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Morphology of the first zoeal stage of a hermit crab of the family Parapaguridae (Decapoda: Anomura) from adjacent waters of Kamchatka Peninsula

Морфология первой стадии зоэа рака-отшельника семейства Parapaguridae (Decapoda: Anomura) из прикамчатских морских вод

N.A. Sedova
Н.А. Седова

Kamchatka Federal Technical University, Petropavlovsk-Kamchatsky, Kluchevskaya, 35, 683003, Russia. E-mail: sedova67@bk.ru
Камчатский государственный технический университет, Петропавловск-Камчатский, ул. Ключевская, 35, 683003, Россия.

KEY WORDS: *Parapagurus benedicti,* zoea I, morphological features, description.
КЛЮЧЕВЫЕ СЛОВА: *Parapagurus benedicti,* зоэа I, морфологические признаки, описание.

ABSTRACT: The morphology of the first zoeal stage of family Parapaguridae (presumably, *Parapagurus benedicti* de Saint Laurent, 1972) is described for the first time. The zoea can be distinguished from the similar species of the family Parapaguridae in the morphology of telson, antennae, rostrum and pleon. The main distinguishing features of the first zoeal stage are longer spines and lateral papillas of the 2nd to 4th pleomeres, lateral spines of rostrum, anteroventral and posterodorsal spines of carapace, outer margin of scaphocerites is shortly pubescent and armed with 5 blunt spines, dorso-terminal spines of telson.

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РЕЗЮМЕ: Описана личинка первой стадии зоэа рака-отшельника сем. Parapaguridae (предположительно, *Parapagurus benedicti* de Saint Laurent, 1972). Личинка отличалась от соответствующей стадии других представителей данного семейства по морфологии тельсона, антенны, рострума, и плеона. Основные признаки описанной стадии зоэа: длинные вентро-латеральные шипы на 2–4-м плеомерах, латеральные бугорки на 2–5-м плеональных сомитах, латеральные шипы на роструме, антеровентральные и постеродорзальные шипы на карапаксе, бугорки на внешнем крае скафоцерита, дорзо-терминальные шипы на тельсоне.

Introduction

The hermit crab family Parapaguridae (Anomura) form one of the most interesting groups of organisms over the continental ocean slope, inhabiting bottom depths [Filhol, 1885; Vinogradov, 1950; Bruun, 1956; Menzies *et al*., 1973; Lemaitre, 1989]. These animals have attracted the attention of zoologists because of their amazing symbiotic relationship with members of the class Anthozoa (sea anemones and zoanthids). Despite the widespread distribution and interesting aspects of their biology, information about these hermit crabs is scarce.

The family Parapaguridae includes 10 genera with about 100 species of hermit crabs. [De Grave *et al*., 2009]. The larvae of the family were described only for *Paragiopagurus diogenes* (Whitelegge, 1900), *Parapagurus pilosimanus* Smith, 1879 and *Sympagurus dimorphus* (Studer, 1883) [de Saint Laurent-Dechance, 1964; Williamson, Levetzow, 1967; Bacardit, Joaquina, 1986]. Description of zoea and megalopa is available for *S. dimorphus*.

The northwestern Pacific contains a relatively rich hermit crab fauna, but the latter is still rather poorly studied systematically. Despite the large number of species that occur even in shallow waters, very little is known about the life histories or larval development of the northwestern Pacific hermit crabs. Of the family Parapaguridae only the species *Parapagurus benedicti* de Saint Laurent, 1972 is known for Kamchatka marine waters. Adults of *P. benedicti* occur over bottom depths between 1000 and 4000 m from the Bering Sea to the Kuril Islands, but nothing is known about their ecology [Vinogradov, 1950; McLaughlin *et al*., 2010; Marin, 2013; Lemaitre, McLaughlin, 2020]. Larval development of this species is not described. Here we describe a unique discovery of a deep-sea hermit crab larva found in the Avacha Gulf of the Kamtchatka Peninsula. The larva was caught as part of planktonic surveys in the waters along the Kamchatka Peninsula.

The purpose of our study is to describe a single larva of the first stage of the zoea of the family Parapagu-

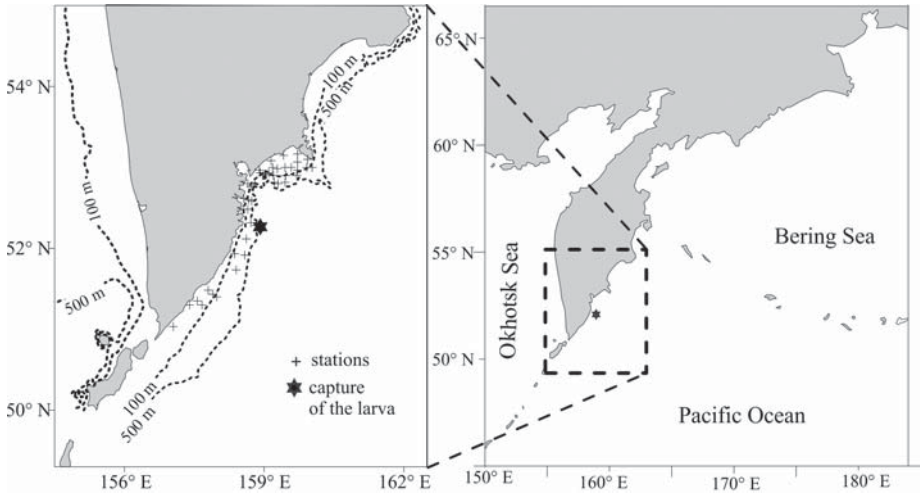

Fig 1. The location of the stations of the planktonic samples between April 25th and May 15th, 2009, and the point where the larva of ? *Parapagurus benedicti* de Saint Laurent, 1972 was caught.

Рис. 1. Схема расположения гидробиологических станций, выполненных с 25 апреля по 15 мая 2009 г. и место поимки личинки ? *Parapagurus benedicti* de Saint Laurent, 1972.

ridae and compare it with the known descriptions of species of the family.

Material and methods

Plankton samples were collected during a research survey in the period of April 25th and May 15th, 2009 in the Pacific waters along the southeastern coast of the Kamchatka Peninsula (Avacha Gulf) at bottom depths of 25–1800 m as part of the fishery research program of the Kamchatka Institute of Fisheries and Oceanography, Petropavlovsk-Kamchatsky, Russia. A single larva of the first zoeal stage was caught in the Avacha Gulf on May 2, 2009 at the station at a depth of 1800 m (52°16′N, 158°55′E) (Fig. 1). A plankton net with a diameter of 0.56 mm and a diameter of 0.8 m was towed vertically to the water surface from the bottom (if the depth is <500 m) and from 500 m below the water surface in deeper marine areas. The minimum bottom depth of the sampling was 9 m, and the maximum bottom depth was 2800 m. Planktonic samples were preserved in 4% formalin. The larva was examined with a stereomicroscope set to 32× and 56× magnification.

The larval description follows the standards proposed by Clark *et al.* [1998] and Garm [2004], and setal terminology follows Garm [2004]. The systematic position of species is determined taking into account modern databases [The World Register of Marine Species, Arcticmegabenthos, MarBEF Data System].

The carapace, abdomen, telson, and separate appendages structures are described and illustrated in detail. Only the appendages featuring morphological differences are presented in Figure 2. The general appearance and specific appendages are demonstrated. Measurements of the larva with an ocular micrometer were carried out as follows: total length from the anterior tip of rostrum to the median margin of telson, excluding telson processes; carapace length from the base of eyes to the terminal margin of carapace; rostrum length from its anterior tip to the base of eyes. The data were rounded to the nearest 0.1 mm.

Abbreviations used in text and figure:

A1 — antennules (antenna I); *A2* — antenna (antenna II); *Mp 1–3* — first-third maxillipeds, respectively; *Mx1* — maxillule; *Mx2* — maxilla; *R* — rostrum; *Md* — mandible; *GV* — general view; *T* — telson; Ts — long seta in telson; TL — total length; CL — carapace length; RL — rostrum length.

Results

? *Parapagurus benedicti* de Saint Laurent, 1972

FIRST ZOEA STAGE

Dimensions. TL= 9.5 mm; CL= 1.6; RL= 1.5 mm.

DESCRIPTION (Fig. 2).

Carapace (Fig. 2 *R, GV*). Posteriolateral margin rounded, each of anterioventral corners with small blunt spine. Similar spines present in the ventral side and in posterodorsal corners. Carapace projecting anteriolaterally, supraorbital spines absent, pterygostomian spine small, short; long, rather broad rostrum with blunt spines on lateral margins, tips slightly curved ventrally, length of rostrum approximately equal to length of carapace. Eyes sessile, somewhat elongated.

Antennule (Fig. 2 *A1*). Uniramous, unsegmented, with 4 aesthetascs terminally, 1 short, 1 long seta subterminally.

Antenna (Fig. 2 *A2*). Biramous, endopod fused with protopod, with 3 long plumose seta terminally, twice shorter than scaphocerite; scaphocerite with short distal spine, inner margin with 10 long plumose setae, outer margin shortly pubescent, armed with 5 blunt spines; protopod with 1 strong spine at base of endopod. This spine covered with small spinules in the proximal part.

Mandibles (Fig. 2 *Md*). Without palps.

Maxillule (Fig. 2 *Mx1*). Coxal endite bilobed, with 3+4 papposerrate setae; basial endite with 2 cuspidate setae, 1 very small seta; endopod 3-segmented, second segment with 0, 1, 3 papposerrate setae, exopod absent.

Maxilla (Fig 2 *Mx2*). Coxal endite bilobed, with 7+4 papposerrate setae; basial endite bilobed, with 5+4 papposerrate setae; endopod unsegmented, bilobed, with 3+4 pap-

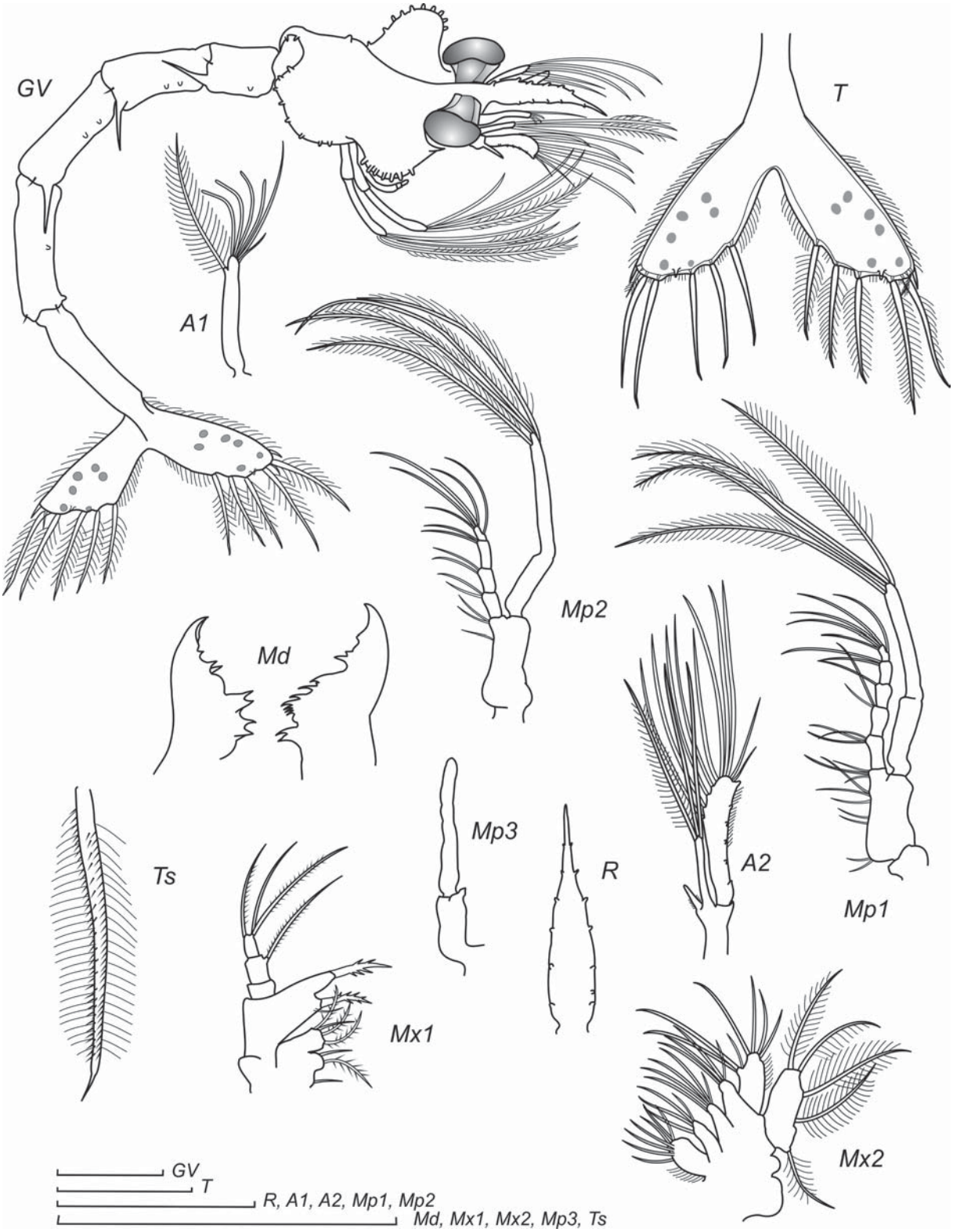

Fig 2. Morphology of the larvae of ? *Parapagurus benedicti* de Saint Laurent, 1972: *GV* — general view; *T* — telson; *R* — rostrum; *Md* — mandible; *A1*— antennule, *A2* — antenna; *Mp1–3* — the 1st–3rd maxilliped; *Mx1* — maxillule; *Mx2* — maxilla; *Ts* — terminal seta of telson. Scale: 1 mm.

Рис. 2. Морфология личинки ? *Parapagurus benedicti* de Saint Laurent, 1972: *GV* — общий вид; *T* — тельсон; *R* — рострум; *Md* — мандибула; *A1* — антеннула, *A2* — антенна; *Mp1–3* — 1–3-й максиллипед; *Mx1* — максиллула; *Mx2* — максилла; *Ts* — терминальная щетинка тельсона. Масштаб: 1 мм.

poserrate setae; scaphognathite with 5 marginal plumose setae.

First maxilliped (Fig. 2 *Mp1*). Biramous, coxa without setae, basis with 10 plumodenticulate setae arranged 2+2+3+3; endopod 5-segmented, with 3, 2, 1, 2, 4+1 plumodenticulate setae; exopod unsegmented, with 3 long terminal, 1 subterminal plumose setae.

Second maxilliped (Fig. 2 *Mp2*). Biramous, coxa without setae, basis with 3 papposerrate setae; endopod 4-segmented with 2, 2, 2, 4+1 plumodenticulate setae; exopod unsegmented, with 3 long terminal, 1 subterminal plumose setae.

Third maxilliped (Fig. 2 *Mp3*). Uniramous, without setae, protopod naked.

Pereiopods absent.

Pleon (Fig. 2 *GV*), Five pleomeres, sixth pleomer fused with telson; second to fourth pleomeres long, with smooth posterior margin, pair of ventrolateral spines; length of pleomeres 3 times their width. Pleomeres from 2nd to 5th bear small papillae on lateral surfaces; also with tiny spines located terminally on dorsolateral surface.

Pleopods absent.

Telson (Fig. 2 *T*). General shape close to triangular, extremely deep median cleft at posterior margin of telson divides it into two lobes, each with 6 pairs small orange chromatophores; pubescent on lateral margin; which normally with 7 pairs of marginal telson processes, outermost spine heaviest, while others represented by plumose setae. Long setae armed along their entire length with 3 rows of short spines; end pointed (Fig. 2 *Ts*). In addition, short dorso-terminal blunt spine present on each of telson lobes. Anal spine absent.

Uropods absent.

Comments

The larvae of the first stage of the family Parapaguridae are of a similar structure in most features (Table). The larva we found differs from zoea I of *Sympagurus dimorphus* [Bacardit, Joaquina, 1986] by a deeper notch in the telson, more elongated eyes, the presence of dorsoterminal spines in the telson, and papillae in the scaphocerite. Ventrolateral spines from the 2nd to the 5th somite in our larva and *S. dimorphus* are of different structures. In the larva of Avacha Gulf, we describe ventro-lateral spines as pointed, straight and very long. In the zoea of *S. dimorphus*, these spines are very complex of shape and shorter of length. The 3th–5th pleomeres of *S. dimorphus* are shorter. Length of the fifth pleomer in *S. dimorphus* is only twice the width. The length of this segment in *Parapagurus pilosimanus* and ? *P. benedicti* exceeds the width by three times.

Our larva differs from zoea I of *Paragiopagurus diogenes* in some morphological characteristics: armed carapace, deep notch in telson, papillae in pleomeres and scaphocerite, long spines in pleomeres, longer pleomeres. Our larva has sculpted formations in the form of tubercles along the outer margin of the scaphocerite, which are absent in *P. diogenes*. Very thin and short dorsolateral spines are found in 3th–5th pleomeres in larvae of *P. diogenes*, which in the smaller larva that we are describing are present in 2nd–5th pleomeres. The terminal notch in the telson *P. diogenes*, like in most larvae of hermit crabs, is small, while in the described larva the notch is very deep. Moreover, the lateral margin of the telson of the described zoea I is covered with pubescence in all sides, where as the margin of the telson of *P. diogenes* has only very small microtrichs in the terminal margin. One of the apical setae in the endopod in Mx1 of zoea I of *P. diogenes* is short, while in the larva that we are describing all apical setae are of equal length. In addition, the zoea of *P. diogenes* bears relatively short pleomeres.

According to the available description [Williamson, Levetzow, 1967], the shape of the carapace and telson of *Parapagurus pilosimanus* is the same as that of the larva from Avacha Gulf. The authors of the description of larvae of *Paragiopagurus diogenes* noted the presence of cuticular tubercles in the surface of the carapace. The larva from Avacha Gulf considered here differs from the existing description of the larvae of *Parapagurus pilosimanus* by long lateral spines in the 2nd–4th pleomeres and by a deeper notch in the telson. Both the larva from the Kamchatka waters and the larvae of *P. pilosimanus* have small papillae, at least in some areas of the body surface. Dorso-lateral spines in zoea I of *P. pilosimanus* are present in 2rd–5th pleonal somites [McLaughlin, 2003], as in the larva described in this study, but in *P. pilosimanus* these spines are somewhat longer. The forms of telson and carapace are similar in these species. There is no information on the presence/absence of chromatophores in the teleson of larvae of *P. pilosimanus*. The structure of the rest of the appendages in our larva and in *P. pilosimanus* is very similar.

Conclusion

The main features that distinguish most species of the family Parapaguridae are as follows: posteriolateral margin of carapace rounded; second to fifth abdominal somites long, with long ventrolateral spines [Saint Laurent, 1972]. Previously, all three of these species belonged to the genus *Parapagurus*. Lemaitre [1989] transferred *P. diogenes* to the genus *Paragiopagurus*, and *P. dimorphus* transferred to the genus *Sympagurus*. The species *P. pilosimanus* remained in the genus *Parapagurus*. Thus, there are now descriptions of three genera of this family. The described three genera practically do not differ in the structure of the maxillule, maxilla, and the first and second maxillipeds. One species of deep-water hermit crab *Parapagurus benedicti* de Saint Laurent, 1972 (=*Parapagurus pilosimanus benedicti*) [Marin, 2016] dwells in the Russian fauna.

There are some differences in the development of third maxilliped. Mp3 of *S. dimorphus* is not segmented and less developed. In stage of zoea I of *P. diogenes* A1 bears one aesthetic less than in other species. The rest of the antenna morphology is similar. The main differences are in the structure of carapace, pleon, and telson (Table). Our larva resembles the zoea I of the

Table. Comparison of morphology of zoeae I of species *Sympagurus dimorphus*, *Paragiopagurus diogenes*, *Parapagurus pilosimanus*, and ? *P. benedicti*.
Таблица. Сравнение морфологии зоэа I *Sympagurus dimorphus*, *Paragiopagurus diogenes, Parapagurus pilosimanus* и ? *P. benedicti*.

Features	*S. dimorphus* [Bacardit, Joaquina, 1986]	*P. diogenes* [Williamson, Levetzow, 1967]	*P. pilosimanus* [Williamson, Levetzow, 1967]	? *P. benedicti* (our data)
Spines in carapace and rostrum	Present	Absent	Present	Present
Depth of notch in telson (part of TL)	3/7	1/4	1/2	2/3
Dorsoterminal spines in telson	Absent	Absent	Absent	Present
Length/width ratio of fifth pleomer	2/1	3/2	3/1	3/1
Location of ventrolateral spines	2nd to 5th pleomeres	Absent	Absent	2nd to 4th pleomeres
Location of dorsolateral spines	2nd to 5th pleomeres	3rd to 5th pleomeres	2ond to 5th pleomeres	2nd to 5fth pleomeres
Eyes	Rounded	Rounded	Cylindrical	Cylindrical
Number of aesthetascs	4	3	4	4
Blunt spines in scaphocerite	Absent	Absent	Absent	Present

genus *Parapagurus* in most of its features. In addition, originally de Saint Laurent [1972] described *Parapagurus benedicti* as a subspecies of *P. pilosimanus*. Therefore, it can be assumed that the larva from Avacha Gulf can be identified as *Parapagurus benedicti*.

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