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A.V. Rzhavsky, E.K. Kupriyanova, A.V. Sikorski

**Field guide to calcareous tubeworms
(Polychaeta, Serpulidae) of the Arctic Ocean**



KMK Scientific Press
Moscow 2018

A.N. Severtzov Institute of Ecology and Evolution RAS
Australian Museum Research Institute
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FIELD GUIDE TO CALCAREOUS TUBEWORMS (POLYCHAETA, SERPULIDAE) OF THE ARCTIC OCEAN

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The book is a taxonomic guide to serpulid polychaetes (including the subfamily Spirorbinae) of the Arctic Ocean. Taxonomic keys include 37 serpulid species described and illustrated in detail. It starts with a description of serpulid morphology and includes a comprehensive glossary. Taxonomic treatment of species includes basic synonymy, references, and brief differential diagnoses. Information is also available on species reproduction, geographical distribution, and habitats in the Arctic Basin. Species illustrations are presented as light and scanning electron microscopy micrographs, photos of live specimens and line drawings. The book is based on extensive (over 600 samples) material collected all over the Arctic Ocean and deposited in Russia, Iceland, Germany, Norway, and Australia. The guide is based on the same material as Rzhavsky et al. (2014) "Calcareous tubeworms (Polychaeta, Serpulidae) of the Arctic Ocean", but it has another concept and target user: it is a simplified and lavishly illustrated field guide for identification definition of calcareous tubeworms in the field and laboratory. Detailed synonymy and taxonomic discussions are excluded. This guide is intended for undergraduate and graduate students, educators and naturalists as well as invertebrate zoologists, marine ecologists, and environmental consultants.

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INTRODUCTION

Serpulidae are obligatory sedentary polychaetes inhabiting calcareous tubes. They share the presence of a radiolar crown and division of the body into thoracic and abdominal regions. Their thorax is flanked by lateral thoracic membranes and the border between thorax and abdomen is marked by chaetal inversion, the chaetal arrangement where thoracic uncini switch from ventral to dorsal in the abdomen, while the chaetae switch from dorsal in the thorax to ventral in the abdomen. Traditionally the family Serpulidae was divided into three subfamilies: Spirorbinae, Serpulinae, and Filograninae (e.g., Rioja, 1923; Fauvel, 1927). Pillai (1970) elevated the Spirorbinae to the family status. Later, a number of authors (e.g., ten Hove, 1984; Smith, 1991; Kupriyanova, 2003; Kupriyanova et al., 2006), based on the results of phylogenetic analyses of morphological and molecular data, concluded that spirorbids are monophyletic and nested inside the Serpulidae. Kupriyanova's (2003) results of morphology-only analyses placed Spirorbinae as a sister group to Serpulinae. However, the results of analyses of both molecular (Lehrke et al., 2007; Kupriyanova et al., 2009) and combined morphological and molecular data (Kupriyanova et al., 2006) indicate that neither Serpulinae nor Filograninae are monophyletic and that Spirorbinae is a sister group to a clade containing mostly "filogranins" and some "serpulins". Therefore, the rank of the spirorbids has been lowered to the subfamily and all six former spirorbids sub-families are now placed at tribal ranks (Rzhavsky et al., 2013). Moreover, the traditional subfamilies Serpulinae and Filograninae have been abandoned pending revision and re-formulation as a result of a nearly comprehensive combined phylogenetic analysis (Kupriyanova et al., in prep.).

The Arctic Ocean, smallest of the world's oceans, centres approximately on the North Pole, covers much of the Arctic and washes upon northern North America and Eurasia. It is connected to the Pacific Ocean by the Bering Strait and to the Atlantic Ocean through the Greenland Sea and Labrador Sea, and is sometimes regarded as an estuary of the Atlantic Ocean. A number of opinions exists regarding the exact borders of the Arctic Ocean. Here we accept the opinion of Makkaveev (2005) that the line separating the Atlantic and Arctic Oceans goes along the entrance to Hudson Strait and through Davis Strait along 70°N from Baffin Island to the west coast of Greenland; then through the Denmark Strait from Cape Brewster on the east coast of Greenland to the Reydinupyr Point on the west coast of Iceland and along the Icelandic northern coast to Gerpir Point on the east. From Iceland the demarcation line goes to the Faroe Islands, passes north of Shetland Islands and then along 61°N to the Norwegian coast.

The border of Arctic and Pacific Oceans passes through the Bering Strait from Cape Dezhnev to Cape Prince of Wales.

GENERAL MORPHOLOGY

The description of serpulid morphology (including that of spirorbins) below is more detailed than one would need to identify only Arctic serpulids. However, this additional information may be useful for understanding of terminology used in other papers on serpulid taxonomy. The most comprehensive review of the serpulid morphology (excluding spirorbins) accompanied by numerous illustrations (ten Hove, Kupriyanova 2009).

Tubes. Serpulid tubes are composed of crystalline calcium carbonate (calcite, aragonite, or both) interspersed with a mucopolysaccharide matrix. The adult tube is secreted by glands located on the collar and tube additions are molded by the collar folds when the worm is in the feeding position. Tubes are usually chalky (**opaque**) white with rough or more or less smooth surface or white with smooth shining (porcellaneous) surface; rarely tubes may be completely or partially semitransparent because of the thin wall. Completely transparent tubes are termed **vitreous**.

Although tubes are mostly white, they may be completely or partly pink, bluish, orange purple, mustard, or even white with dark-brown transverse stripes. In spirorbins with vitreous tubes the inner tube lining or body of live specimens may be visible through tube walls, thus making the tubes appear coloured.

Spirorbins live in small spiral (hence the name) tubes 1.5–4 (up to 8) mm in coil diameter. Normally the spirals are flat, but the distal parts may be uncoiled and raised above the substrate, whorls being positioned on top of each other or attached to the substrate, not forming a spiral. Spirorbin tubes may be coiled clockwise (**sinistral**) or counter clockwise (**dextral**). Most species show only one coiling direction, but tubes of some *Spirorbis* coil in either direction. Rarely, some Circeini and Januini (most of which are dextral) have specimens with opposite coiling directions. Dextral forms have never been recorded for typically sinistral species.

In other serpulids the tube shape is variable and coiling, when present, is irregular. Most tubes are attached by at least the proximal older parts and some tubes are attached to the substrate throughout their entire length. Notable exceptions are the free-living *Ditrupa* (one species is known from the Arctic) and some deep-sea taxa.

Serpulid tubes are usually circular or sub-circular in external cross-section. Longitudinal **keels** usually do not change the tube cross-section, but some species may have triangular, quadrangular, pentangular or even octangular cross-sections. Within a single tube changes may occur from trapezoidal to multiangular or from triangular respectively trapezoidal/semi-circular to circular.

The external ornamentation (**sculpture**) of the tube surface typically consists of **longitudinal** and **transverse** elements. A single major prominent **keel**

may extend beyond the shaft of the chaeta forming a **heel**. Three main types of spirorbin abdominal chaetae (can be considered as sub-types of flat triangular) are: 1) **brush-type** chaetae with very short sharply narrowing blades and around 10 denticles (typical for Romanchellini, see Knight-Jones P., Fordy, fig. 68E-G); 2) **wide-bladed** chaetae with large wide blades that are of the same width along its entire length and sharply narrowing only at the distal end; heel absent or vestigial (typical for Januini); 3) **pennant-shaped** chaetae with the blade of the intermediate length gradually narrowing towards the distal end (Spirorbini, Circeini, Paralaeospirini, and Pileolariiini, as a rule with a heel).

In most serpulids abdominal chaetae usually become progressively longer posteriorly, the most posterior chaetae are capillaries or elongated modified chaetae. If capillary, chaetae of the most posterior abdominal segments are at least an order of magnitude longer than those of anterior and middle abdominal segments, they are referred to as “long capillary chaetae”. In spirorbins **companion capillary hooked** chaetae may be present in addition to flat geniculate chaetae on all abdominal chaetigers or only posteriorly. Long capillary chaetae are absent in spirorbins.

Abdominal uncini. In non-spirorbins saw- and/or rasp-shaped uncini vary according to their position. Rasp-shaped uncini are always found in the most posterior segments. Since polychaetes grow by addition of segments posteriorly, serpulids can shed their juvenile rasp-shaped uncini and replace them with saw-shaped adult uncini as they grow. Thus, juveniles always have rasp-shaped uncini.

In all spirorbins abdominal uncini are rasp-shaped with flat or slightly rounded anterior peg. Uncini may be either fairly symmetrically distributed along both body sides (Spirorbini, Januini, Pileolariiini) or their distribution may be sharply asymmetrical (Circeini, Paralaeospirini, Romanchellini). In the latter group, abdominal uncini on the convex body side are absent or very few only on 2–3 posterior abdominal segments.

METHODOLOGICAL REMARKS

Recommendations for identification of non-spirorbins

1. Removing serpulids from their tubes without any tube damage is rarely possible. Therefore, one needs to examine the tube carefully before breaking it to extract the animals.
2. To determine the number of thoracic chaetigers, one needs to count the number of rows of thoracic uncini on any side of the body and then add 1 for the collar segment (generally, but not always, marked by a bundle of chaetae only).
3. To study the details of the soft body structures (e.g., collar, thoracic membranes) worms should be stained with methylene blue, malachite green or a similar dye immediately before examination.

4. Because non-spirorbins are generally larger (with some exceptions) than spirorbins, mounting of the entire specimen (= destruction of the specimen) on a slide can be avoided. Thoracic chaetae, including collar chaetae, can be pulled with the finest dissecting forceps (watchmaker's forceps), and mounted on a slide. For examination of uncini and abdominal chaetae, a piece of the torus should be carefully extracted from the animal using a dissecting needle, placed on a slide, and covered with a cover slip. Slight pressure should be applied to the cover slip to position the uncini flat on their sides. Alternatively, dissected chaetae and tori with uncini can be placed on a stub and examined with SEM (preferable option).

Recommendations for identification of spirorbins

1. To determine the direction of the spirorbin tube coiling, it should be observed "as is": opposite the substrate, as being projected onto the substrate. Some earlier workers reported the coiling direction as seen from the substrate and this still leads to confusion sometimes. It is recommended to place the tubes in the same position as they are usually illustrated herein, i.e., with their mouths on the top. Examining the tubes in other positions, especially upside down, can easily result in a mistaken tube coiling direction.

2. To determine the number of thoracic chaetigers, one needs to count the number of rows of thoracic uncini on the concave body side and then add 1 for the collar segment. It should be done so because 1) notochaetae usually are present only on three first chaetigers; 2) number of tori may be incomplete on the convex side of body, and 3) tori are absent from 1st chaetiger.

3. To study the details of the soft body structures (e.g., thoracic membranes) the worms should be stained by methylene blue, malachite green or a similar dye immediately before the examination.

4. Mature oocytes lying freely (released spontaneously or because of damage in the tube during preparation) may be confused with embryos.

5. To study the chaetal structure, spirorbin specimens should be mounted on slides in glycerine, Fomblin or any other clearing medium. The animal should be positioned with the body side that in the tube turned to the substrate is facing up. Chaetal structure should be studied using an objective magnification of at least 40X, using phase contrast is helpful. This is a destructive study method (excluding glycerin) and should be done after the external morphology is examined under a dissecting microscope.

6. The collar chaetae should be observed when positioned strictly laterally, though it is not always and easy or possible). If the fin is small or the gap separating the fin from the blade is short, modified fin-and-blade collar chaetae may be mistaken for limbate chaetae.

7. The denticulate distal part of the sickle-shaped chaetae often is optically transparent and thus poorly visible. Besides, because there may be only

1–2 sickle chaetae in a fascicle or their distal denticulate part may be broken off, these chaetae may be overlooked. The best way to examine the chaetal structure is to prepare the entire specimen for SEM when possible.

Identification keys are given separately for non-spirorbins and Spirorbinae because of differences in their morphology. Two separate keys (one based on tube morphology and another on the body and chaetal morphology) are given for non-spirorbins, which is impossible to accomplish for Spirorbinae.

Material studied

In the section “Material” for every species given only the number of samples and specimens which we examined themselves and the detail information given in tables of Rzhavsky et al. (2014).

GLOSSARY

alveolus (*pl. alveoli*): small depression or hole, usually numerous, on the tube wall surface (Fig. 20 A-C).

Apomatus chaeta: sigmoid to overall sickle shaped thoracic chaeta, with a proximal denticulate zone and distal flat zone with rectangular teeth (Fig. 3E; 7G, see also **sickle-chaeta**).

apron: membranous flap formed by thoracic membranes joined ventrally past the last thoracic chaetigers (Fig. 9E; 15D).

basal groove: in spirorbins a depression in the basal part of blade on limbate collar chaetae.

bayonet chaeta: collar chaeta with one or two (sometimes more) large proximal bosses ("teeth") at the base of a distal limbate zone (e.g., Fig. 15G).

blade: distal, seemingly flat portion of a chaeta (see, however, **capillary** or **limbate** chaeta).

boss: small projection or knob-like process in collar chaetae of *Hydroides* and *Serpula* (Fig. 9I, 15G).

brood chamber: a structure for incubation of embryos; generally associated with tube or operculum (e.g., Fig. 5A; 27E; 30D, I).

brush-type chaetae: abdominal flat-geniculate chaetae in spirorbins with very short sharply narrowing blades and small number of denticles (around 10). Romanchellini only (see Knight-Jones P., Fordy, Fig. 68E-G).

capillary chaeta: slender chaeta tapering to a fine point; a collective term for elongate, needle-like chaetae of otherwise variable shape and ontogeny.

chaetal inversion: in serpulids and sabellids the thorax bears notochaetae dorsally and neurochaetae (uncini) ventrally; in the abdomen the position of chaetae and uncini is reversed. Unlike the abdomen of other serpulids that is turned 180° relative to the thorax, the abdomen of spirorbins is turned relative to the thorax by approximately 90°.

collar: an encircling membranous fold or flap covering the base of the radiolar crown (also see **thoracic membranes**).

collar chaetae: notochaetae located on the collar chaetiger, may be **modified** and non-modified (**limbate** or **capillary**).

collar chaetiger: first chaetiger bearing an anterior collar and notochaetae (**collar chaetae**), but lacking uncini.

companion capillary hooked chaeta: small capillary chaetae of spirorbins with curved tip which may have accompanying abdominal flat geniculate chaetae.

constriction: narrowing of the opercular peduncle or a transverse groove, at basis of funnel or ampulla (Fig. 3C, 4D).

crenulated: having a margin with small, low, rounded teeth.

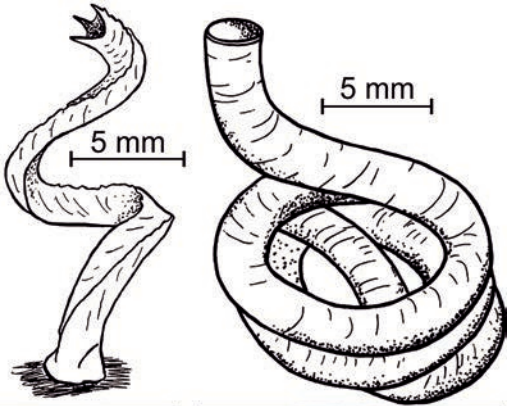
cross-striation of collar chaetae: rows of denticles on blades of modified collar chaetae blades that look like transverse lines under a compound light microscope (Fig. 18I, 20I).

crown of brood chamber: thin-walled circular rim surrounding distal part of opercular brood chamber, entire or consisting of petals (Fig. 32H, M).

KEY TO NON-SPIRORBINS BASED ON TUBE MORPHOLOGY

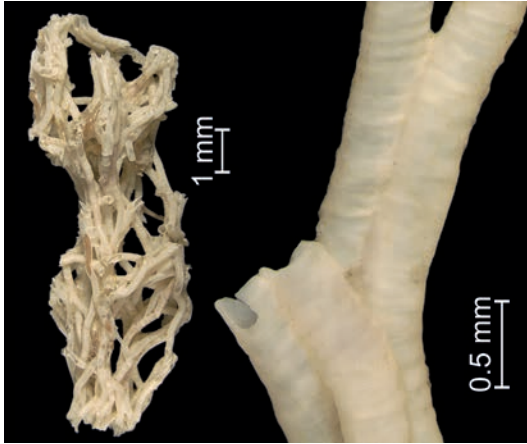


1a) Tube unattached to substrate tusk-shaped
..... *Ditrupa arietina* (p. ...)



1b) Tube attached to substrate at least in the proximal part 2





2a) Tubes forming pseudo-colonies consisting of numerous branching tiny tubes with diameter up to 1 mm. Initially attached to any hard substrate, later found in free clusters on coarse and silty sand, gravel; the pseudo-colony itself becomes a substrate for other organisms *Filograna implexa* (p....)



2b) Tubes solitary, incidentally forming gregarious masses encrusting substrate **3**

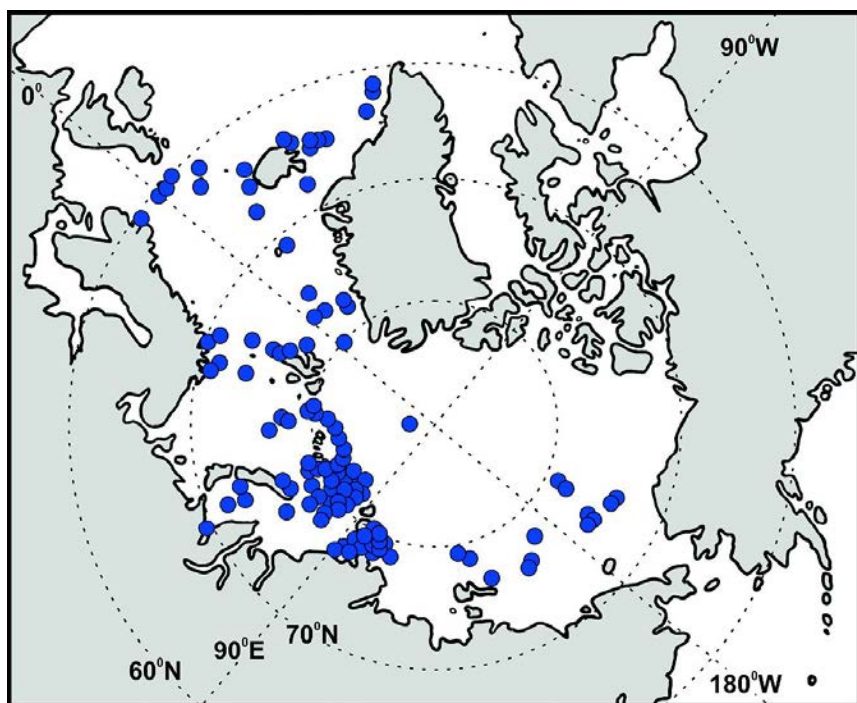
Genus *Apomatus* Philippi, 1844

Type-species: *Apomatus ampulliferus* Philippi, 1844

Tube white, opaque, circular in cross-section, keels and collar-like rings absent. Granular overlay may be present. Operculum a soft membranous vesicle without endplate borne on unmodified pinnulated radiole. Opercular constriction may be present. Pseudoperculum may be present on unmodified radiole. Radioles may be exceptionally flat ribbon-like; arranged in semi-circles (up to 3/4 of a circle), maximum number up to 40 per lobe in larger species. Inter-radiolar membrane present. Radiolar eyes in form of ocellar clusters. Mouth palps present. Seven thoracic chaetigerous segments. Collar trilobed with smooth margin. Thoracic membrane long, forming ventral apron across anterior abdominal segments. Tonguelets lobes absent. Collar chaetae limbate and capillary, may exceptionally be supplemented by *Apomatus* chaetae. *Apomatus* chaetae present in fascicles of other thoracic chaetae. Thoracic uncini saw-to-rasp-shaped with approximately 30 teeth in profile, up to 3–6 teeth in a row above and continuing onto peg; anterior peg long, blunt, almost rectangular. Ventral thoracic triangular depression absent. Abdominal chaetae sickle-shaped with finely denticulate blades; uncini rasp-shaped with approximately 30 teeth in profile. Short achaetous anterior abdominal zone present. Posterior capillary chaetae present. Posterior glandular pad present. (Diagnosis mainly after Kupriyanova, Nishi, 2010).

Remarks. The genera *Protula* Risso, 1826 and *Apomatus* Philippi, 1844 are distinguished by mainly by the presence (*Apomatus*) or absence (*Protula*) of a soft vesicular operculum on an unmodified radiole. The controversy whether *Apomatus* and *Protula* should be regarded as separate genera (e.g., ten Hove, Pantus, 1985) or synonymized under *Protula* (e.g., Kupriyanova, Jirkov, 1997) has not been resolved yet (ten Hove, Kupriyanova, 2009). A proper revision is needed, but here we consider these genera separately.

Nine species (ten Hove, Kupriyanova, 2009; Kupriyanova, Nishi, 2010), one known from the Arctic.



Map 1. Schematic distribution map of *Apomatus globifer* in the Arctic (our data). Records from the North Sea on the border with the Norwegian Sea and south of Greenland on the border with the Greenland Sea also plotted.

Apomatus globifer Théel, 1879

(Fig. 2A-F, map 1)

Apomatus globifer Théel, 1879, p. 66, pl. IV, fig. 63-65; Rzhavsky et al., 2014, p. 26-29, fig. 1 A-E (synonymy).

Protula globifera: Kupriyanova, Jirkov, 1997, p. 222-225, fig. 9A-J, map 9.

Material. About 1700 specimens from 101 samples (Rzhavsky et al., 2014).

Description. Tube white opaque (Fig. 2A, B), up to 5.0 mm in diameter, circular in cross section, usually attached to substrate at base only, distal part free. Tube surface with poorly expressed “honeycombed” structure (Fig. 2B). Body length without radioles up to 26 mm (Fig. 2E). Live animals with white (Fig. 2C) or red radiolar crown, body red.

Number of radioles 10–40 pairs. Radioles connected by inter-radiolar membrane. Radiolar eyes present, but not seen in preserved material. Operculum a globular soft membranous transparent vesicle on a normal pinnulated radiole, no obvious constriction (Fig. 2A, C, E). Sometimes an additional similar operculum (pseudoperculum?) present. Collar entire, short, not covering bases of radiolar lobes, tonguelets absent. Thoracic membranes wide, continuing to last thoracic segment and forming a wide apron ventrally (Fig. 2D, E).

Seven thoracic chaetigers, including six uncinigerous (Fig. 2D, E). Thoracic neuropodia at least three times longer than abdominal notopodia (Fig. 2E). Collar chaetae limbate (Fig. 2F) and capillary. Other thoracic chaetae limbate and *Apomatus* chaetae. All uncini rasp-shaped. Achaetous zone long. Up to 120 abdominal chaetigers. Anterior and middle abdominal chaetae short, sickle-shaped with finely denticulate blades, replaced by long capillaries posteriorly.

Remarks. The tentative record of *Apomatus similis* Marion, Bobretzky, 1875 from the Central Arctic (Knox, 1959) is based on empty tubes and tube fragments from three stations. For synonymy details see Rzhavsky et al. (2014).

Ecology and reproduction. In the Arctic found at depths of 18–3384 m corresponding to average temperature of 2.0°C, attached to rocks, gravel in various soft substrates excluding fine sands and rarely on coarse sand. Reproduction unknown.

Distribution. Arctic: Chukchi, East-Siberian, Laptev, Kara, Barents, Norwegian, Greenland Seas, around Iceland, and Central Arctic Basin.

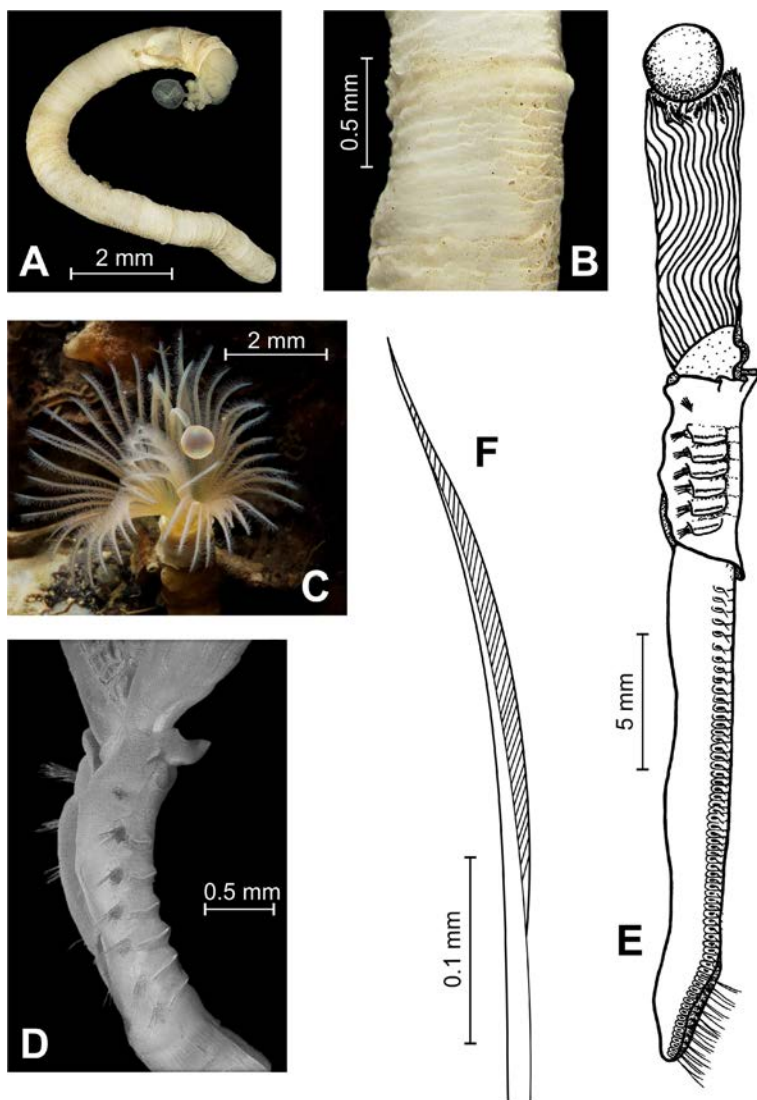


Figure 2. *Apomatus globifer*. A – preserved animal in tube; B – tube fragment; C – live worm with opened radiolar crown and operculum on pinnulated radiole; D – thorax; E – entire body, lateral view; F – limbate collar chaeta. E-F – from Kupriyanova, Jirkov (1997). A-B, D – photo E. Wong, C – photo F. Pleijel.

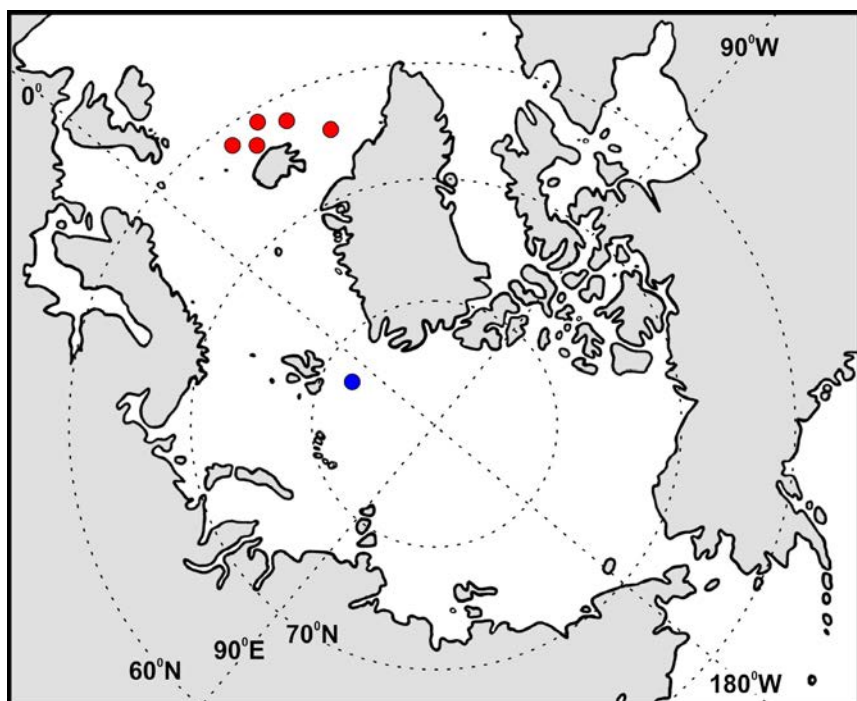
Genus *Bathyvermilia* Zibrowius, 1973a

Type-species: *Bathyvermilia challenger* Zibrowius, 1973a.

Tube white, opaque, circular in cross-section, keel(s) may be present. Collar-like rings present. Granular overlay absent. Operculum sub-globular, with simple flat to slightly conical chitinous endplate, which may be encrusted by calcareous deposit. Peduncle cylindrical, smooth or wrinkled, without distal wings; inserted as second dorsal radiole on one side, constriction present. Pseudoperculum absent. Arrangement of radioles in semi-circles, up to 35 per lobe. Inter-radiolar membrane absent. Radiolar eyes not observed. Mouth palps may be present. Seven thoracic chaetigerous segments. Collar trilobed or non-lobed with entire edge, tonguelets absent. Thoracic membranes variable, ending at 2nd–7th thoracic segments. Collar chaetae limbate and capillary. *Apomatus* chaetae present. Thoracic uncini saw-shaped, with 6 to 10 teeth. Anterior fang pointed. Abdominal chaetae flat narrow geniculate with blunt teeth; abdominal uncini saw-shaped, except in a few far posterior segments, with rasp-shaped uncini. Achaetous zone present. Posterior capillary chaetae present. Posterior glandular pad present.

Remarks. Zibrowius (1973a) established the genus *Bathyvermilia* for the deep-water *Vermiliopsis langerhansi* Fauvel, 1909 and the newly described *Bathyvermilia challenger* (new name for *Placostegus ornatus* not Mörch, 1863, but *sensu* McIntosh, 1885). Later, three species (*Bathyvermilia zibrowiusi* Kupriyanova, 1993b from Kurile-Kamchatka trench, *B. islandica* Sanfilippo, 2001 from off Iceland, and *B. kupriyanovae* Bastida-Zavala, 2008 off California) were added and *Vermiliopsis? eliasoni* Zibrowius, 1970 was transferred to *Bathyvermilia* by Kupriyanova, Nishi (2010).

Six species, two known from the Arctic.



Map 2. Schematic distribution map of *Bathyvermilia eliasoni* (blue, our data) and *Bathyvermilia islandica* (red, literature data) in the Arctic.

***Bathyvermilia eliasoni* (Zibrowius, 1970)**

(Fig. 3A-G, map 2)

Vermiliopsis (gen?) *eliasoni* Zibrowius, 1970, p. 121-122. *Vermiliopsis eliasoni*: ten Hove, Kupriyanova, 2009, p. 91, 102; *Bathyvermilia eliasoni*: Kupriyanova, Nishi, 2010, p. 57-60, fig. 3, 4; Rzhavsky et al., 2014, p. 29-31, fig. A-J (synonymy).

Material. Two specimens from two samples (Rzhavsky et al., 2014).

Description. Tube white opaque (Fig. 3A, B), up to 2.0 mm in diameter, more or less circular in internal cross-section, attached to substrate throughout their length, with three keels made of long curved spines, no peristomes. Tube surface smooth. Body length without radioles up to 21 mm. Colour of live animals unknown.

Number of radioles 7–10 pairs. No inter-radiolar membrane. Radiolar eyes not observed in preserved material. Operculum inverted cone with white, calcareous, slightly depressed endplate (Fig. 3C). Pseudoperculum absent. Peduncle circular in cross-section, slightly thicker than normal radioles and inserted as a second radiole. Deep constriction at junction of ampulla and peduncle. Collar penta-lobed, with two latero-dorsal and a ventral lobe subdivided into three lobes, tonguelets absent. Thoracic membranes short, continuing to 3rd thoracic chaetiger.

Seven thoracic chaetigers, including six uncinigerous. Thoracic neuropodia several times longer than abdominal notopodia. Abdominal tori short. Collar chaetae limbate and capillary (Fig. 3D). Other thoracic chaetae limbate and *Apomatus* chaetae (Fig. 3E). Thoracic uncini saw-shaped. Achaetous zone short. Up to 60 abdominal chaetigers. Anterior abdominal chaetae flat narrow geniculate with blunt teeth (Fig. 3F), replaced by capillary chaetae posteriorly. Anterior abdominal uncini saw-shaped (Fig. 3G), uncini of middle and posterior abdominal segments rasp-shaped. Posterior glandular pad present.

Remarks. This species differs from all other *Bathyvermilia* spp., including *B. islandica* from the Arctic, by its very characteristic tube, lacking peristomes, but with three keels made of distinct long spines.

Ecology and reproduction. In the Arctic known from 3570 m. Reproduction unknown.

Distribution. Arctic: Jesup Rise 84°5.9'N, 14°24.88'E – 85°25.1'N, 12°7.06'E).

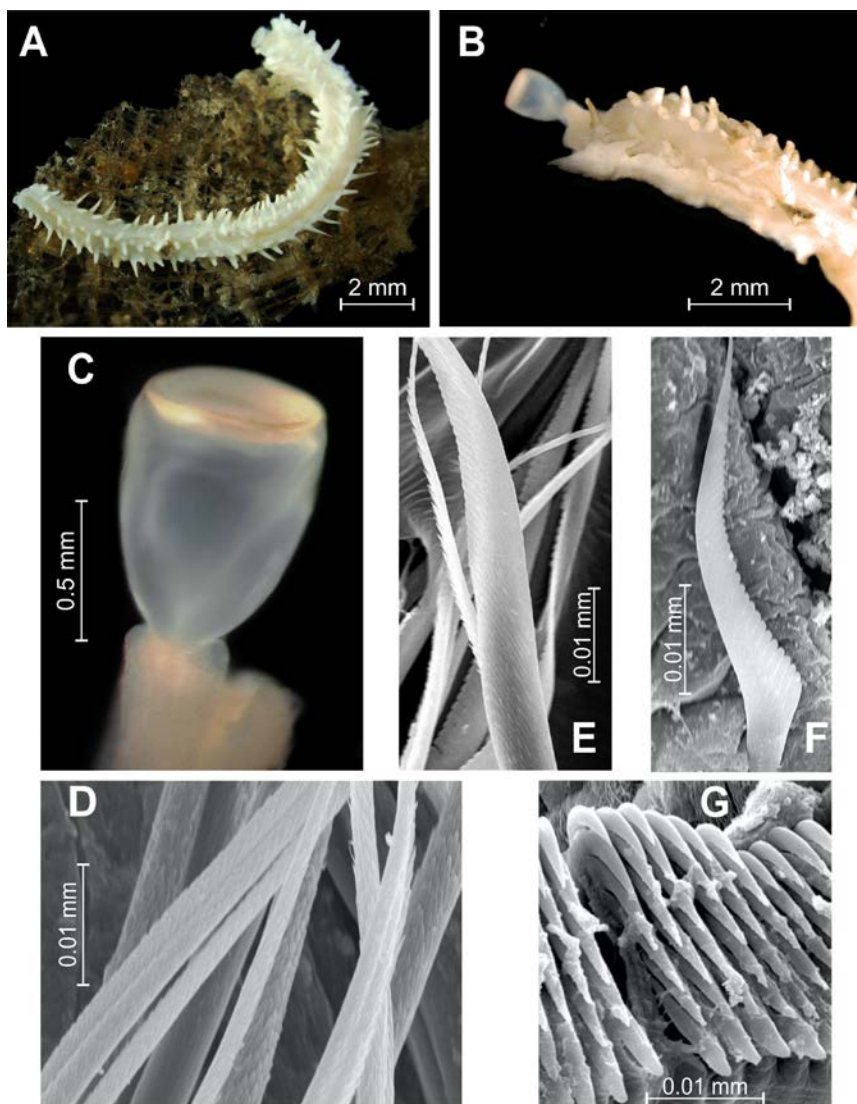


Figure 3. *Bathyvermilia eliasoni*. A – tube; B – tube fragment with body; C – operculum with calcareous endplate; D – collar limbate and capillary chaetae; E – *Apomatus* chaetae; F – abdominal chaeta; G – thoracic uncini. A, C-G – from Kupriyanova, Nishi (2010), B – photo E. Nishi.

***Bathyvermilia islandica* Sanfilippo, 2001**

(Fig. 4A-F, map 2)

Bathyvermilia islandica Sanfilippo, 2001, p. 178-181, fig. 2A-F, 3A-G.

Material. One specimen (holotype). Known only from original description.

Description. Tube (Fig. 4A, B) white opaque, solid, 3.8 mm in diameter with porcellaneous surface; circular in cross section, attached to substrate throughout entire length, forming a peripheral basal flange. Distal tube part may be raised from substrate. Undulating peristomes rarely present along tube. Tube mouth simple, with one dorsal and two lateral lobes resulting in an undulating edge, widened into a peristome. Body length without radioles 14 mm. Colour of live animals unknown.

Number of radioles 12–13 (based on Sanfilippo 2001). Radioles not connected by inter-radiolar membrane. Radiolar eyes not observed in preserved material. Operculum an inverted cone (Fig. 4D), hollow (with a smaller soft operculum inside), covered with a slightly convex, light-yellow chitinous endplate, with two or more concentric indistinct zones, no calcareous deposit. Deep constriction at junction of ampulla and peduncle. Pseudoperculum absent. Collar unlobed, short, of uniform width, barely covering bases of radiolar lobes (Fig. 4C), tonguelets absent. Thoracic membranes wide, continuing up to 2nd segment and then narrowing sharply, ending at 7th thoracic chaetiger, but not forming apron (Fig. 4C).

Seven thoracic chaetigers, including six uncinigerous (Fig. 4C). Thoracic neuropodia several times longer than abdominal notopodia. Collar chaetae limbate and capillary, other thoracic chaetae limbate and *Apomatus* (Fig. 4E, F). Thoracic uncini saw-shaped. Achaetous zone present. Up to 60 abdominal chaetigers. Anterior abdominal chaetae flat geniculate, with broad triangular denticulate blades, replaced by numerous long capillary chaetae posteriorly. Anterior abdominal uncini saw-shaped replaced by rasp-shaped on most posterior segments. Posterior glandular pad unknown.

Remarks. *Bathyvermilia islandica* differs from another Arctic species, *B. eliasoni*., by its tube with smooth shiny surface, rare undulating peristomes and by the operculum covered with a convex chitinous endplate, lacking calcareous deposits. *Bathyvermilia islandica* is also distinct in having long thoracic membranes ending at the 7th thoracic chaetiger as opposed to the 3th–4th thoracic chaetiger in all other *Bathyvermilia* spp.

Ecology and reproduction. Deep and cold-water species found at depths 770–2399 m on volcanic rock, “soap-stones”, corals, mollusc and brachiopod shells. Reproduction unknown.

Distribution. On border of Atlantic and Arctic Oceans. South of Iceland, from 61°N–64°N, type locality only (Sanfilippo, 2001).

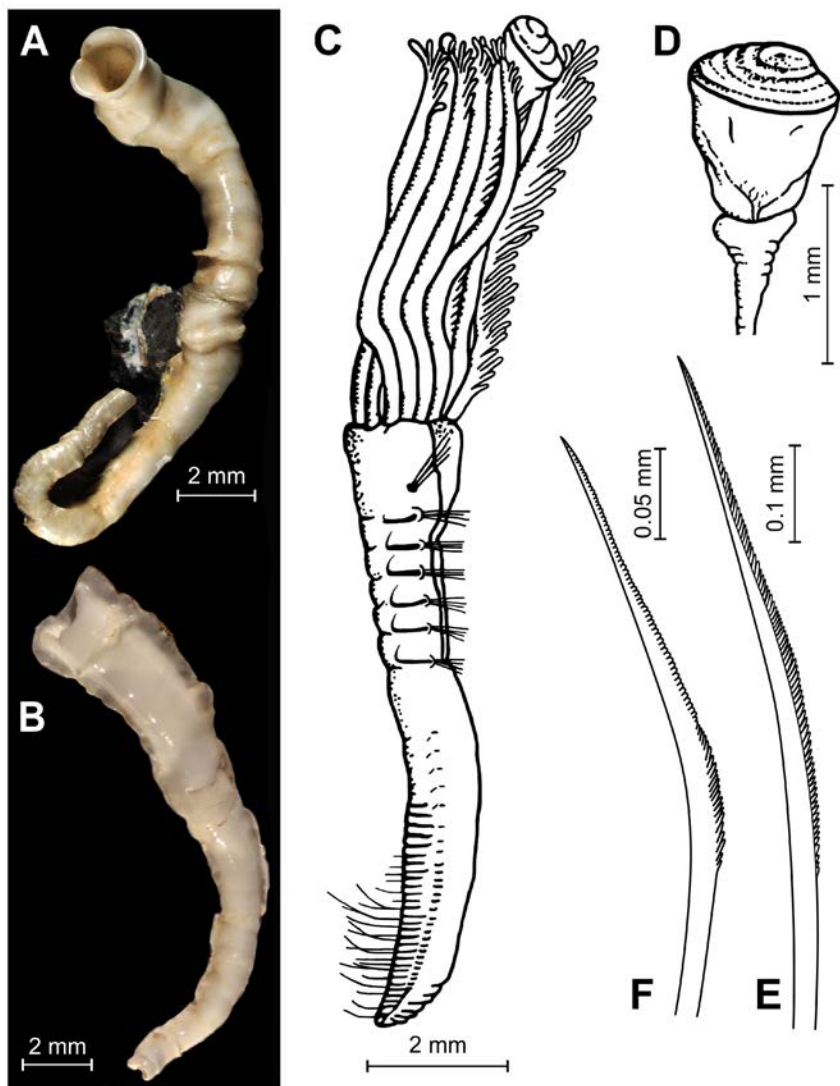
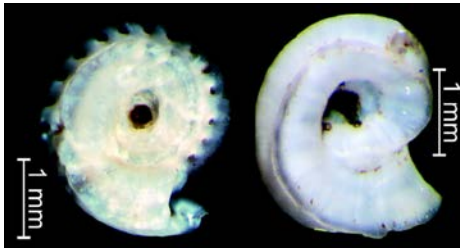


Figure 4. *Bathyvermilia islandica*. A, B – tubes; C – entire body, lateral view; D – operculum; E – limbate collar chaeta; F – *Apomatus* chaeta. B-F – from Sanfilippo (2001), A – photo R. Sanfilippo.

KEY TO SPIRORBINS



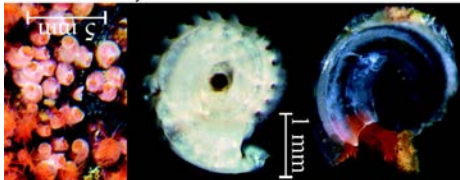
1a) Tube dextral (rarely some species have sinistral specimens) **2**



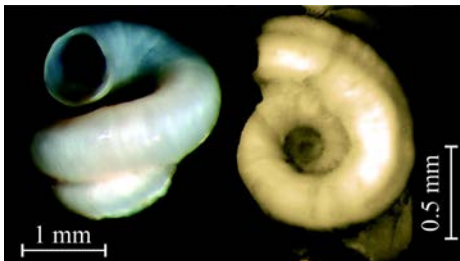
1b) Tube always sinistral **6**

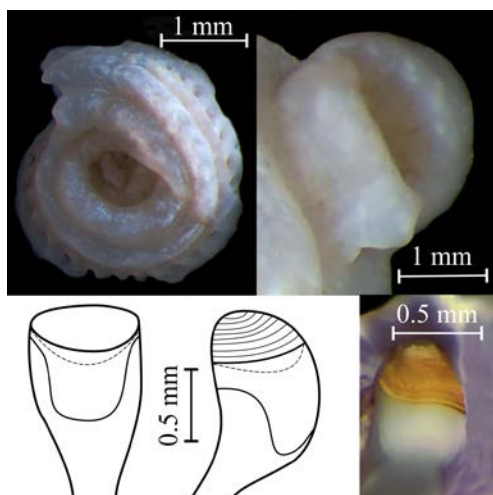


2a) Tube thick-walled, hard (preparation needle may be easily broken during tube destruction); vitreous (preserved may be white non-transparent); inner lining of tube or body of live specimens may be seen through tube walls make tubes to appear coloured. Four thoracic chaetigers **3** (*Paradexiospira*)

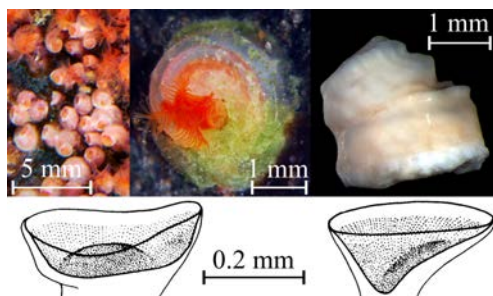


2b) Tube thin-walled, fragile (easily broken by preparation needle), white opaque, porcellaneous or not; body colouration not visible through tube walls. Three thoracic chaetigers **4**

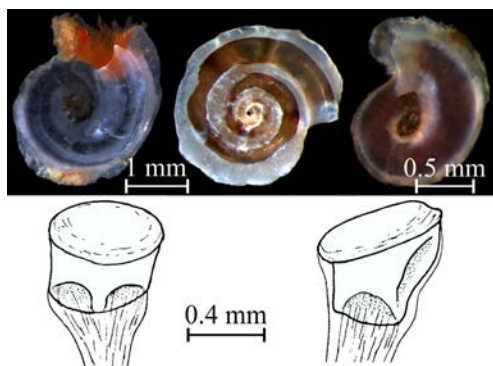




3a) Tube planospiral; peripheral alveoli present (may absent in juveniles). Body of live worms colourless, inner tube lining absent, so tubes looking greyish-white. Opercular endplate cup-shaped, covered by easy broken brown domed membrane forming a hollow cavity under endplate; talon thick, shovel-shaped
... *Paradexiospira (Spirorbides) cancellata* (p. ...)



3b) Tube planospiral or with overlapping whorls making tubes turret-shaped when their height equal to or exceeding diameter; alveoli absent. Red body of live animals visible through transparent wall making tube appear pink. Opercular endplate cup-shaped, slightly calcified, not covered by domed membrane. Talon absent or vestigial cone-shaped
... *Paradexiospira (Spirorbides) vitrea* (p. ...)



3c) Tube planospiral, alveoli absent. Deep violet or brown inner tube lining visible through tube walls making tubes appear almost black. Opercular endplate calcified flat or slightly convex, covered by brown membrane tightly attached to endplate surface. Talon massive with two oval lateral incisions
..... *Paradexiospira (Paradexiospira) violacea* (p. ...)

Circeini Knight-Jones P., 1978

Type genus *Circeis* Saint-Joseph, 1894.

Embryos stick to each other and directly to inside of tube wall. Operculum a distal plate usually with a talon. Larvae without white attachment glands. Thoracic uncini wide, rasp-shaped, with 3–15 longitudinal rows of teeth and blunt anterior peg. Abdominal uncini distributed asymmetrically, on convex body side may be absent or present on last chaetigers only. Largest abdominal tori on concave body side in anterior half of abdomen. Abdominal chaetae flat geniculate, pennant-shaped, usually with a thick (optically dense) projecting heel; their blade lengths not exceeding that of largest collar chaetae, width decreasing gradually towards tips. Abdominal companion capillary hooked chaetae absent or present on last chaetigers only.

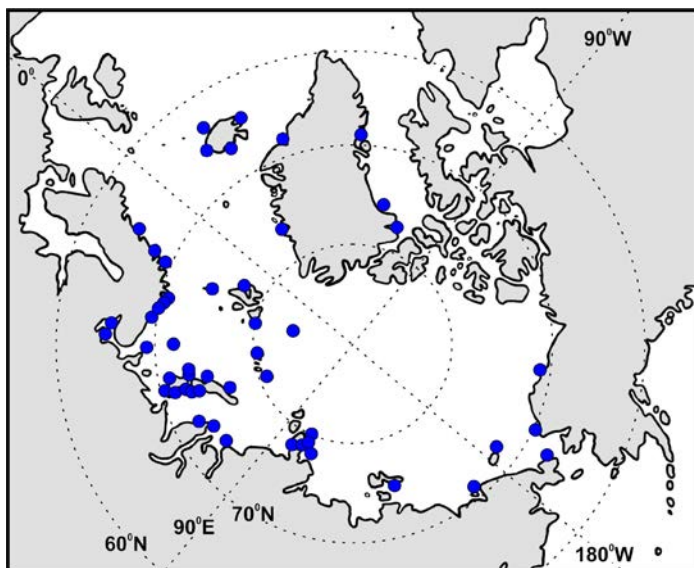
Two genera, *Circeis* and *Paradexiospira*, both known from the Arctic.

Genus *Circeis* Saint-Joseph, 1894

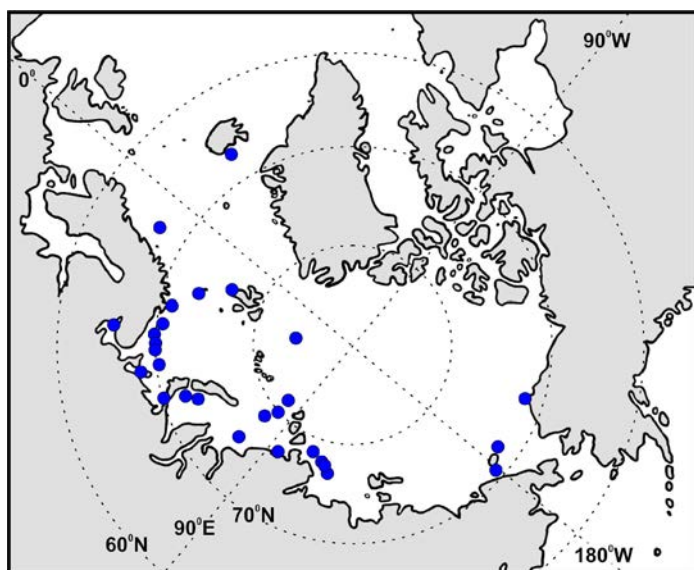
Type species: *Circeis armoricana* Saint-Joseph, 1894.

Tubes usually dextral, one species regularly and several species occasionally coiled sinistrally. Margins of collar and thoracic membranes not fused over thoracic groove. Large collar chaetae modified, bent (usually strongly), with vestigial lateral cross-striation or cross-striated from “frontal side” of blade, not visible laterally under a dissecting microscope. Sickles (*Apomatus*) chaetae absent. Always three thoracic chaetigers.

Six species, two known from the Arctic.



Map 14. Schematic distribution map of *Circeis armoricana* in the Arctic (our and literature data).



Map 15. Schematic distribution map of *Circeis spirillum* in the Arctic (our and literature data).

Circeis armoricana Saint-Joseph, 1894

(Fig. 17A-K, map 14)

Circeis armoricana Saint-Joseph, 1894 p. 350, tab. XIII, fig. 387; Rzhavsky et al., 2014, p. 77-80, fig. 17 A-E (synonymy). *Circeis spirillum* non (Linnaeus, 1758): Tzetlin, 1985, p. 44, fig. 1R-Zh.

Material. Some thousands specimens from 61 samples (Rzhavsky et al., 2014).

Description. Tube (Fig. 17A-D) normally dextral, sinistral specimens recorded from Pacific coast of North America (Knight-Jones P. et al., 1979) and Baltic Sea (Bock, 1953, as “*spirillum*”). Up to 2–2.5 mm in coil diameter. Tube walls typically unsculptured or with one (rarely up to 3) keels; usually planospiral; on filamentous algae and uneven substrates whorls overlapping, ascending over substrate or last whorl may be erected. Tube walls white, opaque, slightly porcellaneous, often with narrow semitransparent transverse rings. Live worms with colourless radioles and light orange body (Fig. 17E).

Endplate (Fig. 17F-I) slightly concave or flat. Talon eccentric, small, conical in frontal view, sometimes large and flattened.

Large collar chaetae (Fig. 17J, K) modified, strongly bent, their blades almost perpendicular to chaetal shaft on body convex side, but less strongly curved on concave side. Vestigial cross-striation on “frontal side” (Knight-Jones P., Fordy, 1979, Fig. 11) of blade not visible laterally (SEM examination needed). Under dissecting microscope blades looking somewhat serrated, without cross-striation.

Remarks. For a long time, *C. armoricana* was synonymized with *C. spirillum*. Tubes of “*spirillum*” are typically strongly ascending, brightly porcellaneous, semi-transparent. Blades of modified collar chaetae of “*spirillum*” from convex body side are never perpendicular to the chaetal shaft and have vestigial basal cross-striation; the talon is always large and flattened. Three subspecies of “*armoricana*” are described from the North Atlantic (Knight-Jones P., Knight-Jones E.W. 1977). Later *C. a. paguri* was elevated to species rank as *Circeis paguri* Knight-Jones P., Knight-Jones E.W., 1977 by Al-Ogily S.M., Knight-Jones E.W. (1981). *Circeis* “*armoricana*” is likely a species complex that needs further study.

Ecology. A common and abundant species in the Arctic *C. armoricana* recorded from the intertidal zone to 271 m deep (preferred depths 0-50 m, attached to macrophytes, rocks, shells, crustaceans, polychaete tubes, ascidians, artificial substrates, rarely bryozoans and hydrozoans. Live mixed with many other spirorbins. In literature often reported as “*S. spirillum*”.

Distribution. Arctic: Central Arctic Basin, Chukchi, East-Siberian, Laptev, Kara, Barents, White, Norwegian, Greenland Seas; also reported from Arctic coast of Alaska and off Iceland.

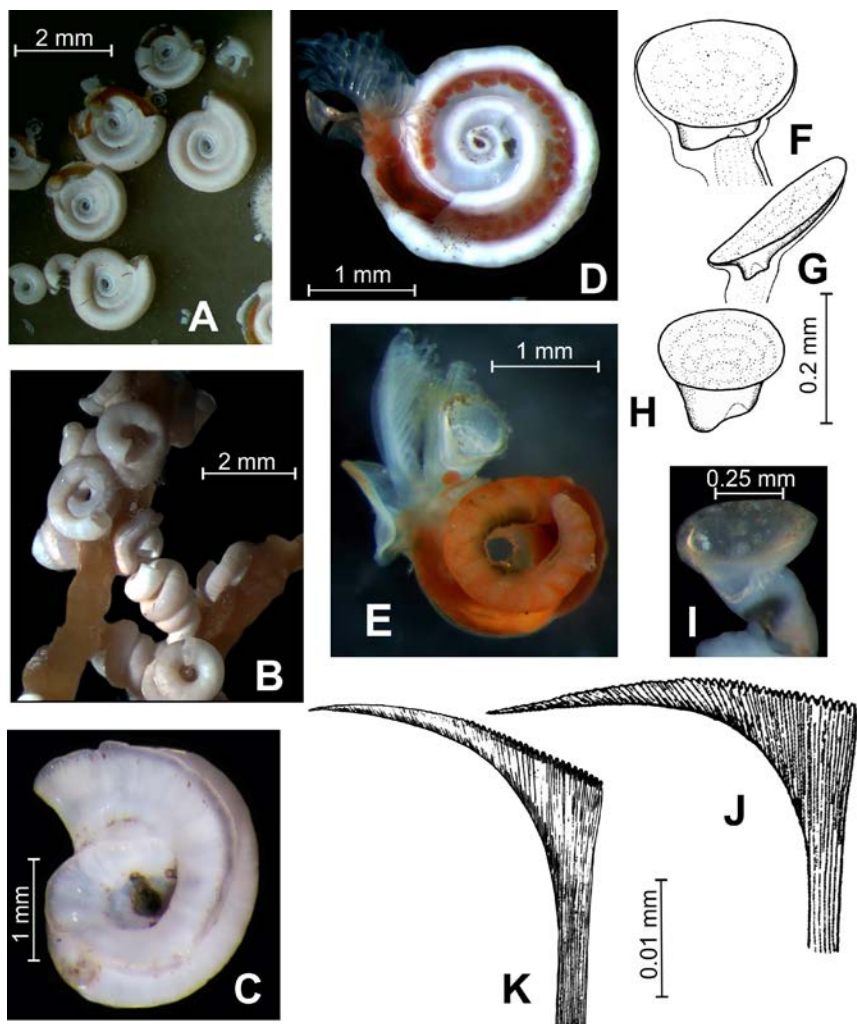


Figure 17. *Circeis armoricana*. A – planospiral unsculptured tubes on *Laminaria* sp.; B – tubes with overlapping coils on filamentous alga; C – tube with one longitudinal keel; D – tube with embryos, inside view; E – complete worm's body, view from the side of substrate; F, G, I – typical operculum, frontal and lateral views; H – operculum with well-developed talon similar with *C. spirillum*; J – modified collar chaeta from convex body side; K – modified collar chaeta from concave body side. F-H, J, K – from Knight-Jones P., Knight-Jones E.W. (1977). A-E, I – photo A.V. Rzhavsky.

***Circeis spirillum* (Linnaeus, 1758)**

(Fig. 18A-J, map 15)

Serpula spirillum Linnaeus, 1758, p. 786; 1767, p. 1264. *Serpula lucida* Montagu, 1803, p. 515-516. *Spirorbis (Dexiospira) spirillum*: Bergan, 1953: 41-42, non fig. 6a-c (partim?). *Circeis spirillum*: Knight-Jones P., Knight-Jones E.W., 1977, p. 471, fig. 5N-U; Rzhavsky et al., 2014, p. 81-83, fig. A-G, pl. 2 H (synonymy).

Material. About 500 specimens from 44 samples (Rzhavsky et al., 2014).

Description. Tube dextral, only initial whorls planospiral, others overlapping or ascend over substrate (Fig. 18A-E), tube length up to 6–7 mm; unsculptured; white, semitransparent, porcellaneous. Colour of live specimens unknown. Body short compared to tube length.

Endplate (Fig. 18F-H) slightly concave; talon eccentric and flat, widely spatulate in frontal view.

Large collar chaetae modified and asymmetrically cross-striated: vestigial cross-striation visible only on basal parts of blades from body convex side (Fig. 18I). Chaetae from concave body side bent at 45° (Fig. 18G), while chaetae from convex side only slightly bent.

Remarks. *Serpula lucida* (Montagu, 1803) is an accepted synonym of *C. spirillum*, other nominal taxa may have been synonymized erroneously or their taxonomical position is unclear. For a long time, *C. armoricana* was considered a junior synonym of “*spirillum*” though these two species are clearly distinct. Often *C. spirillum* was reported as *Spirorbis spirillum* var. *ascendens*, whereas *C. armoricana* as “*spirillum*”. Unlike *C. spirillum*, *C. armoricana* typically has planospiral tubes, even though whorls may be ascending or overlapping on substrates with limited area of attachment. The tubes of “*armoricana*” are not so brightly porcellaneous and not completely semitransparent. Collar chaetae in “*armoricana*” are strongly bent with blades positioned almost perpendicular to the chaetal shaft, and have no lateral cross-striation; the talon is smaller and usually conical. These two species usually differ ecologically. *C. spirillum* almost exclusively uses hydrozoans and bryozoans as a substrate, whereas “*armoricana*” is eurythopic, but rarely settles on bryozoans and hydrozoans. Other details see in Rzhavsky et al. (2014).

Ecology. In the Arctic Ocean mainly encrusts hydrozoans and bryozoans at depths of 5–171 m, preferred bathymetric range 50–100 m. As an exception, “*spirillum*” was recorded from the White Sea on red algae *Ptilota* (see Jakovis, 1997). Sometimes lives mixed with *B. (J.) quadrangularis* and *B. (J.) acuticostalis*.

Distribution. Arctic: Central Arctic Basin, Chukchi, Laptev, Kara, Barents, White, Norwegian and Greenland Seas.

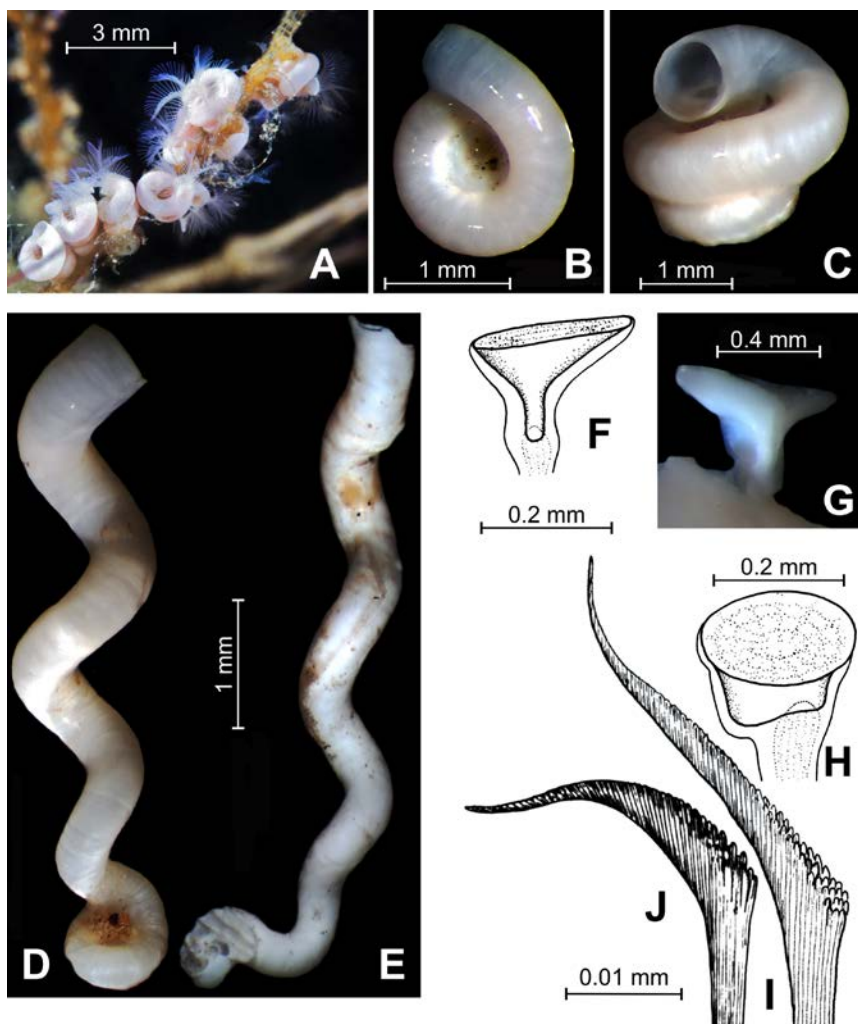


Figure 18. *Circeis spirillum*. A – settlement on hydrozoans in the field; B – planospiral juvenile specimen; C – tubes with overlapping coils; D, E – typical ascending tubes; F, G – operculum, lateral view; H – operculum, frontal view; I – modified collar chaeta with vestigial lateral cross-striation from convex body side; J – collar chaeta with without vestigial lateral cross-striation from concave body side. F, H-J – from Knight-Jones P., Knight-Jones E.W. (1977). A – photo A. A. Semenov, B-E, G – photo A. V. Rzhavsky.

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