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New records of horsehair worms (Nematomorpha, Gordiida) from Sweden and Norway

Keywords Nematomorpha, Gordiida, Scandinavia, Sweden, Norway, new record

Abstract Records of horsehair worms from Scandinavia are comparably few, although there are indications that the existing diversity of taxa is higher. We report here the occurrence of *Gordius* cf. *spiridonovi* Schmidt-Rhaesa, 2010 from two locations in Sweden and of *Gordionus wolterstorffii* (Camerano, 1888) from Norway. This is the first record from Norway. *Gordionus wolterstorffii* is a common species in Northern Europe. *Gordius spiridonovi* was described from Estonia. The newly reported Swedish specimens resemble *G. spiridonovi* in several characters, but *G. terminosetosus* Schmidt-Rhaesa, 2010 in others. This can be explained either by character plasticity or by the Swedish specimens representing an own species. This question cannot be resolved with the current material.

Introduction

Horsehair worms (Nematomorpha) are distributed worldwide. They are parasites of terrestrial insects and other arthropods, from which they emerge at maturity to reproduce in freshwater. This accounts to the about 360 species of the taxon Gordiida, additionally there are 5 marine species in the genus *Nectonema*.

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Global species diversity was investigated only on a very rough scale (Poinar 2008) and the numbers of described species per zoogeographic region might reflect the intensity of collecting rather than real species numbers. This also accounts to the records of “Nematomorpha” in the database iNaturalist (www.inaturalist.org), where most records occur in North America and in Europe, with much fewer records in e.g. the tropical regions, which likely harbor a greater diversity of species. But even in the “better sampled” regions information on species diversity is still patchy and incomplete (Poinar 2008). This accounts for example to Scandinavia, from which comparably few records are known so far.

There are three publications on gordiids from Scandinavia (Denmark, Sweden, Norway and Finland; the Russian parts of Scandinavia, Karelia and the Oblast Murmansk, are not included here): Levander (1908) from Finland, Montén (1951) from Sweden and Schmidt-Rhaesa & Kristensen (2006) from Denmark. Both Levander (1908) and Montén (1951) mention gordiids to be broadly distributed and common in Finland and Sweden. Their own records span entire Scandinavia, from southern Finland to slightly north of the Polar Circle (up to about 68°N). Levander (1908) reports two species, *Gordius aquaticus* Linné, 1758 and *Gordionus violaceus* Baird, 1853. Of particular interest is the record of *G. aquaticus* from two locations in the Baltic Sea in southern Finland. The occurrence of this freshwater species in the marine environment might be explained by the low salinity (5‰), but this is to our knowledge the only such record. Levander (1908) did not document his specimens or mention any diagnostic characters. The two reported species are common and widespread in Europe, but especially species in the genus *Gordius* are very difficult to identify and vary in subtle character differences (Schmidt-Rhaesa 2010). Montén (1951) claims that three species were reported in the literature so far from Sweden, but doesn't give a citation for it and such records are unknown to the authors. In the references, only the publication of Levander (1908) is listed, therefore Montén probably referred to records from entire Scandinavia and not particularly from Sweden (Levander reported the two species mentioned above and a third from Karelia). Montén (1951) further mentioned own unpublished observations of three species in Sweden, *Gordius albopunctatus* Müller, 1926 as the most abundant, *G. aquaticus* and *Gordionus scaber scaber* Müller, 1926 as less abundant, but still common. He estimates the species number in Sweden to be about 15. Described are four species of *Gordionus* from a lake, Virihaure, in Lapland in Northern Sweden: *G. alpestris* (Villot, 1885), *G. brunneus* n. sp., *G. lapponicus* n. sp., *G. scaber*. Beyond these records, *Gordius lapponicus* Von Linstow, 1906 was described from “Lapland” (Von Linstow 1906), *Gordius aquaticus* Linne, 1758 was mentioned from Denmark (Wesenberg-Lund 1937) and *Gordius albopunctatus* Müller, 1927 and *Gordionus violaceus* (Baird, 1853) were reported from Bornholm, Denmark (Schmidt-Rhaesa & Kristensen 2006). No gordiid was so far been reported from Norway.

Identification of gordiids has moved from light microscopy to scanning electron microscopy (SEM; see, e.g. Schmidt-Rhaesa 2010). The observation of fine structural details sometimes makes the comparison with older descriptions difficult, because they were sometimes overlooked. For example, SEM has shown tiny bristles to be present on

the cuticle and, sometimes in particular arrangement patterns, on the posterior end of male gordiids (Schmidt-Rhaesa 2010). Such structures may have been overlooked, as they are rarely mentioned in older species descriptions. A further problem are intraspecific variability and interspecific morphological uniformity. Both appear to exist at least in some species. Variability of cuticular characters is present e.g. in *Gordionus wolterstorffi* (Camerano, 1888) (Schmidt-Rhaesa 2001). Morphological similarity was for example shown in North American *Gordius* specimens, which are poor in diagnostic characters (smooth cuticle, few characters in the male posterior end) and correspond to the description of *Gordius robustus* Leidy, 1851, but turned out to be multiple species by DNA barcoding (Hanelt et al. 2015). The latter method is becoming used more and more frequently in nematomorphs. We report here new records from Sweden and the first record from Norway.

Material and Methods

Specimens were collected from freshwater lakes by hand by the second author, preserved in 70 % ethanol and sent to the first author for identification. Specimens were investigated under a binocular. Length measurements were made to the gently outstretched worms with a ruler and rounded to the next cm. The diameter was measured with a caliper. For Scanning Electron Microscopy (SEM), the posterior end and a 1 mm section from the middle were dehydrated in an increasing ethanol series, critically point dried and sputtered with gold. Investigation took place with a LEO SEM 1524.

Results

Gordius cf. *spiridonovi* Schmidt-Rhaesa, 2010

Material investigated

4 males from the shore of lake Unden, Sannerud, Sweden (N 58.7991, E 14.5330), collected on 20. July 2008 by Maria Weißbecker. 2 males from the shore of lake Buvattnet, in nature reserve Glaskogen near Glava, Sweden (N 59.5167, E 12.3616), collected on 4. August 2008 by Maria Weißbecker. Both locations with stones and little fine sediment, worms between stones. In the collection Schmidt-Rhaesa at the Museum of Nature – Zoology, LIB, Hamburg, under the number 1604a–d (Karlsborg) and 1616a, b (Glaskogen).

From the six males, one (Nr. 1616b) is in bad condition and was not measured. The others measure 160, 170, 170, 180 (specimens 1604a–d) and 195 (specimen 1616a) mm in length and have a diameter between 0.4 and 0.6 mm. All are almost white, with a faintly visible dark collar in the anterior end, from which in some specimens a dark line extends posteriorly.

The cuticle in midbody is structured into polygonal flat areoles (=slightly elevated structures) of irregular size (Fig. 1A, B, 2B). At high magnification the areoles have a rough surface created by a fine network of small projections (Fig. 1B). In the badly preserved specimen, the cuticle contains areoles, which are centrally depressed (Fig. 1C).

The posterior end was very well preserved in specimen 1616a, but less well or partly covered with dirt in the other specimens. It is bifurcated, the tail lobes are about twice as long as broad (Fig. 1D) or shorter (Fig. 1E, 2A, C). The semicircular postcloacal crescent is at the posterior margin between the tail lobes, its branches reach slightly onto the tail lobes (Fig. 1D, F). The cloacal opening is about 25 µm anterior of the anterior margin of the postcloacal crescent and it is, as far as it could be observed, round (Fig. 1D, F). At least in one specimen it is surrounded by a slight polygonal structuring of the cuticle (Fig. 1D). Very slight polygonal patterning is present in some parts of the posterior end, e.g. the inner side of the tail lobes (Fig. 1D, F), but in other parts the cuticle appears to be smooth. Small bristles are present scattered over the entire posterior end and concentrated in some regions: anterior of the postcloacal crescent (Fig. 1D, E), from there is a line leading posterior, passing the outer edges of the postcloacal crescent (Fig. 1E) and extending onto the inner side of the tail lobes (Fig. 1G). In the Karlsborg specimens and in 1616b the patterns of bristles are, as far as they could be observed, also present, but not as pronounced as in specimen 1616a (Fig. 1E, 2A, C).

Gordionus wolterstorffii (Camerano, 1888)

Material investigated

1 female from *Pterostichus niger* (Carabidae) which was caught in a flight intersection trap. The worm was halfway emerged when it was preserved and it was completely expelled for identification. From Norway, Telemark, Tokke, Lindeviki (59,4082°N, 8,2891°E), col. K. M. Olsen and Ø. Gammelmo, 9.6.-16.7.2015. In the collection Schmidt-Rhaesa at the Museum of Nature – Zoology, LIB, Hamburg, under the number 2229.

The cuticular surface includes areoles which attach each other in longitudinal direction, sometimes they are confluent with each other (Fig. 3A, B). Interareolar furrows with short bristles are present mainly between longitudinal stripes of areoles (Fig. 3A) or become further restricted to smaller “islands” (Fig. 3B).

Discussion

For identification of gordiids, the presence of areoles and the bristles in the posterior end are the most important characters. Within the genus *Gordius*, several species have areoles, but many species have a smooth cuticle (see Schmidt-Rhaesa 2010). Fine bristles on the posterior end were included in very few species descriptions in the past. The most prominent one is the description of the species *Gordius impressus* Schneider, 1866. Strong bristles are described from the posterior end of a specimen with unknown location (probably

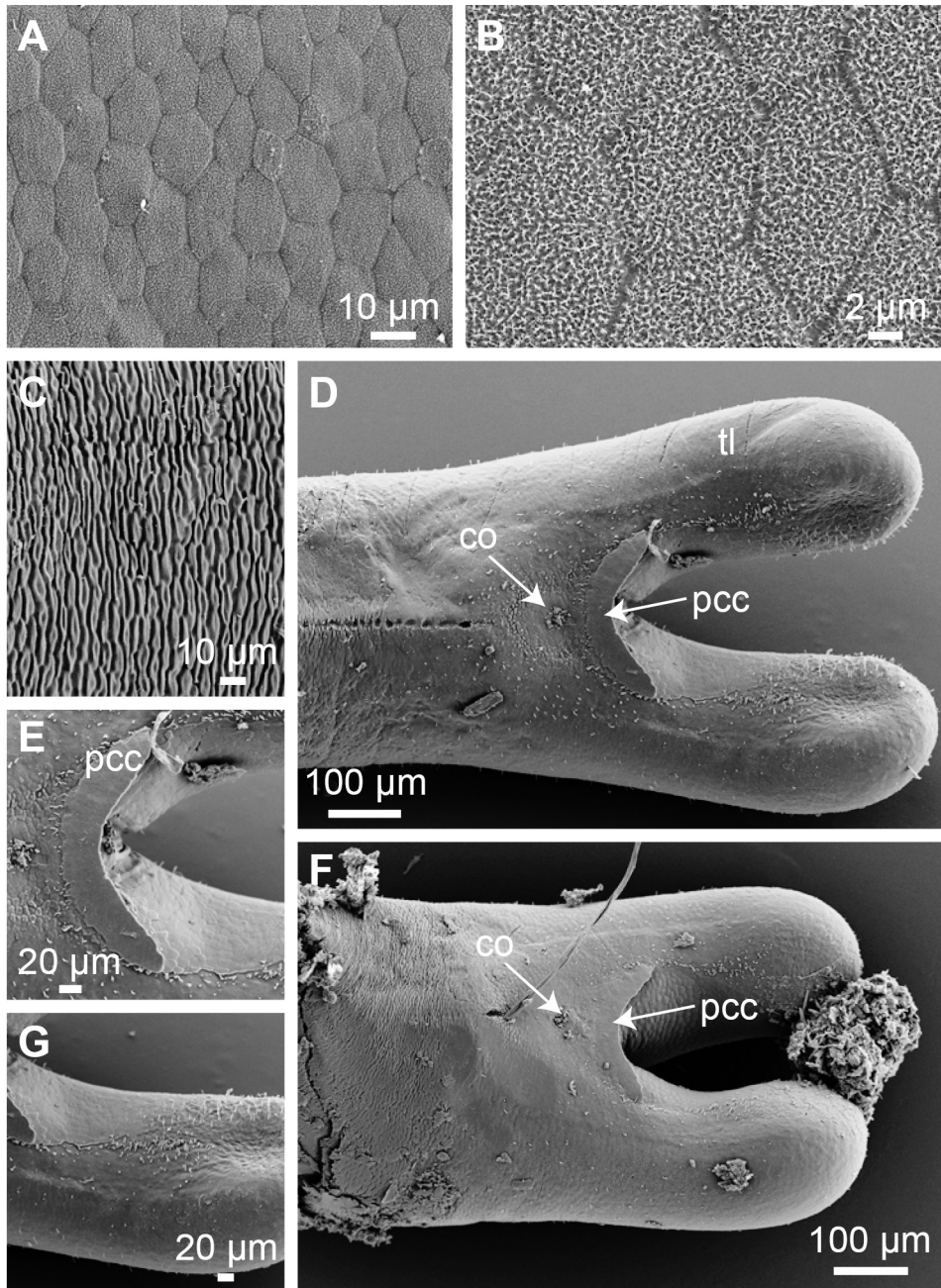


Fig. 1 *Gordius* cf. *spiridonovi*, specimens from Glaskogen, Sweden. A, B. Cuticular surface of specimen 1616a with polygonal areoles in two different magnifications. C. Cuticle of specimen 1616b. D. Ventral view on the posterior end of male 1616a showing the cloacal opening (co), postcloacal crescent (pcc) and tail lobes (tl). E, G. Magnifications from D showing the distribution of small bristles. F. Posterior end of a male 1616b, for labels see D. All images SEM.

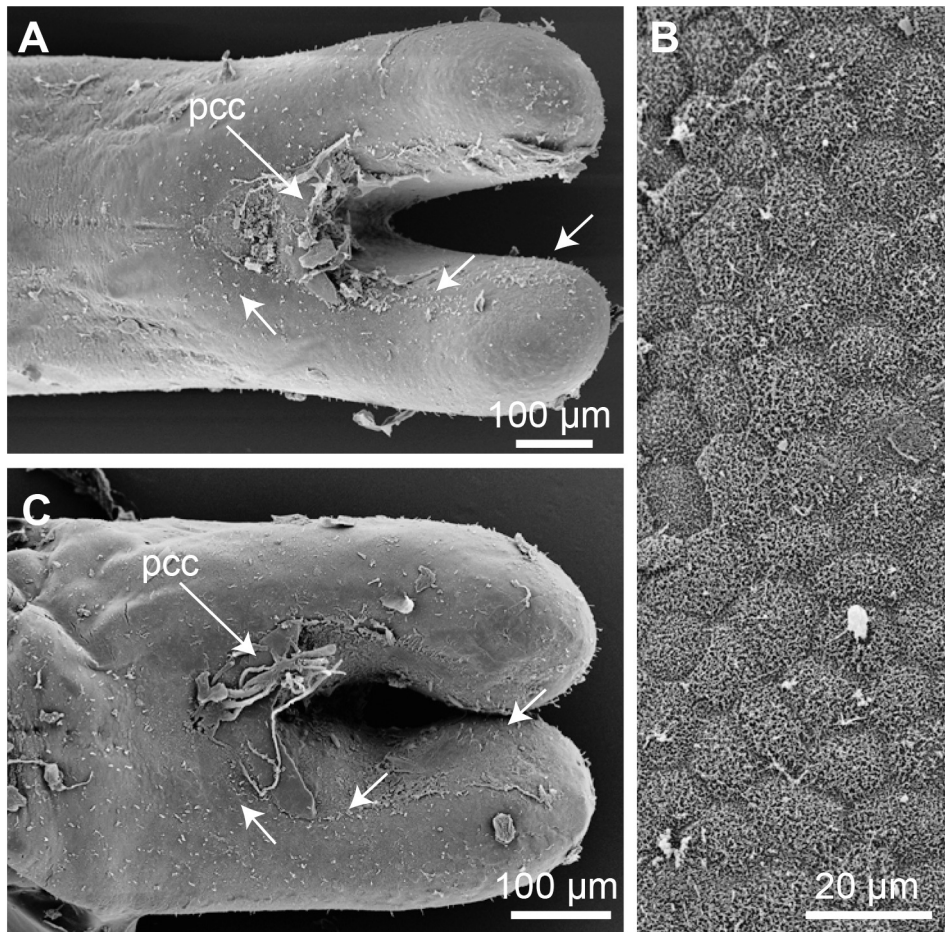


Fig. 2 *Gordius* cf. *spiridonovi*, specimens from Karlsborg, Sweden. A, C. Posterior end of two males (1604c, d) showing the postcloacal crescent (pcc) and distribution of bristles (arrows). B. Cuticle of specimen 1604d. All images SEM.

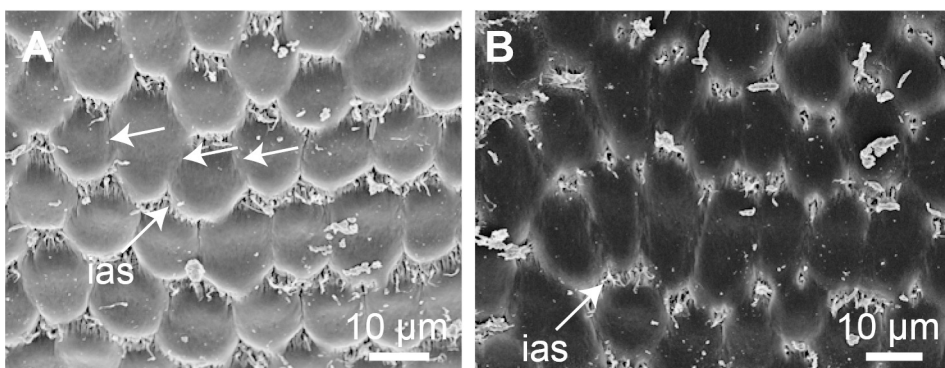


Fig. 3 *Gordionus wolterstorffii* from Norway. A, B. Cuticular surface at two different locations from the middle region of the animal. Arrows point at confluences between neighboring areoles. Between areoles are small patches with interareolar structures (ias). Both figures SEM.

Berlin, Germany) (Schneider 1866) and along the entire inner side of the tail lobes in specimens from Saint-Nizier (France) (Villot 1874). This species has areoles on the cuticle. In *G. borisphaenicus* Spiridonov, 1998 from the Ukraine and Moldova, bristles are described from the region anterior of the postcloacal crescent and running onto the tail lobes, with a conspicuous round concentration after about 2/3 of the tail lobe length (Spiridonov 1998). After SEM was established as an essential tool for gordiid identification, minute bristles on the posterior end were observed in several species (Schmidt-Rhaesa 2010). The distribution pattern of such bristles was regarded as species specific (Schmidt-Rhaesa 2010). Among those species with posterior bristles, the species with a smooth cuticle are excluded for comparison with the Swedish specimens: *G. helveticus* Schmidt-Rhaesa, 2010 and *G. zwicki* Schmidt-Rhaesa, 2010 (see Schmidt-Rhaesa 2010). *Gordius karwendeli* Schmidt-Rhaesa, 2010 has areoles, but the inner side of the tail lobes is very smooth, in contrast to the Swedish specimens (Schmidt-Rhaesa 2010). This restricts the comparison to two species: *G. spiridonovi* Schmidt-Rhaesa, 2010 and *G. terminosetosus* Schmidt-Rhaesa, 2010 (Schmidt-Rhaesa & Prous 2010), both from Estonia [note that both species were described deliberately with single authorship in a double-authorship publication]. Both are very similar. In *G. spiridonovi* the tail lobes are reported to be slightly longer than twice their width and the cloacal opening is slightly oval. In *G. terminosetosus* the cloacal opening is round and the tail lobes twice as long as wide. In this species, the postcloacal crescent is conspicuously wide and thick. Bristles run from anterior of the frontal margin of the postcloacal crescent in a line onto the tail lobes in *G. spiridonovi* and become scattered in the posterior part of the tail lobes. In *G. terminosetosus* bristles are very few around the postcloacal crescent, but they are concentrated in the inner side of the tips of the tail lobes in (all information Schmidt-Rhaesa & Prous 2010).

The Swedish specimens show characters of both *G. spiridonovi* and *G. terminosetosus*. The shape of the postcloacal crescent resembles the one in *G. spiridonovi* and is not as bold and broad as in *G. terminosetosus*. The length of the tail lobes and the shape of the cloacal opening is more as in *G. terminosetosus*. The bristles are present before and along the postcloacal crescent and also on the inner side of the tail lobes, therefore more or less combining the characters of both species. How can this be interpreted?

Unfortunately, most species of gordiids are described on the basis of single specimens and DNA barcoding is still rarely applied. Our specimens from Sweden show some variability in the length of the tail lobes and in the distribution of bristles, making it possible that there is some intraspecific plasticity. There are two possibilities. Either the Swedish specimens represent an own species with new character combination or the Swedish specimens belong to the same species as the Estonian specimens, but then there would be some character plasticity and *G. spiridonovi* and *G. terminosetosus* might even be the same species. This question cannot be answered with the material at hand and therefore we prefer to call the Swedish specimens *G. cf. spiridonovi*.

Gordionus wolterstorffii is a common species, mostly distributed in Northern Europe (Schmidt-Rhaesa 2013). This species has not been reported from Scandinavia so far, but

several other species from the genus *Gordionus* are present: *G. violaceus* (from Finland: Levander 1908, from Denmark: Schmidt-Rhaesa & Kristensen 2006), *G. scaber*, *G. alpestris*, *G. brunneus* and *G. lapponicus* from Sweden (Montén 1951). A review of the genus *Gordionus* is needed, as several species differ only slightly from each other and the reported plasticity of *G. wolterstorffii* (Schmidt-Rhaesa 2001) potentially includes several other species.

In summary, the following species are known from Scandinavia:

- Denmark: *Gordius albopunctatus*, *Gordius aquaticus* and *Gordionus violaceus*
 Sweden: *Gordius albopunctatus*, *Gordius aquaticus*, *Gordius* cf. *spiridonovi*, *Gordionus alpestris*, *Gordionus brunneus*, *Gordionus lapponicus* and *Gordionus scaber*
 Finland: *Gordius aquaticus* and *Gordionus violaceus*
 Norway: *Gordionus wolterstorffii*
 “Lapland”: *Gordius lapponicus*

Acknowledgements

We thank Kjell Magne Olsen for making available *G. wolterstorffii* from Norway.

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