Prog Ser.* 2006;308:49–60.
- Desbruyères D, Segonzac M, Bright M. Handbook of deep-sea hydrothermal vent fauna. 2nd ed. Biologiezentrum: Linz; 2006.
- Dixon DR. The energetics of tube production by *Mercierella enigmatica* (Polychaeta: Serpulidae). *J Mar Biol Assoc UK.* 1980;60:655–9.
- Fujikura K, Hashimoto J, Okutani T. Estimated population densities of megafauna in two chemosynthesis-based communities: a cold seep in Sagami Bay and a hydrothermal vent in the Okinawa trough. *Benthos Res.* 2002;57:21–30.
- Fujikura K, Kojima S, Hashimoto J. Seep and hydrothermal vent communities. In: Fujikura K, Okutani T, Maruyama T, editors. Deep-sea life—biological observations using research submersibles. Kanagawa: Tokai University Press; 2008. p. 57–80. [in Japanese].
- Gallagher ED, Jumars PA, Trueblood DD. Facilitation of soft-bottom benthic succession by tube builders. *Ecology.* 1983;64:1200–16.
- Govenar B, Fisher CR. Experimental evidence of habitat provision by aggregations of *Riftia pachyptila* at hydrothermal vents on the East Pacific Rise. *Mar Ecol.* 2007;28:3–14.
- Govenar B, Freeman M, Bergquist DC, Johnson GA, Fisher CR. Composition of a one-year-old *Riftia pachyptila* community following a clearance experiment: insight to succession patterns at deep-sea hydrothermal vents. *Biol Bull.* 2004;207:177–82.
- Govenar B, Le Bris N, Gollner S, Glanville J, Aperghis AB, Hourdez S, et al. Epifaunal community structure associated with *Riftia pachyptila* aggregations in chemically different hydrothermal vent habitats. *Mar Ecol Prog Ser.* 2005;305:67–77.
- Järnegren J, Tobias CR, Macko SA, Young CM. Egg predation fuels unique species association at deep-sea hydrocarbon seeps. *Biol Bull.* 2005;209:87–93.
- Jenkins CD, Ward ME, Turnipseed M, Osterberg J, Dover CL. The digestive system of the hydrothermal vent polychaete *Galapagomystides aristata* (Phyllococidae): evidence for hematophagy? *Invertebr Biol.* 2002;121:243–54.
- Jones, ML. *Riftia pachyptila*, new genus, new species, the vestimentiferan worm from the Galápagos Rift geothermal vents (Pogonophora). *Proc Biol Soc Wash.* 1981;93:1295–1313.
- Jones, ML. On the Vestimentifera, new phylum: six new species, and other taxa, from hydrothermal vents and elsewhere. *Bull Biol Soc Wash.* 1985;6:117–158.
- Kobayashi, G, Miura, T, Kojima, S. *Lamellibrachia sagami* sp. nov., a new vestimentiferan tubeworm (Annelida: Siboglinidae) from Sagami Bay and several sites in the northwestern Pacific Ocean. *Zootaxa.* 2015;4018:97–108.
- Maldonado M, Young CM. A new species of poecilosclerid sponge (Porifera) from bathyal methane seeps in the Gulf of Mexico. *J Mar Biol Assoc UK.* 1998;78:795–806.
- Martin D, Britayev TA. Symbiotic polychaetes: review of known species. *Oceanogr Mar Biol.* 1998;36:217–340.
- McLean JH. New species and records of *Lepetodrilus* (Vetigastropoda: Lepetodrilidae) from hydrothermal vents. *Veliger.* 1993;36:27–35.
- Miura T. A new species of the genus *Protomystides* (Annelida, Polychaeta) associated with a vestimentiferan worm from the Hatsushima cold-seep site. *Proc Jpn Soc Syst Zool.* 1988;38:10–4.
- Miura T. *Nicomache otai*, new species (Polychaeta: Maldanidae) collected from the Hatsushima cold-seep in Sagami Bay. *Proc Biol Soc Wash.* 1991;104:159–65.
- Miyake H, Hashimoto J, Chikuchishin M, Miura T. Scyphopolyps of *Sanderia malayensis* and *Aurelia aurita* attached to the tubes of vestimentiferan tubeworm (*Lamellibrachia satsuma*) at submarine fumaroles in Kagoshima Bay. *Mar Biotechnol.* 2004;6:S174–8.
- Reise K. Experimental removal of lugworms from marine sand affects small zoobenthos. *Mar Biol.* 1983;74:327–32.
- Sen Gupta BK, Smith LE, Lobegeier MK. Attachment of foraminifera to vestimentiferan tubeworms at cold seeps: refuge from seafloor hypoxia and sulfide toxicity. *Ecol Monogr.* 2007;72:365–82.
- Stewart RJ, Weaver JC, Morse DE, Waite JH. The tube cement of *Phragmatopoma californica*: a solid foam. *J Exp Biol.* 2004;207:4727–34.
- Trueblood DD. Spatial and temporal effects of terebellid polychaete tubes on soft-bottom community structure in Phosphorescent Bay, Puerto Rico. *J Exp Mar Biol Ecol.* 1991;149:139–59.
- Tsurumi M, Tunnicliffe V. Tubeworm-associated communities at hydrothermal vents on the Juan de Fuca Ridge, northeast Pacific. *Deep Sea Res Part 1 Oceanogr Res Pap.* 2003;50:611–29.
- Tunnicliffe V, Southward AJ. Growth and breeding of a primitive stalked barnacle *Leucolepas longa* (Cirripedia: Scalpellomorpha: Eolepadidae: Neolepadinae) inhabiting a volcanic seamount off Papua New Guinea. *J Mar Biol Assoc UK.* 2004;84:121–32.
- Vinn O, Kupriyanova EK. Evolution of a dense outer protective tube layer in serpulids (Polychaeta, Annelida). *Carnets de Géologie-Notebooks on Geology.* 2011;CG2011_L05:137–47.
- Yamamoto T, Kobayashi T, Nakasone K, Nakao S. Chemosynthetic community at North Knoll, Iheya Ridge, Okinawa Trough. *JAMSTEC J Deep Sea Res.* 1999;15:19–24.
- Zbinden M, Le Bris N, Compère P, Martinez I, Guyot F, Gaill F. Mineralogical gradients associated with alvinellids at deep-sea hydrothermal vents. *Deep Sea Res Part 1 Oceanogr Res Pap.* 2003;50:269–80.
- Zühlke R, Blome D, van Bernem KH, Dittmann S. Effects of the tube-building polychaete *Lanice conchilega* (Pallas) on benthic macrofauna and nematodes in an intertidal sandflat. *Senck Marit.* 1998;29:1–6.

Submit your next manuscript to BioMed Central and we will help you at every step:

- We accept pre-submission inquiries
- Our selector tool helps you to find the most relevant journal
- We provide round the clock customer support
- Convenient online submission
- Thorough peer review
- Inclusion in PubMed and all major indexing services
- Maximum visibility for your research

Submit your manuscript at
www.biomedcentral.com/submit

