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First occurrence of ophiuroid-parasitic genus *Ophieulima* (Mollusca: Gastropoda: Eulimidae) in the North Pacific Ocean

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Abstract

A eulimid gastropod of the genus *Ophieulima*, parasitic on the disc of the ophiactid brittle star *Ophiactis dyscrita*, was collected from 256–343 m deep off Kanagawa, central Japan. This represents the first record of the genus from Japanese waters and even from the North Pacific Ocean. Here we describe it as *Ophieulima yoshiharai* n. sp. The generic assignment is justified by its conchological characters including (1) a small, conical shape with convex teleoconch whorls, (2) many fine growth lines and some strong growth pause scars on the teleoconch, (3) a well-developed, twisted columella, and (4) a multispiral, brownish transparent protoconch. *Ophieulima yoshiharai* n. sp. is distinguishable from the three (two named and one undescribed) extant, as well as two fossil congeners by its slender shell with the length of 2.1 times larger than width, a small aperture and a protoconch of 3.5 whorls. The new species is also characterized by its bathymetric distribution, which is shallower than the extant species of *Ophieulima*. On the other hand, the hosts of *Ophieulima* species are so far restricted to ophiuroids of the genus *Ophiactis* and the three named species have mostly been found attached to the lateral and/or dorsal sides of the host's disc, suggesting their similar parasitic ecology.

Introduction

Gastropods of the family Eulimidae (Caenogastropoda: Vanikoroidea) are parasites of all five extant classes of Echinodermata: Asterozoa (sea stars), Crinozoa (feather stars and sea lilies), Echinozoa (sea urchins), Holothurozoa (sea cucumbers), and Ophiurozoa (brittle stars; Warén, 1983a). At least 14 eulimid genera are known to contain ophiuroid-parasitic species. These genera include *Ersilia* Monterosato, 1872, *Eulima* Risso, 1826, *Fuscipex* Warén, 1981, *Fusculimoides* Takano, Kano, Mogi and Okanishi, 2023, *Hemiliostraca* Pilsbry, 1917, *Mucronalia* A. Adams, 1860, *Ophieulima* Warén and Sibuet, 1981, *Ophioarachnicola* Warén, 1980, *Ophiolamia* Warén and Carney, 1981, *Punctifera* Warén, 1981, *Pyramidelloides* G. Nevill, 1885, *Sticteulima* Laseron, 1955, *Stilapex* Iredale, 1925, and *Vitreolina* Monterosato, 1884 (Warén, 1980, 1981, 1983a, 1983b; Bouchet and Warén, 1986; Dgebuadze, 2014; Takano *et al.*, 2023).

The genus *Ophieulima* consists of parasites of deep-sea ophiuroids (Warén and Sibuet, 1981). Only two named and one undescribed species have been reported from bathyal depths as extant taxa (Warén, 1981; Warén and Sibuet, 1981). The type species, *Ophieulima minima* (Dall, 1927), inhabits the Atlantic Ocean and Mediterranean, 452–2140 m deep, parasitizing *Ophiactis abyssicola* (M. Sars, 1861) of Ophiactidae (Warén and Sibuet, 1981; Bouchet and Warén, 1986; Hoffman *et al.*, 2011; Romani *et al.*, 2014; Souza *et al.*, 2021). Its shell is characterized by (1) a conical shape with convex teleoconch whorls, (2) a length of up to 3 mm, (3) many fine growth lines and up to two strong growth pause scars on the teleoconch, (4) a solid and twisted columella, (5) a sculpture of oblique incised line segments, and (6) a brownish transparent protoconch with *ca.* 3 whorls (Warén and Sibuet, 1981; Romani *et al.*, 2014; Souza *et al.*, 2021; but see Remarks below). Other notable characters of the species include the lack of pigmented eyes and the radula (a tongue-like feeding apparatus of the Mollusca), presence of the operculum, separate sexes, and sexual dimorphism with the female of 2.5–3 mm in shell length and the male of 1–1.5 mm (Warén and Sibuet, 1981; but see O'Reilly, 2016: figure 24 for the presence of pigmented eyes).

Another extant species, *Ophieulima fuscoapicata* Warén, 1981, was reported from off Kermadec Islands of New Zealand, 1189–1225 m deep, parasitizing *Ophiactis profundis* Lütken and Mortensen, 1899 (Warén, 1981). *Ophieulima fuscoapicata* morphologically resembles to the type species but differs in having a smaller aperture and irregular spiral sculpture of the shell, and a protoconch of 3.9 whorls (Warén, 1981). In addition, an undescribed species has been known from off Gabo Is., Victoria, Australia, 400–438 m deep, without host information (Warén, 1981). This species is seemingly characterized by a relatively small aperture (Warén, 1981).

Two fossil species were also described under this genus. *Ophieulima antecessor* Lozouet, 1999 was reported from the Upper Oligocene deposits of Aquitaine, southwestern France (Lozouet, 1999). Its shell is characterized by a more globose outline than the three extant



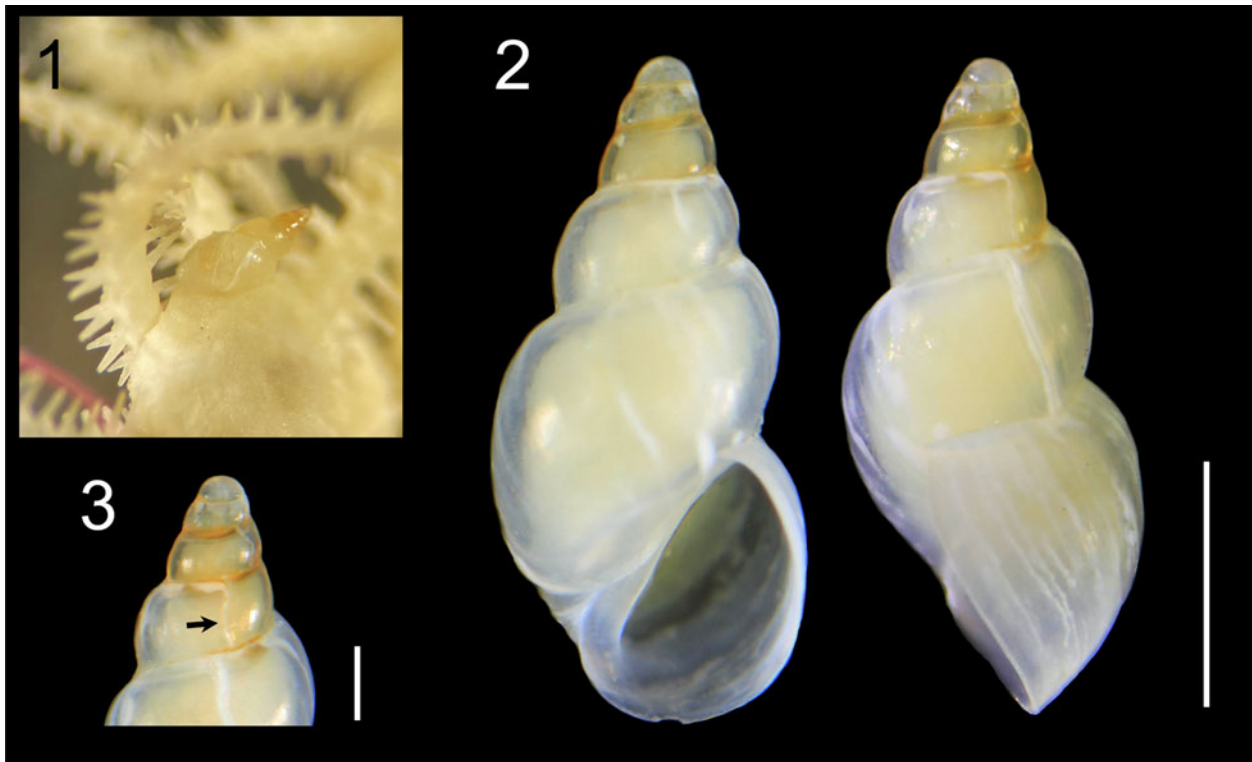


Figure 1–3. *Ophieulima yoshiharai* n. sp.: (1) holotype NSMT-Mo 79481 *in situ* on host brittle star *Ophiactis dyscrita*; (2) holotype, apertural and lateral views; (3) close-up view of protoconch. Arrow denotes demarcation line between protoconch and teleoconch. Distinct scar exists at 2.3 whorls from apex or 1.2 whorls from demarcation line. Scale bars: (2) 500 µm; (3) 200 µm.

taxa, 2.45 mm in length and 1.65 mm in width, a large, inflated body (ultimate) whorl, and a protoconch of only two whorls (Lozouet, 1999). The other fossil species, *Ophieulima lobilloensis* Landau and Mulder, 2022, was described from the Lower Piacenzian (upper Pliocene) deposits of Estepona, southwestern Spain (Landau and Mulder, 2022). This species possesses an elongate ovate shell of 1.4 mm in length and 0.82 mm in width, with a large, pyriform aperture occupying 50% of total length and a pupiform protoconch of >2.5 whorls (Landau and Mulder, 2022).

Here, we describe *Ophieulima yoshiharai* n. sp. as a new extant species of the genus from central Japan, parasitic on *Ophiactis dyscrita* H. L. Clark, 1911. This is the first record of the genus from Japanese waters and even from the North Pacific Ocean.

Materials and methods

Six individuals of the brittle star *Ophiactis dyscrita* were collected from off Jogashima Is., Miura, Kanagawa, Japan (256–343 m deep; *R/V Rinkai-Maru* St. 2) on 24 June 2010 using a 0.5 m biological dredge. A parasitic snail of Eulimidae was found on one of the six brittle stars, attaching to the lateral side of the disc (Figure 1); the snail and host were directly preserved in 99% ethanol. The preserved specimens were observed and identified under a stereoscopic microscope by referring to previous taxonomic studies (Warén, 1981, 1983a; Warén and Sibuet, 1981 for snail, and Clark, 1911; Matsumoto, 1917 for brittle star). Unfortunately, tissue clipping for molecular works was impossible without breaking the shell for the present snail specimen. Voucher material was deposited in the National Museum of Nature and Science, Tokyo (NSMT).

Results

The newly collected snail was identified as a species of *Ophieulima* based on its conchological characters including (1)

a small, conical shape with convex teleoconch whorls, (2) many fine growth lines and some strong growth pause scars on the teleoconch, (3) a well-developed, twisted columella, and (4) a multispiral, brownish transparent protoconch (Figures 2, 3; see Warén and Sibuet, 1981). We describe it as *Ophieulima yoshiharai* n. sp.

Superfamily Vanikoroidea Gray, 1840
Family Eulimidae Philippi, 1853
Genus *Ophieulima* Warén and Sibuet, 1981
Ophieulima yoshiharai n. sp.

(Figures 1–3)

<http://zoobank.org/AF229D6A-AAE1-4F6D-9FC8-F0A2A07B4880>

Type specimen

Holotype NSMT-Mo 79481, found attached to lateral side of host's disc, preserved in 99% ethanol together with host ophiuroid.

Type locality

Off Jogashima Is., Miura, Kanagawa, Japan (35°07.12–07.28' N, 139°33.72–33.21' E; 256–343 m deep), sandy bottom.

Type host

Ophiactis dyscrita H. L. Clark, 1911 (Echinodermata: Ophiuroidea: Amphilepidida: Ophiactidae).

Etymology

After Mr. Toshiyuki Yoshihara, the owner of the Meguro Beer Pub SCENT, who continuously encouraged the study of the first author.

Table 1. Morphological and ecological features of extant *Ophieulima* species, referred by Warén (1981), Warén and Sibuet (1981), Hoffman *et al.* (2011), Romani *et al.* (2014), O'Reilly (2016) and Souza *et al.* (2021)

	<i>O. yoshiharai</i> n. sp.	<i>O. minima</i> (type)	<i>O. fuscoapicata</i>	<i>Ophieulima</i> sp.
Shell length	1.57 mm	1–3 mm	2.22 mm	2.48 mm
Shell width	0.73 mm	1.0–1.5 mm*	1.28 mm	1.28 mm*
Shell length/ width ratio	2.1	1.5–1.9*	1.7	1.9*
Protoconch whorls	3.5	2.7–3.7?*	3.9	NA
Exposed part of protoconch	480 µm	380–430 µm	560 µm*	NA
Aperture height	0.62 mm	0.78–1.04 mm*	1.02 mm	0.98 mm*
Aperture width	0.51 mm	0.6–1.03 mm*	0.70 mm	0.69 mm*
Pigmented eyes	Present	Present?	Present	NA
Geographic distribution	Japan	Atlantic Ocean, Mediterranean	New Zealand	Australia
Habitat depth	256–343 m	452–2140 m	1189–1225 m	400–438 m
Host	<i>Ophiactis dyscrita</i>	<i>Ophiactis abyssicola</i>	<i>Ophiactis profundi</i>	NA
Infection site	Lateral side of disc	Lateral and dorsal sides of disc; arm	Dorsal side of disc	NA
Figures	This study: Figures 1–3	Warén and Sibuet, 1981: figures 1–5; Hoffman <i>et al.</i> , 2011: figures 45, 46; Romani <i>et al.</i> , 2014: figure 1; O'Reilly, 2016: figure 24; Souza <i>et al.</i> , 2021: figure 19	Warén, 1981: figure 1B, E	Warén, 1981: figure 1C, F

*Including values measured by authors from figures in previous studies.

Diagnosis

Ophieulima species with a slender shell with its length 2.1 times larger than width. Body whorl and shell aperture small for genus, occupying 70% and 39% of total length, respectively. Protoconch multispiral with 3.5 whorls.

Description

Holotype NSMT-Mo 79481: Shell minute, 1.57 mm high, 0.73 mm wide, white translucent, thin but not fragile, conical with 5.6 whorls (Figure 2). Protoconch conical, multispiral, brownish transparent with 3.5 whorls; a distinct scar present at 2.3 whorls from apex; exposed whorls 480 µm high, slightly convex, smooth (Figure 3). Teleoconch whorls 2.1, bearing many fine growth lines and slightly curved, irregularly spaced strong growth pause scars, which are situated at 0.1, 0.6, 0.8, 0.9, 1.2 and 1.7 whorls from demarcation line between teleoconch and protoconch. Body whorl occupies 70% of total shell height. Aperture wide, semicircular, 0.62 mm in height and 0.51 mm in width; outer lip simple, prosocline, arched in lateral view, with its most protruding part at 1/4 of aperture height from suture (Figure 2); parietal wall and columellar lip join in a straight line; columellar callus well developed, twisted, extended outward near round base. Operculum yellowish transparent, thin. Pigmented eyes present.

Remarks

Table 1 summarizes morphological and ecological differences among extant *Ophieulima* species. *Ophieulima yoshiharai* n. sp. has the slenderest shell among them, with the length of 2.1 times larger than width. Shell length/width ratio ranges 1.5–1.9 in the other known extant species including the type species *O. minima*. The new species has a protoconch of 3.5 whorls, which is more coiled than that of the type species (2.7–3 whorls according to previous studies) and less than *O. fuscoapicata* (3.9 whorls). However,

it should be noted that the protoconch of *O. minima* apparently has up to 3.7 whorls (see Souza *et al.*, 2021: figure 19F, G). As in the present new species, one or two distinct scars, which might be confused with the demarcation line between the protoconch and teleoconch, exist on the protoconch at 0.8–1.2 whorls from the demarcation line. Further verification is required for the protoconch morphology of *O. minima*. The presence or absence of pigmented eyes might exist within the genus. Warén and Sibuet (1981) noted that 'no eyes can be seen' in *O. minima*, whereas this may be attributable to damage by long-term storage. Two pigmented eyes are visible through the shell in O'Reilly's (2016: figure 24) fresh material. Pigmented eyes are also present in *O. yoshiharai* n. sp. and *O. fuscoapicata*.

The extant species of *Ophieulima* also have different geographical and bathymetric distributions. The type species habitats 450–2100 m deep in the Atlantic Ocean. The two Pacific species have been recorded around 1200 m of Kermadec Islands and 420 m of Australia, respectively (Table 1). *Ophieulima yoshiharai* n. sp., collected from 256 to 343 m in this study, thus represents the shallowest record of the genus. On the other hand, the hosts of *Ophieulima* species have so far been restricted to ophiuroids of the ophiactid genus *Ophiactis* (Table 1). The three named species have mostly been found attached to the lateral and/or dorsal sides of the host's disc (Warén, 1981; Warén and Sibuet, 1981; Bouchet and Warén, 1986; but see O'Reilly, 2016: table 6), suggesting their similar parasitic ecology.

Ophieulima yoshiharai n. sp. is easily distinguished from the two fossil species. *Ophieulima antecessor* has a much more globose shell with a protoconch of only 2 whorls (Lozouet, 1999). Its paucispiral protoconch infers this fossil species is phylogenetically distinct from, or even totally unrelated to, the extant species of the genus. *Ophieulima lobilloensis* differs from the new species in having an elongate ovate profile of the shell and a large, pyriform aperture occupying 50% of total shell length (Landau and Mulder, 2022).

Discussion

In this study we reported the eulimid genus *Ophieulima* from the North Pacific Ocean for the first time and described *O. yoshiharai* n. sp. as the third extant species of the genus. Given a few previous occurrence records (Warén, 1981; Warén and Sibuet, 1981; Bouchet and Warén, 1986; Hoffman *et al.*, 2011; Romani *et al.*, 2014; O'Reilly, 2016; Souza *et al.*, 2021) and low prevalence (1.4% for *O. minima*; see O'Reilly, 2016), the species of *Ophieulima* are rare, while the genus possibly has a global distribution. Their minute sizes and deep-sea habitats may have also been making it difficult to discover *Ophieulima* species.

Morphological and ecological traits do not provide a clear suggestion for the phylogenetic position of *Ophieulima*. Warén (1983a) has proposed a systematic hypothesis that eulimid species in closely related genera parasitise echinoderms of a single class. Molecular phylogenetic study of Eulimidae have confirmed that the host's class rather than shell shape tends to reflect intrafamilial relationships (Takano and Kano, 2014; Takano and Goto, 2021). However, ophiuroid-parasitic species were recovered as polyphyletic groups with *Fusceulimoides* distantly related to *Eulima* + *Hemiliostraca* + *Pyramidelloides* (Takano and Goto, 2021; Takano *et al.*, 2023). Species of *Eulima*, *Hemiliostraca*, and *Pyramidelloides* have a brownish protoconch, whereas the protoconch of *Fusceulimoides* is white (Warén, 1983a, 1983b; Takano *et al.*, 2023; T. Takano, pers. obs.). The presence of a brownish protoconch is a possible synapomorphy for the former three genera and *Ophieulima*, suggesting their close phylogenetic kinships.

The presence or absence of the radula also accords well with the eulimid phylogeny (Takano and Kano, 2014). All radula-less species analysed so far have been recovered as a robust clade, except for species of the highly modified endoparasitic genus *Asterophila* Randall and Heath, 1912 (Takano and Kano, 2014; Takano and Goto, 2021). *Asterophila* was found to be sister to the radula-bearing genus *Niso* Risso, 1826 (see Warén, 1983a), indicating the radula has been lost multiple times in the evolutionary history of Eulimidae (Takano and Goto, 2021). Among ophiuroid-parasitic eulimids above, species of *Eulima*, *Hemiliostraca*, and *Pyramidelloides* possess the radula (Warén, 1983a; 1983b). The anatomy of *Fusceulimoides* has not been investigated, while this genus is nested in the radula-less clade and thus probably lacks the radula (Takano *et al.*, 2023). In this view, the absence of the radula in the type species *O. minima* (Warén and Sibuet, 1981) suggests its close affinity to *Fusceulimoides*. Other radula-less genera parasitic to ophiuroids include *Stilapex* and *Vitreolina* (Warén, 1983a); Bouchet and Warén (1986) pointed a conchological similarity between *Ophieulima* and *Stilapex*. As discussed above, *Ophieulima* may be closely related to *Eulima*, *Hemiliostraca*, and *Pyramidelloides* and in that case the absence of the radula is an apomorphic condition of *Ophieulima*. Molecular phylogenetic analysis might answer this complicated systematic issue.

Data availability. The data supporting the findings of this study are available within the article.

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Author contributions. TT conducted morphological observation of the new species and prepared the manuscript. HK and MO collected the specimens,

identified the host ophiuroid, revised drafts, and gave final approval for publication.

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