

**A new species of *Rhodinicola* (Copepoda: Clausiidae), parasitic copepod of the shell-boring polychaete *Polydora brevipalpa* (Annelida: Spionidae) from the Sea of Japan**

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**ABSTRACT:** The new clausiid copepod *Rhodinicola polydora* sp.n. is an ectoparasite of a spionid polychaete *Polydora brevipalpa* Zachs, 1933 in Peter the Great Bay of the Sea of Japan (East Sea). The host polychaete bores into shells of the Yesso scallop *Mizuhopecten yessoensis* (Jay, 1857). This is the first report of annelidicolous copepods from the Sea of Japan (East Sea) and the first description of a copepod parasitic on spionid polychaetes from Asia.

**KEY WORDS:** clausiid copepod, annelidicolous parasite, adult morphology.

**Новый вид копеподы *Rhodinicola* (Copepoda: Clausiidae), паразитирующей на сверлящей полихете *Polydora brevipalpa* (Annelida: Spionidae) в Японском море**

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**РЕЗЮМЕ:** Новый вид копепод клаузиид *Rhodinicola polydora* sp.n. паразитирует на полихете спиониде *Polydora brevipalpa* Zachs, 1933 в заливе Петра Великого Японского моря. Полихета-хозяин — сверлильщик раковин приморского гребешка *Mizuhopecten yessoensis* (Jay, 1857). Это первое сообщение о копеподах, паразитирующих на полихетах в Японском море, и первое описание копепод, паразитирующих на полихетах спиониде в прибрежных водах Азии.

**КЛЮЧЕВЫЕ СЛОВА:** копеподы, полихеты, паразитизм, морфология.

## Introduction

Copepods exhibit diverse modes of life; they are primarily free-living but have evolved symbiotic relationships with many marine organisms. They are known to utilize as hosts virtually every metazoan phylum (Boxshall, Halsey, 2004; Gotto, 2004). More than 120 species of Copepoda are associated with annelids and most of these are either external or internal parasites of polychaetes (Humes, 1994; Boxshall, Halsey, 2004; Gotto, 2004). The annelid associates, collectively called annelidicolous copepods, have been placed in 17 families of copepods: Bradophilidae Marchenkov, 2002, Clausidiidae Embleton, 1901, Clausiidae Giesbrecht, 1895, Entobiidae Ho, 1984, Eunicolidae Sars, 1918, Gastrodelpyidae List, 1889, Herpyllobiidae Hansen, 1892, Lichomolgidae Kossmann, 1877, Saccopsidae Lützen, 1964, Monstrillidae Dana, 1849, Nereicolidae Claus, 1875, Phyllodicolidae Delamare-Deboutteville et Laubier, 1961, Pseudanthessiidae Humes et Stock, 1972, Sabelliphilidae Gurney, 1927, Serpulidicolidae Stock, 1979, Spiophanicolidae Ho, 1984, and Xenocoelomatidae Bresciani et Lützen, 1966. Besides annelid symbionts, these families also contain free-living members and/or associates of other invertebrates, thus symbiotic relationships with polychaetes might have evolved independently from various copepod ancestors. Annelidicolous copepods are usually associated with a specific host but some occur on more than one host species (see Gotto, 2004: Host-Associate List). Polychaetes hosting copepods belong to families Acoetidae Kinberg, 1856 (including Polyodontidae Augener, 1918), Ampharetidae Malmgren, 1866, Amphinomidae Savigny in Lamarck, 1818, Capitellidae Grube, 1862, Eunicidae Berthold, 1827, Flabelligeridae de Saint-Joseph, 1894, Maldanidae Malmgren, 1867, Nereididae Johnston, 1865, Opheliidae Malmgren, 1867, Phyllodocidae Örsted, 1843, Polynoidae Malmgren, 1867, Sabellidae Latreille, 1825 (including Serpulidae Rafinesque, 1815), Siboglinidae Caullery, 1914, Spionidae Grube, 1850, Syllidae Grube, 1850, and Terebel-

lidae Malmgren, 1867 (including Trichobran- chidae Malmgren, 1866).

The copepod family Clausiidae includes mainly ectoparasites of maldanid and spionid polychaetes living in diverse habitats worldwide. Ho and Kim (2003) provided the first phylogenetic analysis of 20 species of Clausiidae based on 28 morphological characters, all from the thoracic legs. The resulting cladograms suggested inclusive relationships among six groups of species, *Pontoclausia* (*Likroclausia* (*Rhodinicola* (*Mesnilia* (*Clausia* (*Pseudoclausia*)))) which did not correspond exactly to the genera recognized at that time (Ho, Kim, 2003: Fig. 8). Based on these results, the authors established a new genus *Likroclausia* Ho et Kim, 2003 and suggested that the *Clausia* Claparède, 1863, *Mesnilia* Canu, 1898, *Pontoclausia* Băcescu et Por, 1959, *Pseudoclausia* Bocquet et Stock, 1960, and *Rhodinicola* Levinson, 1878 should be treated as valid genera in the Clausiidae, while the taxonomical status of the genera *Indoclausia* Sebastian & Pillai, 1974, *Megaclausia* O'Reilly, 1995, *Pherma* Wilson C.B., 1923, and *Seridium* Giesbrecht, 1895 remains uncertain. Since then, a new genus *Spionicola* was established by Björnberg and Radashevsky (2009) to accommodate a new species from Brazil, *S. mystaceus* Björnberg et Radashevsky, 2009.

In the Asian Pacific, nine species of copepods from the families Clausidiidae, Clausiidae and Sabelliphilidae have been described as ectoparasitic on the adult polychaetes from the families Arenicolidae, Capitellidae, Nereididae, Sabellidae and Terebellidae from the coastal waters of the Korea Strait and the Yellow Sea in Korea (Ho, Kim, 1990, 2003; Kim, Ho, 1992; Kim, 1998, 2000, 2001a,b,c). Unidentified copepods endoparasitic in the adults of *Polydorella* Augener, 1914 (Spionidae) were reported from the South China Sea, Vietnam (Radashevsky, 1996) and Philippines (Williams, 2004).

During a study of the spionid polychaetes in the Sea of Japan (East Sea), one pair of endoparasitic copepods were found in adult *Dipolydora trilobata* Radashevsky, 1993 that was boring into shells of the Pacific oyster *Crassostrea*

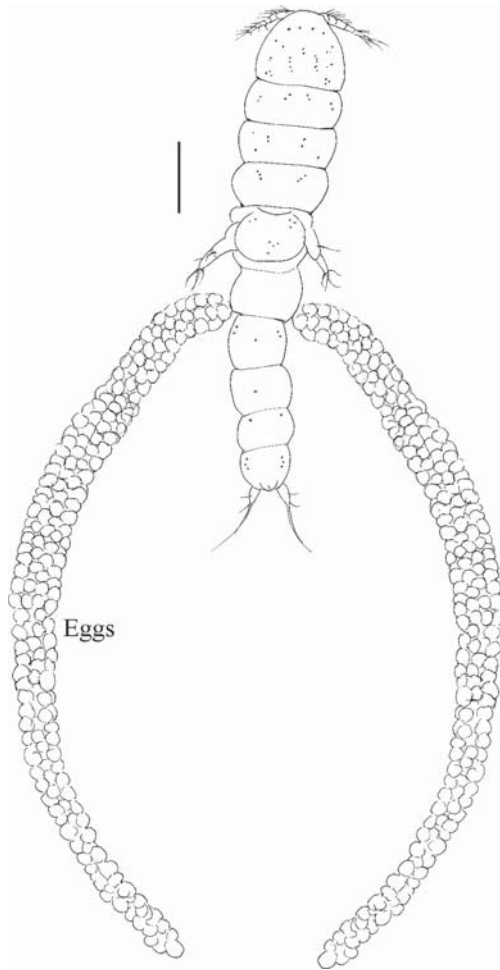


Fig. 1. *Rhodinicola polydorae* sp.n. Female morphology. Dorsal view, with egg strings (Eggs). Scale bar: 0.5 mm.

Рис. 1. *Rhodinicola polydorae* sp.n. Самка. Вид со спинной стороны, с кладкой яиц (Eggs). Масштаб: 0,5 мм

*gigas* Thunberg, 1793, one pair of ectoparasitic copepods was found on adult *Boccardiella hamata* (Webster, 1879) boring into shells of the Yesso scallop *Mizuhopecten yessoensis* (Jay, 1857), and numerous ectoparasitic copepods of another species were found on adults of *Polydora brevipalpa* Zachs, 1933, obligate borer of the Yesso scallop *M. yessoensis* (see Radashevsky, 1993). The morphology of the latter copepods is described and illustrated in the present paper.

This is the first report of annelidicolous copepods in the Sea of Japan (East Sea) and the first description of a copepod parasitic on spionid polychaetes in Asia (see Table 1).

### Material and methods

Field collections were made in Vostok Bay (part of the larger Peter the Great Bay) of the Sea of Japan (East Sea) intertidally and in shallow water using SCUBA from 2000 through 2011. Samples were processed at the *Vostok* Marine Biological Station of the Institute of Marine Biology. Sediment samples were sieved with 0.5 mm mesh sieve; mollusc shells were broken with hammer and pliers. Adults of more than 30 species of spionid polychaetes living in temporary mucous and permanent silty tubes, boring into sponges and shells of various mollusks were examined alive with a microscope to separate parasitic copepods. Numerous ectoparasitic copepods found on *Polydora brevipalpa* boring in shells of the Yesso scallop *M. yessoensis* were detached from the worms, fixed in 10% formalin solution, rinsed in fresh water, and transferred to 70% ethanol. For examination, entire copepods and divided parts were cleared in lactic acid and mounted on slides with glycerin. Drawings were made using a camera lucida; photographs were taken using a digital camera at the Center of Marine Biology, University of São Paulo. Fixed specimens were deposited at the Museum of the Institute of Marine Biology, Vladivostok, Russia (MIMB) and the Zoological Museum of the University of São Paulo, São Paulo, Brazil (MZUSP).

### Results

Copepoda Milne-Edwards, 1840  
 Clausiidae Giesbrecht, 1895  
*Rhodinicola* Levinsen, 1878

*Rhodinicola polydorae* sp.n.  
 Figs 1–6.

MATERIAL. RUSSIA, Sea of Japan, Vostok Bay of Peter the Great Bay: 42°53.6'N, 132°44'E, from spionid polychaete *Polydora brevipalpa* boring in shells of Yesso

Table 1. List of spionid polychaetes hosting parasitic copepods.  
 Таблица 1. Список полихет спионид, на которых обнаружены паразитические копеподы.

Host Spionidae	Parasitic Copepoda	Association	Locality	Reference
<i>Boccardiella hamata</i> (Webster, 1879)	Copepoda	ectoparasite	Sea of Japan, Russia	present study
<i>Dipolydora armata</i> (Langerhans, 1880)	<i>Spionicola mystaceus</i> Björnberg & Radashevsky, 2009 (Clausiidae)	ectoparasite	São Paulo, Brazil	Björnberg & Radashevsky, 2009
<i>Dipolydora flava</i> (Claparède, 1870)	<i>Mesnilia cluthae</i> (T. & A. Scott, 1896); <i>Mesnilia martinensis</i> Canu, 1898 (Clausiidae)	ectoparasite	La Manche, France	Bocquet & Stock, 1959
<i>Dipolydora trilobata</i> Radashevsky, 1993	Copepoda	endoparasite	Sea of Japan, Russia	present study
<i>Polydora brevipalpa</i> Zachs, 1933	<i>Rhodinicola polydora</i> sp.n. (Clausiidae)	ectoparasite	Sea of Japan, Russia	present study
<i>Polydora ciliata</i> (Johnston, 1838)	<i>Mesnilia cluthae</i> (T. & A. Scott, 1896) (Clausiidae)	ectoparasite	La Manche, France	Bocquet & Stock, 1959
<i>Polydorella dawydoffi</i> Radashevsky, 1996	Copepoda	endoparasite	South China Sea, Vietnam	Radashevsky, 1996
<i>Polydorella stolonifera</i> (Blake & Kudenov, 1978)	Copepoda	endoparasite	Philippines	Williams, 2004
<i>Spiophanes berkeleyorum</i> Pettibone, 1962	<i>Spiophanicola spinulosus</i> Ho, 1984 (Spiophanicolidae)	ectoparasite	California, USA	Ho, 1984
<i>Spiophanes kroyeri</i> Grube, 1860	<i>Spiophanicola spinulosus</i> Ho, 1984 (Spiophanicolidae)	ectoparasite	California, USA	Ho, 1984
<i>Spiophanes missionensis</i> Hartman, 1941	<i>Spiophanicola spinulosus</i> Ho, 1984 (Spiophanicolidae)	ectoparasite	California, USA	Ho, 1984

scallop *Mizuhopecten yessoensis*, 3–10 m depth, coll. V.I. Radashevsky, 8 Apr 2009: MIMB 26496 (**holotype**: female), MZUSP 24448 (**allotype**: male), MIMB 26498 (1 paratype: female), MZUSP 24447 (2 paratypes: females); 6 Oct 2007: MIMB 26497 (paratype: female with egg strings); 12 Dec 2010: MIMB 26499 (19 paratypes: 17 females + 2 males); 27 Apr 2011: MIMB 26500 (19 paratypes: 15 females with egg strings + 4 males).

**FEMALES** (Figs. 1–4, 6A, B). Body elongate, 10-segmented, broader anteriorly, 0.53–0.82 mm wide on widest cephalosome and second somite, 1.9–3.5 mm long from anterior margin of rostrum to end of caudal rami (setae excluded). Cephalothorax subtriangular. Pedigerous somites short; each about twice wider than long. Urosomites each about 1.5 times wider than long. Caudal rami twice longer than wide, with four short and one long terminal

setae distinctly longer than caudal ramus. Pores, each with a sensillum, scattered over dorsal part of body. Anal pseudopericulum small, rounded posteriorly.

Rostrum (Figs. 2B, 3A) small, dorsally weakly defined, wider than long. Antennule (Fig. 2C) 6-segmented, tapering gradually, shorter than cephalosome, setal formula: 5, 7, 10, 5, 2 + aesthetasc, 8 with setiform aesthetascs on the second, third, fifth and sixth segments. All setae naked. Antenna (Fig. 2D) 3-segmented, coxa with wide patch of spinules and one distal seta; second and third segments with spinules; third segment also bearing lateral row of setules, two inner short setae, two long outer setae and row of four terminal claws increasing in length from



Fig. 2. *Rhodinicola polydorae* sp.n. Female morphology.

A — ventral view, right third leg omitted, showing antennule (An1), antenna (An2), caudal rami (Ca), and Leg V (L5); B — left lateral view; C — antennule; D — antenna. Scale bars: A, B — 0.5 mm, C, D — 0.1 mm.

Рис. 2. *Rhodinicola polydorae* sp.n. Самка.

A — вид с брюшной стороны, третья правая конечность не показана; антеннула (An1), антенна (An2), хвостовые придатки (Ca), ножка V (L5); B — вид слева; C — антеннула; D — антенна. Масштаб: A, B — 0,5 мм, C, D — 0,1 мм.

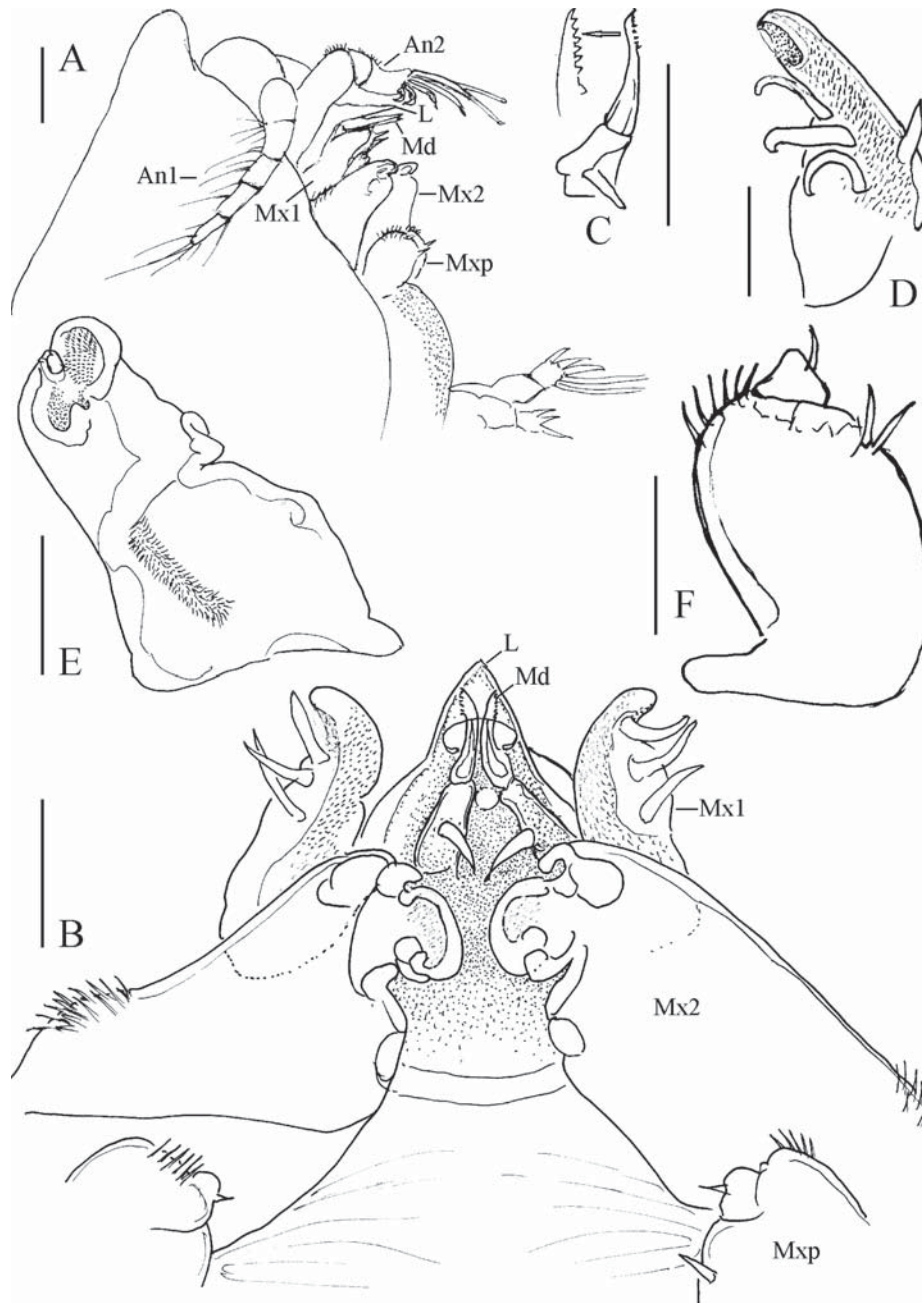


Fig. 3. *Rhodinicola polydoraе* sp.n. Female morphology.

A — right lateral view of mouth region, showing antennule (An1), antenna (An2), labrum (L), mandible (Md), maxillule (Mx1), maxilla (Mx2), and maxilliped (Mxp); B — ventral view of mouth region; C — mandible; D — maxillule; E — maxilla; F — maxilliped. Scale bars: A — 0.1 mm, B–F — 0.05 mm.

Рис. 3. *Rhodinicola polydoraе* sp.n. Самка.

A — ротовая область, вид справа; антеннула (An1), антенна (An2), верхняя губа (L), мандибула (Md), максиллула (Mx1), максилла (Mx2), максиллипед (Mxp); B — ротовая область, вид с брюшной стороны; C — мандибула; D — максиллула; E — максилла; F — максиллипед. Масштаб: A — 0,1 мм, B–F — 0,05 мм.

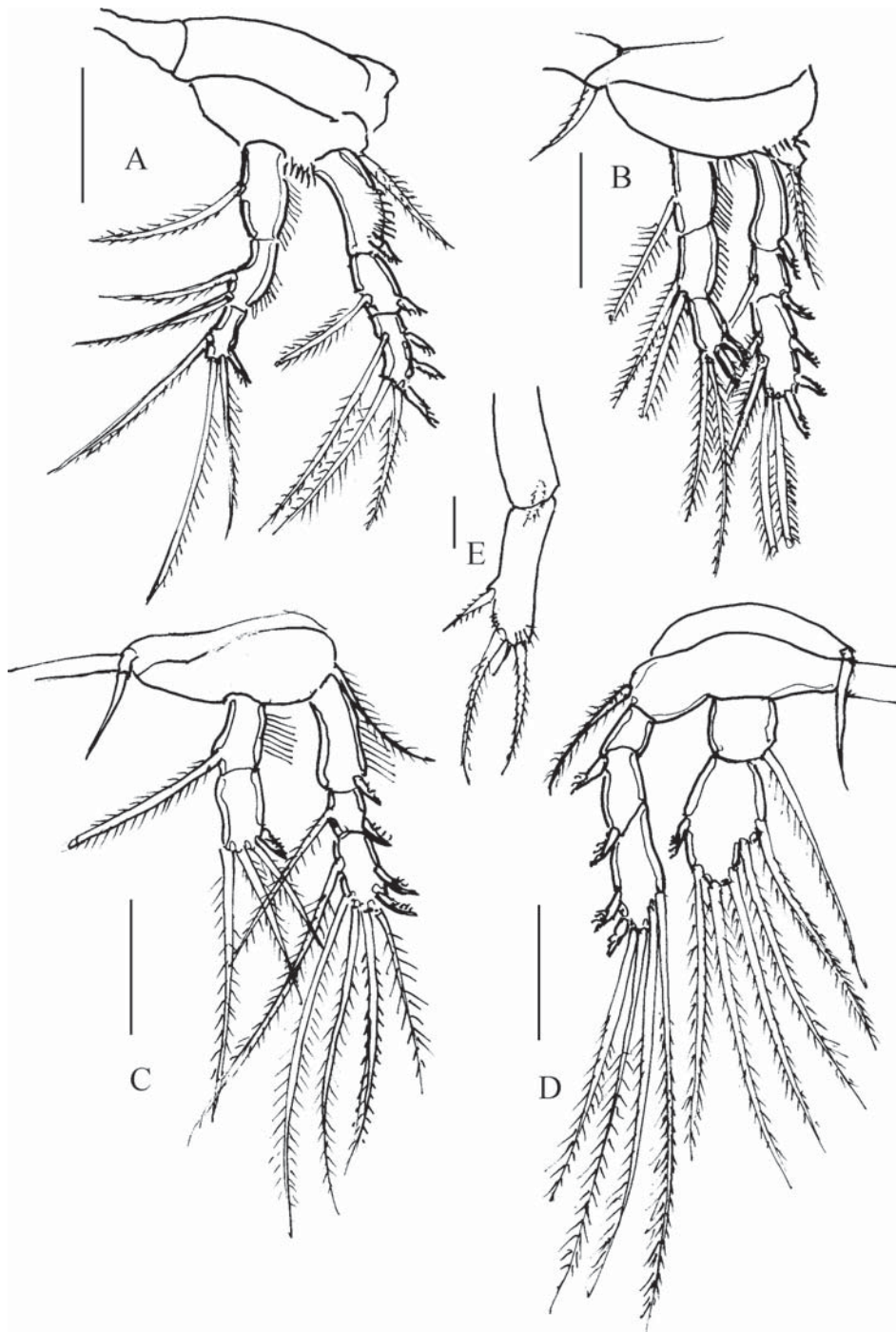


Fig. 4. *Rhodinicola polydorae* sp.n. Female morphology.

A — Leg I; B — Leg II; C — Leg III; D — Leg IV; E — Leg V. Scale bars: A–E — 0.1 mm.

Рис. 4. *Rhodinicola polydorae* sp.n. Самка.

A — ножка I; B — ножка II; C — ножка III; D — ножка IV; E — ножка V. Масштаб: A–E — 0,1 мм.

inner towards outer side. Labrum transparent, triangular, pointed, hardly visible (Fig. 3A, B), covering distal part of mandible. Mandible (Fig. 3C) with one distal and one lateral spine; distal spine armed with several teeth distally. Maxillule (Fig. 3D) small, tapering slightly distally, bearing three outer and one inner setae with long patch of minute spinules. Maxilla (Fig. 3E) largest oral appendage, 2-segmented, cone-shaped, with outer strip of setules and distal cushion-like pad bearing setules. Maxilliped (Fig. 3F) small, oval and 2-segmented; proximal segment with patch of spinules distally and two larger medial spines; subtriangular endopod tipped by one small spine.

Legs 1 to 4 (Fig. 4A–D) biramous; first and second legs with 3-segmented exopods and endopods; third and fourth legs with 3-segmented exopods and 2-segmented endopods. Marginal rows of strong spinules present on first exopodal segment and first two endopodal segments of leg 1. Formula of spines and setae on these legs as follows:

	Coxa	Basis	Exopod	Endopod
Leg 1:	0	1	I, 0–I, 1–III, 1, 2	0 1–0–I, 2, 1
Leg 2:	1	1	I, 0–I, 1–III, 2, 2	0 1–0 2–I, 1, 2
Leg 3:	1	1	I, 0–I, 1–II, 2, 3	0 1–I, 2, 1
Leg 4:	1	1	I, 0–I, 0–II, 2, 2	0 1–I, 2, 3

Leg 5 uniramous, 2-segmented, large and laterally projecting (Fig. 4E): proximal segment with one dorsal seta; distal segment with one lateral spine, two terminal long setae and one thin small seta.

Leg 6 represented by one minute seta on egg attachment area.

**MALES** (Fig. 5). Slender and about half as small as females, 0.34–0.44 mm wide and 1.3–1.7 mm long. Body with 10 somite complexes. Pores, each with sensillum, scattered over dorsum (Fig. 5A). Appendages similar to those in females, except maxilliped being more powerful (Fig. 5D), with one strong terminal hook, one large, tapering medial process, two setae and patches of setules on second segment. Legs 1–5 similar to those in females, except distal spine of leg 1 endopod being stronger than in females. Leg 6 represented by one lateral seta on each distal margin of genital somite.

**BIOLOGY.** Adults of *R. polydora* sp.n. are ectoparasites on adult spionid polychaetes *P. brevipalpa*, living attached along the dorsum of the middle part of the worm's body. Host polychaetes attain 70 mm long and 2 mm wide for 170 chaetigers; constant beating of cilia on the branchiae and dorsum provides ventilation inside the worm burrow and brings oxygen to the parasitic copepods. The copepods grasp the host worms with antennal hooks and pierce the body wall with mandibles. One host spionid is usually infested by one pair of copepods, female and smaller male, within close proximity to each other. Observations indicate that once disturbed, the copepods easily detach themselves from the host and swim away.

Some females had two long external strings of eggs attached to the genital sixth somite (Figs. 1, 6A), and most females contained numerous oocytes in the coelomic cavity (Fig. 6A, B). Eggs in the strings were about 50 µm in diameter. The larval development is unknown but possibly partly occurs inside the worm burrow in the shell.

Up to eight species of spionid polychaetes bore into shells of the Yesso scallop *M. yessoensis* in north-western part of the Sea of Japan (see Radashevsky, 1993). Although boring spionids often co-occur on one scallop shell, *R. polydora* sp.n. was found as a common associate of only one of them, *P. brevipalpa*.

**ETYMOLOGY.** The species name, *polydora* refers to the host spionid polychaete, *Polydora brevipalpa*. In Greek mythology, *Polydora* is one of 3000 Oceanides, daughters of the God of the river Oceanus and Tethys, the Titan goddess of the sources fresh water which nourished the earth, a daughter of Uranus and Gaea.

## Discussion

A comprehensive hypothesis about relationships of parasitic copepods has not yet been developed, and placing annelidicolous species into genera and even families is often still problematic. According to the cladistic analysis by Ho and Kim (2003), clausiid copepods with a posteromedial element (spine or seta) on the



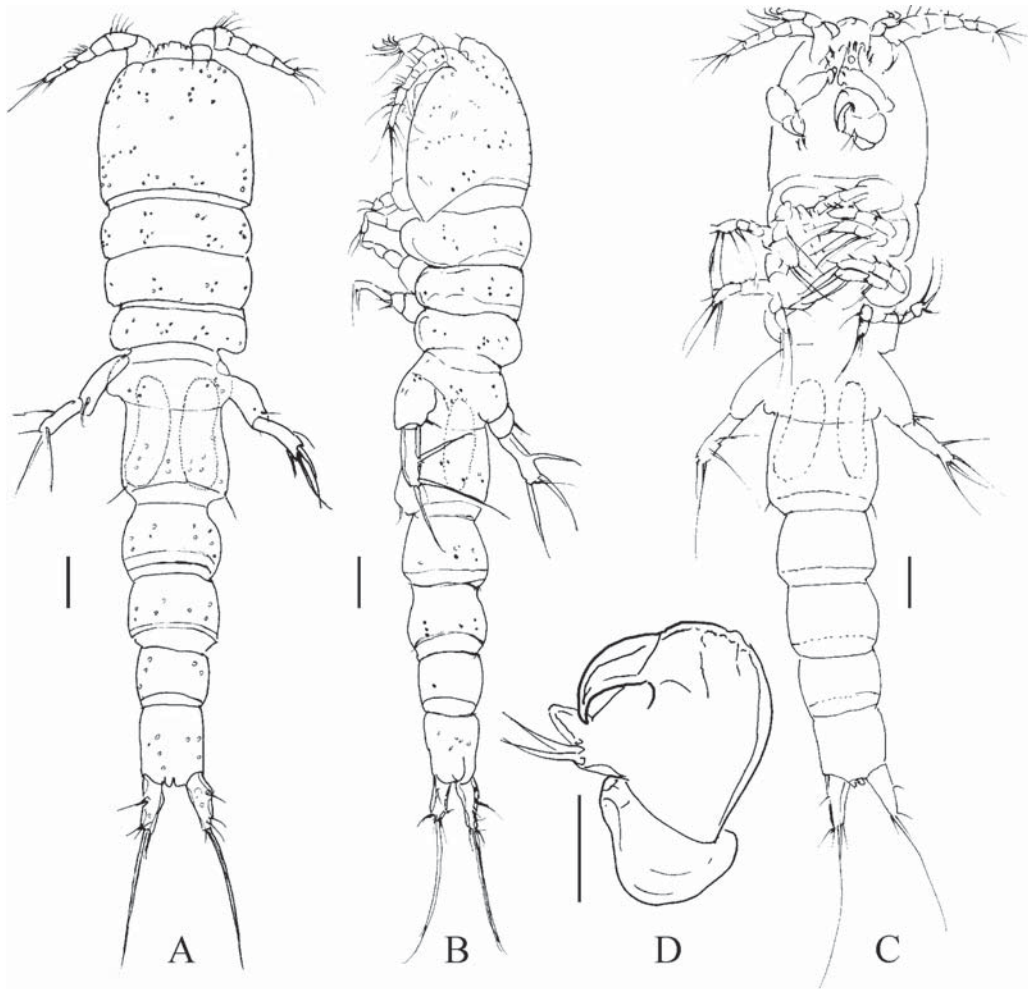


Fig. 5. *Rhodinicola polydora* sp.n. Male morphology.

A — dorsal view; B — left lateral view; C — ventral view; D — maxilliped. Scale bars: A–C — 0.1 mm, D — 0.05 mm.

Рис. 5. *Rhodinicola polydora* sp.n. Самец.

A — вид со спинной стороны; B — вид сбоку; C — вид с брюшной стороны; D — максиллипод. Масштаб: A–C — 0,1 мм, D — 0,05 мм.

basis of leg 1 formed two groups, *Pontoclausia* and *Likroclausia*, while the rest of clausiids share a derived synapomorphy, the absence of this element. This analysis also suggested that clausiids with biramous legs 1 to 4 formed three groups, *Pontoclausia*, *Likroclausia*, and *Rhodinicola*, while other clausiids had uniramous thoracic legs with endopods lacking. *Pontoclausia* contained the most primitive clausiids carrying a spine on the posteromedial surface of the basis

of leg 1; *Likroclausia* was unique in the possession of a naked seta on the posteromedial surface of the basis of leg 1, and also the antler-like projections on the pedigers 2 through 4 and the conversion of leg 1 endopod into a prehensile structure; while *Rhodinicola* members shared the absence of an element on the posteromedial surface of the basis of leg 1, and the presence of 3-segmented endopods on thoracic legs 3 and 4 (Ho, Kim, 2003). Despite their not sister but



Fig. 6 *Rhodinicola polydorae* sp.n. Adult morphology.

A — female with left egg string, right egg string missing, ventral view; B — female, dorsal view; C — male, dorsal view. A–C — fixed specimens. Scale bars: A–C — 0.5 mm.

Рис. 6. *Rhodinicola polydorae* sp.n.

A — самка с левой кладкой яиц, правая кладка яиц отсутствует, вид с брюшной стороны; B — самка, вид со спинной стороны; C — самец, вид со спинной стороны. A–C — фиксированные особи. Масштаб: A–C — 0,5 мм.

inclusive relationships, these groups were considered as valid genera by Ho and Kim (2003).

The clausiid copepods described herein have all thoracic legs biramous and no seta or spine on the posteromedial surface of the basis of leg 1. According to the analysis by Ho and Kim (2003), they should therefore be referred to *Rhodinicola*. In a comprehensive review of copepods, Boxshall and Halsey (2004) stated that they followed the scheme by Ho and Kim (2003), and included the species mentioned by Ho and Kim (2003) into *Rhodinicola*. However, in the identification key for the genera of Clausiidae they did not consider the basal posteromedial element on leg 1. Consequently, according to Boxshall and Halsey's (2004) key for the genera, the copepods described herein should be referred to *Pontoclausia*. In the present paper, we follow Ho and Kim (2003) and refer the new

species to *Rhodinicola*.

Adults of *R. polydorae* sp.n. differ from those of other species of *Rhodinicola* in having 2-segmented instead of 3-segmented endopods on legs 3 and 4 that were considered by Ho and Kim (2003) as plesiomorphic for clausiids. It is remarkable that adults of other species of *Rhodinicola*, *R. elongata* Levinsen, 1878, *R. gibbosa* Bresciani, 1964, *R. rugosa* (Giesbrecht, 1897), and *R. thomassini* Laubier, 1970 are all parasites of maldanid polychaetes (Maldanidae; see Boxshall, Halsey, 2004) whereas adults of *R. polydorae* sp.n. are parasites of a spionid polychaete (Spionidae).

*Rhodinicola polydorae* sp.n. is most similar to *R. laticauda* Ho et Kim, 2003 from the Yellow Sea, Korea. The latter species was described based on single female obtained from washings of an unidentified polychaete collect-

ed on intertidal sandstone (Ho, Kim, 2003). Besides the presence of 2-segmented endopods on legs 3 and 4, *R. polydora* sp.n. differs from *R. laticauda* in having a transparent pointed labrum. These two species differ from *R. gibbosa* and *R. elongata* in lacking papilliform spines on the basal segment of the antennule, in having a subterminal spine on the mandible, a thumb-like spinulose projection on the maxillule, a much reduced maxilliped in the female and a smaller caudal ramus in comparison with the anal somite.

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