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Polychaete-parasitizing copepods from the deep-sea Kuril–Kamchatka Trench (Pacific Ocean), with the description of a new *Ophelicola* species and comments on the currently known annelidicolous copepods

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ABSTRACT

The annelid associated copepods, collectively called annelidicolous, were placed in 21 families. Some genera, such as *Ophelicola*, are considered phylogenetically isolated and are placed into the order Cyclopoida as *incertae sedis*. In this paper, we describe *Ophelicola kurambia*, the second species recorded for the genus and the first for the Pacific Ocean. The single known specimen, a female, was found during the German–Russian deep-sea expedition KuramBio at the deep-sea Kuril–Kamchatka Trench. The new species differs from *Ophelicola drachi* (known from the Gulf of Biscay, Atlantic Ocean) in being attached to the host through the mandibles instead of maxillae and, specially, in the formula of the antennular armature. The study of the new species contributes to clarify the diagnosis of the genus, which clearly differs from *Notomasticola* (another *incertae sedis* genus), and resembles both the most modified clausiids (in the mandibular shape and antennular segmentation) and the clausidiids (in the shape of maxilla). However, it does not contribute to clarify the position of *Ophelicola* within the order Cyclopoida. The paper includes a list of the known annelidicolous copepods (excluding Monstrilloidae) and summarises the main trends shown in terms of diversity, distribution and relationships. Currently, 168 species of copepods from to 74 genera and 22 families and 7 *incertae sedis* (excluding Monstrilloida) are known to be involved in 235 parasitic relationships (mostly ectoparasitic) with polychaetes. Host polychaetes include 156 species belonging to 104 genera from 22 families (plus 14 unknown). About 50% of these relationships are known from European waters, mainly from shallow depths.

1. Introduction

More than 120 species of Copepoda belonging to at least 21 families, the so called annelidicolous copepods, were reported to be associated with annelids, most of them being external or internal parasites of polychaetes. Some families include annelid symbionts together with free-living members and/or associates of other invertebrates. However, some others are known as exclusive parasites of polychaete hosts (Boxshall and Halsey, 2004; Humes, 1994).

The symbiotic relationships with polychaetes might have evolved independently from various copepod ancestors (Björnberg and Radashevsky, 2011). A comprehensive hypothesis about the relationships involving parasitic copepods has not yet been developed and therefore, placing annelidicolous species into genera and even families is often problematic (Kim et al., 2013). In fact, the definition of some families is rather nebulous and the boundaries among families are sometimes poorly defined, such as those among Clausidiidae Embleton, 1901, Clausiidae Giesbrecht, 1895 and Anomoclausiidae Gotto, 1964 (Boxshall and Halsey, 2004; Humes and Ho, 1967; Kim et al., 2013). This also caused some genera to be phylogenetically isolated due to their unusual features.

In 1978, Laubier described a new genus of annelidicolous copepod collected from an unidentified ophelid polychaete found between 4706 and 4475 m depth in the Atlantic coast of France. The genus *Ophelicola* Laubier, 1978 was considered as phylogenetically isolated due to its unusual features. Thus, it was placed into the order Cyclopoida as *incertae sedis* (Boxshall and Halsey, 2004).

During the German–Russian deep-sea expedition KuramBio (Kuril–Kamchatka Biodiversity Study) to the Kuril–Kamchatka Trench and abyssal plain, two specimens of moderately transformed copepods associated with polychaete worms were collected. Parasitic copepods from polychaete hosts are seldom reported, likely because

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their very low prevalence. Usually, these parasites are found only after observing large numbers of potential hosts (Kim et al., 2013), which is a particularly difficult task in the deep-sea. Accordingly, in this paper we describe one of the specimens as a new species of *Ophelicola*, despite having found a single female, and discuss whether this new discovery provides new insights in the relationship of *Ophelicola* within the cyclopoid families. Unfortunately, the second annelidicolous copepod, belonging to the genus *Anomopsyllus* G.O. Sars, 1921, was in very poor conditions and, thus, it could not be formally described. This paper also includes a list of the known annelidicolous copepods (excluding Monstrilloidae) and summarises all known characteristics in terms of diversity of both the symbionts and the hosts, type of relationship and bathymetrical and geographical distribution.

2. Material and methods

The polychaete hosts were collected during the KuramBio Expedition 2012 to the Kuril–Kamchatka Trench and abyssal plain, with the help of the supranet of the epibenthic sledge EBS-S or the box corer GKG, both operated from the R/V *SONNE*-223. Infested host were extracted from sediments collected in stations 223-3-9 (4987–4991 m depth) and 2–5 A (4869 m depth), carefully washed on board, photographed alive, and then fixed in 70% ethanol.

In the laboratory, the copepods were extracted from the hosts, dissected in lactic acid prior to staining with Chlorazol black E (Sigma® C-1144), examined as temporary mounts in lactophenol, and finally sealed with Entellan as permanent mounts. Drawings were made with the help of a *camera lucida* attached to a Leica DMLB differential interference microscope. Body length was measured from the anterior margin of the rostrum to the posterior margin of the caudal rami. All appendage segments and setation elements are named and numbered according to Huys and Boxshall (1991).

The dissected holotype is deposited in the Museo Nacional de Ciencias Naturales of Madrid (MNCN), Spain.

3. Results and discussion

3.1. Taxonomic account

Subclass Copepoda
Order Cyclopoida
Incertae sedis
Genus *Ophelicola* Laubier, 1978

Diagnosis (redefined): Body of adult female transformed by swelling and fusion of free pedigerous somites. Prosome comprising cephalothorax incorporating 1st pedigerous somite and swollen 2nd to 4th pedigerous somites. Urosome distinct, comprising partly swollen 5th pedigerous somite fused to genital somite, and 4 free abdominal somites. Genital apertures paired, located posterolaterally on genital somite. Caudal rami with 6 setae.

Rostrum weakly developed. Antennule 5-segmented, distal 3 segments homologous, with XXI–XXIV, XXV and XXVI–XXVIII; armature 4(5), 16(14), 4+aesthetasc, 2+aesthetasc, 7+aesthetasc. Antenna uniramous, 4-segmented with coxa and basis fused to form coxobasis bearing single seta; 1st endopodal segment with 1 mid-margin seta, 2nd with 4 elements sometimes including 1 claw, 3rd with 7 elements; exopod lacking. Entognathous, with mouthparts arranged in perioral depression. Mandible small, consisting of a strongly sclerotized gnathobase with articulated distal portion denticulate or plumose. Maxillule lobate, with 5–9 setae. Maxilla 2-segmented, comprising large unarmed syncoxa and basis; basis with basal naked seta, produced into trifid claw-like process and articulated bifid claw. Maxilliped reduced, sometimes located in transverse groove on surface of cephalothorax, indistinctly 3-segmented, 1st segment unarmed, 2nd with setulose seta, and 3rd smallest, bearing short naked seta and small spine.

Table 1
Genus *Ophelicola* (redefinition). Armature formula of legs 1–4.

	Coxa	Basis	Exopodal segments	Endopodal segments
Leg 1	0-0	1-0	I-0;I-1;III,I,4	0-1;0-1;II,4
Leg 2	0-0	1-0	I-0;I-1;III,I,5	0-1;0-2;II,4 (I,II,3)
Leg 3	0-0	1-0	I-0;I-1;III,I,5	0-1;0-2;II,4 (I,II,3)
Leg 4	0-0	1-0	I-0;I-1;III,I,5 (4)	0-1;0-2;III,2 (I,III,1)

Swimming legs 1–4 ventrally on somites. Intercoxal sclerite in leg 1 only. Legs 1 to 4 biramous, with 3-segmented rami. Spine and seta formula as in Table 1.

Inner basal seta absent on leg 1. Inner coxal setae absent in all legs. 5th leg small, located laterally on somite; 2-segmented with protopodal segment more or less separate from somite and bearing outer seta: exopodal segment with 3 setae. 6th legs represented by paired opercula in female, sometimes with 1 seta. Egg sacs unknown.

Type species: *Ophelicola drachi* Laubier, 1978.

Remarks: The original description of *Ophelicola* pointed out the similarities with the family Clausidiidae in the general structure of the maxillae and swimming legs. However, *Ophelicola* lacks armature in the maxillar syncoxa, which is armed in clausidiid genera (except for *Conchyliurus* Bocquet & Stock, 1957 and *Hippomolgus* G.O. Sars, 1917). Except for *Hyphalion* Humes, 1987, *Conchyliurus*, and *Hermadona* Ho and Kim, 2004, most female clausidiids have well-developed 4-segmented maxillipeds (Ho and Kim, 2003), contrarily to the rudimentary limbs of *Ophelicola* females. Furthermore, the antennules of the Clausidiidae, with the exception of *Hermadona, Conchylirius*, and *Hersilioides* Canu 1888, are 7-segmented (Boxshall and Humes, 1987; Ho and Kim, 1990, 2003, 2004). Moreover, the derived structure of the mandible excludes *Ophelicola* from the Clausidiidae and indicates a possible relationship with the Clausiidae (Boxshall and Halsey, 2004). In fact, the mandible and the antennule segmentation of *Ophelicola* resemble that of the most modified genera of this family (such as *Boreoclausia* Kim et al., 2013, *Vivgottoia*, Kim et al., 2013, and *Sheaderia* Kim et al., 2013). However, these genera have also very reduced and modified legs 1–4, present the typical clausiid maxillule and maxilla, and have a single free abdominal segment. The clausiid genus *Spionicola* Bjornberg & Radashevsky, 2009 shares the 5-segmented antennules with *Ophelicola* (Björnberg and Radashevsky, 2009), but clearly differs in all remaining characteristics. *Ophelicola* resembles the clausiid genus *Rhodinicola* Levinsen, 1878 in having 3-segmented rami of legs 1–4 and in lacking posterior median element at the basis of leg 1 (Björnberg and Radashevsky, 2011). However, most oral appendages of *Ophelicola* (i.e. mandible and maxilla) differ from the typical clausiid form (Boxshall and Halsey, 2004).

Finally, the *incertae sedis* genus *Notomasticola* Kim et al., 2013 clearly differs from *Ophelicola* in having 1-segmented abdomen, 4-segmented antennule, antennal armature, reduced oral appendages lacking maxilliped, 2-segmented rami of legs 1–3, reduced leg 4, and 2-segmented leg 5 (Kim et al., 2013).

Therefore, nearly forty years later from its description, the genus *Ophelicola*, cannot be placed with confidence in any existing family, and should still be considered as *incertae sedis* within Cyclopoida until a full cladistic analysis of the annelidicolous