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## A NEW SPECIES OF *RARICIRRUS* (POLYCHAETA, CTENODRILIDAE) FROM THE CONTINENTAL SLOPE OF THE LAPTEV SEA NEAR THE GAKKEL RIDGE

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### ABSTRACT

*Raricirrus arcticus* sp. nov. is described with specimens collected near the Gakkel Ridge, Laptev Sea, from one station in the hydrothermal area, at nearly 2000 m. The new species differs from the other species of the genus in the presence of long serrate chaetae with thin straight tips in neuropodia of the middle part of the body, and in the position of the heart body, which first appears much more anteriorly than in all previously described species of both genera comprising the subfamily Raphidrilinae Hartmann-Schröder, 1971. *Raricirrus arcticus* sp. nov. is likely most closely related to the geographically nearest *R. beryli* Petersen et George, 1991 sharing the absence of a modified region with enlarged spines and the presence of distinct ventral ciliary fields in the area of the mouth and the neural ciliary band on a few anterior segments. Asexual and sexual reproduction is noted for the new species. The hypothesis of Petersen and George (1991) about the role of the heart body in the head regeneration process is supported by revealed correlation of the anteriormost occurrence of the heart body with the number of segments in anterior regenerates in *R. arcticus* sp. nov., as in other *Raricirrus* species. Systematic position of the family Ctenodrilidae and taxonomic differences between the genera *Raricirrus* Hartman, 1961 and *Raphidrilus* Monticelli, 1910 are discussed. Morphological characters useful in distinguishing species within the genus *Raricirrus* are defined. A key to identify the known species of *Raricirrus* is given.

**Key words:** Arctic Ocean, Ctenodrilidae, morphology, Polychaeta, *Raricirrus arcticus* sp. nov., reproduction

## НОВЫЙ ВИД *RARICIRRUS* (POLYCHAETA, CTENODRILIDAE) С КОНТИНЕНТАЛЬНОГО СКЛОНА МОРЯ ЛАПТЕВЫХ В РАЙОНЕ ХРЕБТА ГАККЕЛЯ

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### РЕЗЮМЕ

Приводится описание нового вида рода *Raricirrus* Hartman, 1961, найденного на глубине около 2000 м в море Лаптевых. Экземпляры *Raricirrus arcticus* sp. nov. были добыты в гидротермальном районе в зоне разлома, отделяющего хребт Гаккеля от Бассейна Нансена. Новый вид отличается от других видов рода наличием длинных зазубренных щетинок с тонкими прямыми концами в нейроподиях средней части тела и положением сердечного тела, которое начинается значительно ближе к голове, чем у всех видов, ранее описанных в обоих родах, составляющих подсемейство Raphidrilinae Hartmann-Schröder, 1971. *Raricirrus arcticus* sp. nov. вероятно наиболее близкородственен географически ближайшему *R. beryli* Petersen et George, 1991. Оба вида объединяет отсутствие модифицированного отдела тела с увеличенными крючками и наличие отчетливых

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ресничных полей на вентральной стороне тела в области ротового отверстия и нейральной ресничной полоски на нескольких передних сегментах тела. У нового вида обнаружено бесполое и половое размножение. Выявлена корреляция между передним положением сердечного тела и количеством сегментов в головных регенератах *R. arcticus* sp. nov. и других видах рода *Raricirrus*, что поддерживает гипотезу М. Петерсен и Д. Джорджа (Petersen and George 1991) о роли сердечного тела в процессе регенерации головы у представителей рода. Обсуждаются систематическое положение семейства Ctenodrilidae и таксономические различия между родами *Raricirrus* и *Raphidrilus* Monticelli, 1910. Определены морфологические признаки, пригодные для различения видов в пределах рода *Raricirrus*. Представлен определительный ключ для известных видов *Raricirrus*.

**Ключевые слова:** Северный Ледовитый океан, Ctenodrilidae, морфология, Polychaeta, *Raricirrus arcticus* sp. nov., размножение

## INTRODUCTION

The collection gathered during the expedition of the German research vessel *Polarstern* in the Arctic Ocean in 1993 contained the first specimens of ctenodrilid polychaetes to be reported from Eurasian Arctic Seas. The worms were obtained from the Laptev Sea and initially were recorded as *Raricirrus* sp. without description (Buzhinskaja 2001). In the present paper the specimens are described as *Raricirrus arcticus*, new species of the subfamily Raphidrilinae Hartmann-Schröder, 1971. Only three species of the genus *Raricirrus* Hartman, 1961 were hitherto described: *R. maculatus* Hartman, 1961 from the north-eastern Pacific off California, *R. beryli* Petersen et George, 1991 from the north-eastern Atlantic, and *R. variabilis* Dean, 1995 from the Caribbean. Among these species only *R. variabilis* was found living in deep-water, 4000 m depth, while the two other species are known from shallow waters at depths ranging from 46 to 300 m. *Raricirrus maculatus* and *R. beryli* possess both sexual and asexual modes of reproduction, and only sexual reproduction is known for *R. variabilis* (Dean 1995). The material herein reported allowed us to study reproductive patterns of *R. arcticus* sp. nov.

The subfamily Raphidrilinae Hartmann-Schröder, 1971 comprises two genera: *Raphidrilus* Monticelli, 1910 and *Raricirrus* (Petersen and George 1986). This paper provides additional evidence concerning the taxonomic separation of these genera, and further elucidates their diagnostic characters. The systematic position of the family Ctenodrilidae is briefly discussed and it is retained as a separate family from Cirratulidae.

**Institutional abbreviations.** ZIN: Zoological Institute, Russian Academy of Sciences (Saint Petersburg), Russia.

## MATERIAL AND METHODS

A few dozen specimens of ctenodrilid-like polychaetes were taken by Agassiz trawl from 1992–1993 m depth along the continental slope in the northern Laptev Sea, in the fault zone separating the Gakkel Ridge from the Nansen Basin. This fault zone is seismically and thermally active (Kim et al. 2006). The specimens of *Raricirrus arcticus* sp. nov. were found on the surface sediment layer among subfossil bivalve shells belonging to the genus *Archivesica* Dall, 1908 (fam. Vesicomidae). These mussels are characteristic inhabitants of cold seeps and hydrothermal vents, and the presence of their shells indicates that the actual seeping activity in the neighborhood of the Gakkel Ridge is low or absent now, though methane and hydrogen sulfide are still detected in the sediments (Sirenko et al. 2004; Kim et al. 2006). Any representatives of infauna were absent in the sample (Kim et al. 2006). The sediments were mainly mud with clay. The material was originally fixed in 75% ethanol or 4% formaldehyde and later transferred to alcohol. Specimens were studied using both light microscopy and scanning electron microscopy (SEM). SEM photos were taken by Quanta 250 after specimens had been critical-point dried and coated with platinum. The observations, measurements and drawings were performed using standard binocular and compound light microscopes with a camera lucida. All material is deposited at the Zoological Institute of the Russian Academy of Sciences, Saint Petersburg (ZIRAS).

**SYSTEMATICS****Family Ctenodrilidae Kennel, 1882****Subfamily Raphidrilinae Hartmann-Schröder, 1971****Genus *Raricirrus* Hartman, 1961*****Raricirrus arcticus* sp. nov.**

(Figs. 1–3)

*Raricirrus* sp. Buzhinskaja 2001: 59.

**Material examined.** R.V. Polarstern, 10.09.1993, ARK-IX/4 (expedition), station 50: North of the Laptev Sea, 77°41'43"N, 125°55'09"E, depth 1992–1993 m, bottom silty pelite with a strong odour of hydrogen sulfide and some part of fine sand, temperature near bottom –0.81 °C, salinity 34.86‰. Gear: AGT (Agassiz trawl). Collected by B.I. Sirenko. Type material: holotype ZIRAS 1/50650; paratypes ZIRAS 2/50561 (25 specimens).

**Etymology.** The specific name refers to the occurrence of the species in the Arctic Ocean.

**Description**

**Tube.** Tubes consist of pellicle with dense layer of small grey or rust-coloured particles (grains of sand and silt) agglutinated together by mucus; upper layer weaker, more delicate. Two or rarely three specimens occur in same tube laying tightly side by side “head to tail”. A few adherent tubes found.

**Body.** Holotype (Fig. 1A) 14.5 mm long, 0.75 mm maximum width (widest segment in midbody part), 30 chaetigers; last 9 chaetigers narrower, forming a slightly depressed caudal region. Paratypes up to 35 segments and about 20 mm in length, with up to 12 (usually 8–10) chaetigers in caudal region.

Prostomium oval-triangular, with lateral oral folds; eyes lacking. Nuchal organs not clearly discernible among wide patches of cilia along anterolateral surfaces of the head (Fig. 2A). Ciliary fields also present anterior and posterior to the mouth and as a narrow ventral band on first few (up to five) chaetigers (Fig. 2B, C). Prostomium, peristomium and first chaetiger continuous dorsally, separated ventrally.

Branchiae long, filiform, emerging posterodorsal to notochaetae, near posterior border of segments, very fragile and easily lost or broken (Fig. 2B, D). Holotype has complete branchiae on chaetiger 11 and underdeveloped one on chaetiger 12. A few pairs of branchiae in paratypes are located on variable chaetigers, such as 5–9, 6–8, 9–11, 10–12, and one pair on

the 13. Pygidium oval-triangular with dorsoterminal anus (Fig. 2E).

Heart body in dorsal blood vessel, clearly visible as pink tube beginning in second chaetiger, convoluted and thickened along chaetigers 10–15 (Fig. 1A). All paratypes have heart body pink to brown (black from chaetigers 12–14), extending from chaetiger two to chaetigers 13–18 depending on worm size, convoluted (staggered) beginning from 3–13 chaetiger in different specimens and slightly widened on midbody segments (6–10, 7–9 or 9–13).

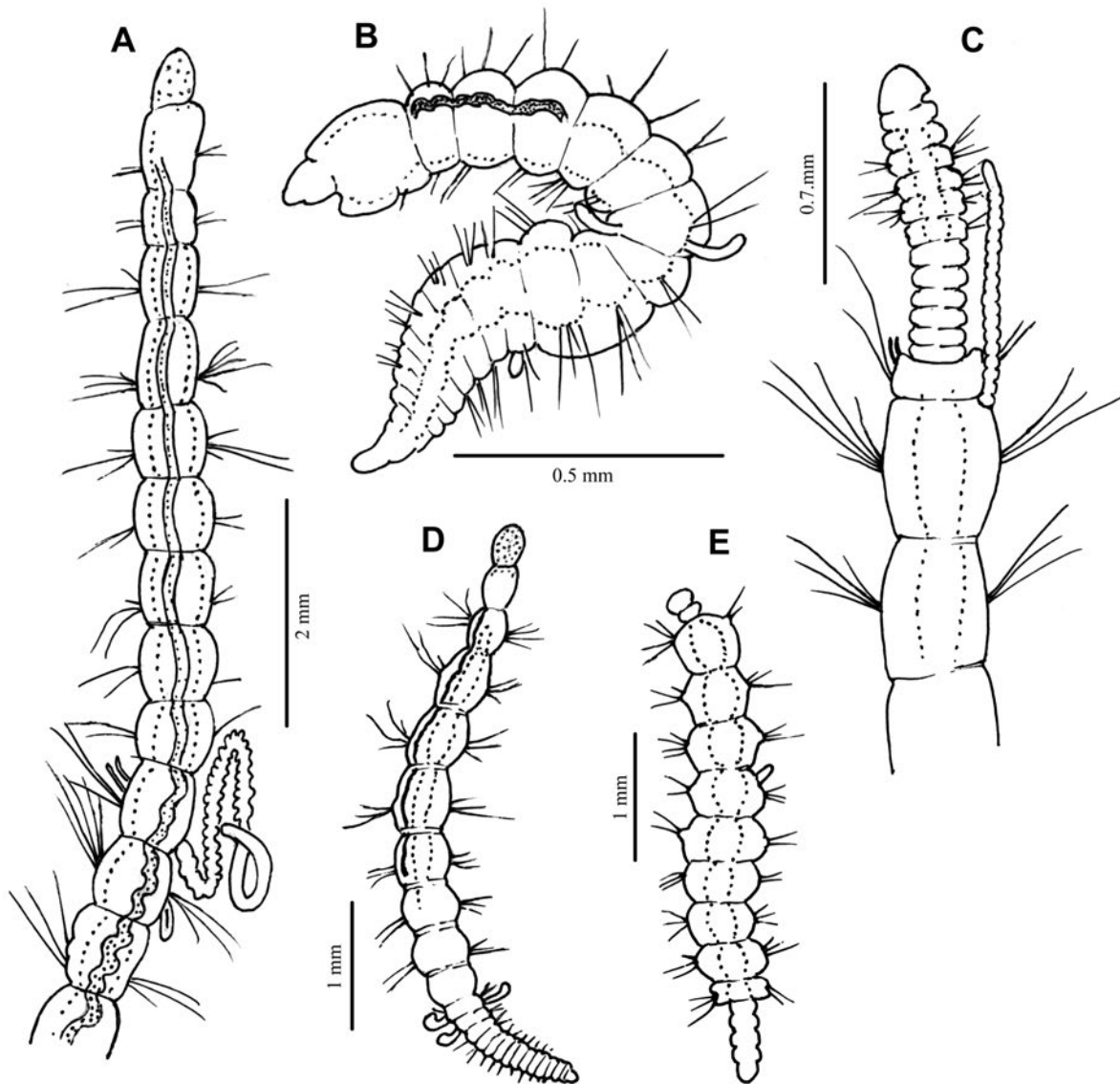
Noto- and neurochaetal bundles emerging directly from body wall, lateral in anterior segments, displaced more ventrolaterally posteriorly (Fig. 2F). Notochaetae of two types: 4–12 capillaries (1–4 longer and 3–8 shorter ones in each anterior and midbody bundle), tips finely serrate, and 2–3 straight thick, coarsely serrate chaetae in caudal region. Capillaries on chaetigers 3–11 longer than body width. Neurochaetae of three types: 3–9 pectinate falcigers anteriorly with 1–3 longer serrate chaetae with thin straight smooth tips in midbody chaetigers, and posteriorly 1–2 coarsely serrate chaetae similar to those found in caudal notopodia. Pectinate falcigers short or long with different size of teeth in different chaetae (Figs. 2G, I, J, 3A, B). Long serrate chaetae with triangular teeth decreasing gradually in size towards chaetal tips (Figs. 2I, 3C, D). Coarsely serrate chaetae with different forms of teeth, including some forked teeth (Fig. 2H, K, L). No modified segments. Heavy spines in chaetal bundles absent (Fig. 2E).

Few oocytes observed in 10 segments (in chaetigers 7–16) of one specimen having 30 chaetigers. Oocytes oval, 48–54 µm in max diameter, or rounded with up to 36 µm in diameter.

Only one short fragment of midbody region of probably dispersal (epitokous) stage found, with longer, abundant capillary chaetae in notopodial bundles.

Juvenile specimen 1.9 mm long, 0.27 mm wide (in widest region) with 15 chaetigers and five achaetous underdeveloped segments (Fig. 1B). Heart body convoluted, extending through three segments in chaetigers 2–4. One pair of short branchiae on chaetiger 7, and one branchia on chaetiger 11.

Most of specimens in different stages of regeneration of either anterior or posterior ends (Fig. 1C), or in both of them (Fig. 1D, E). In anterior region no more than 1–2 regenerated segments, while in posterior region regenerates consist of much more numerous segments.

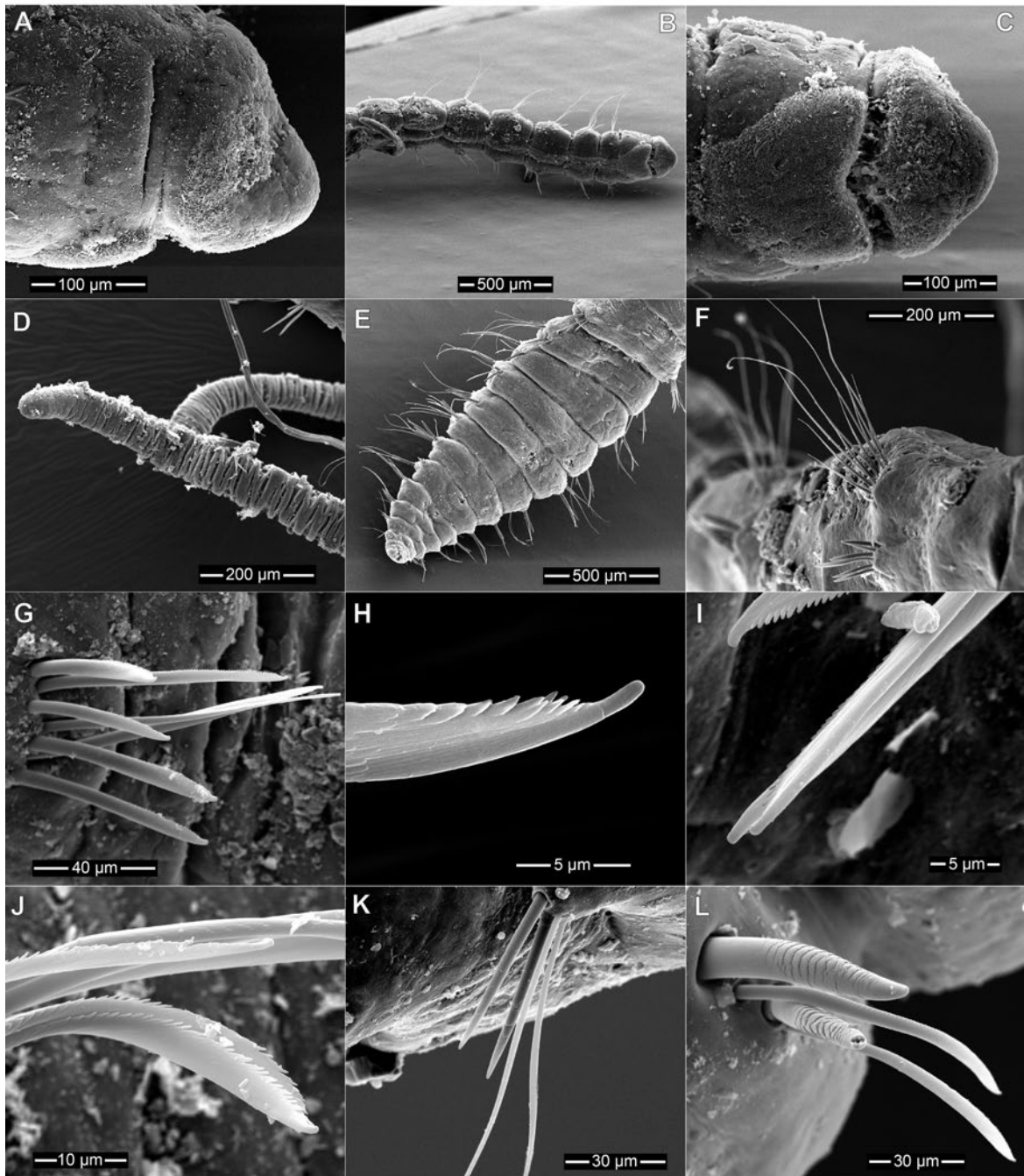


**Fig. 1.** *Raricirrus arcticus* sp. nov. A – holotype, dorsal view of anterior region; heart body visible from chaetiger two; branchiae present on chaetigers 11 and 12; B – juvenile specimen; heart body begins from chaetiger two; branchiae present full-size on chaetiger 7 and as buds on chaetiger 11; C – specimen regenerating anterior end; D, E – specimens regenerating both anterior and posterior ends.

Colour of worms red-brown. Head and anterior segments often with red spots.

**Remarks.** *Raricirrus arcticus* sp. nov. differs from other species of the genus in the position of the heart body, which first appears much more anteriorly, in chaetiger 2, and also in the presence of long serrate chaetae with thin straight tips in neuropodia of the

midbody region. The anteriormost occurrence of the heart body is likely correlated in *R. arcticus* sp. nov., as in other *Raricirrus* species, with the number of segments in anterior regenerates, which confirms the idea of Petersen and George (1991) about the role of the heart body in the regeneration of anterior region in this genus. *Raricirrus arcticus* sp. nov.



**Fig. 2.** *Raricirrus arcticus* sp. nov. SEM photos. A – dorsolateral view of anterior end showing continuous ciliary patches without clearly differentiated nuchal organs; B – anterior region of whole specimen in mainly ventral view showing ventral ciliation in front of and posterior to mouth, continuing as a ventral band, anteriorly wide, then gradually narrowing and finally vanished on segment five; branchiae is visible in midbody region; C – anterior end, ventral view, showing wide ciliary fields in mouth area; D – two branchiae showing absence of club-like ends; E – posterior region, ventral view; F – right side of an anterior chaetiger showing notopodial capillaries long or short, and regular neuropodial pectinate falcigers; G – midbody neuropodial pectinate falcigers and long serrate chaetae with thin straight tips; H – tip of coarsely serrate neurochaeta; I – details of tips of pectinate falciger and of long serrate neurochaetae; J – detail of tips of neuropodial short pectinate falcigers; K – bundle of posterior notochaetae with long slender capillaries and stout coarsely serrate chaetae; L – neuropodium of posterior region with pectinate falcigers and coarsely serrate chaetae.

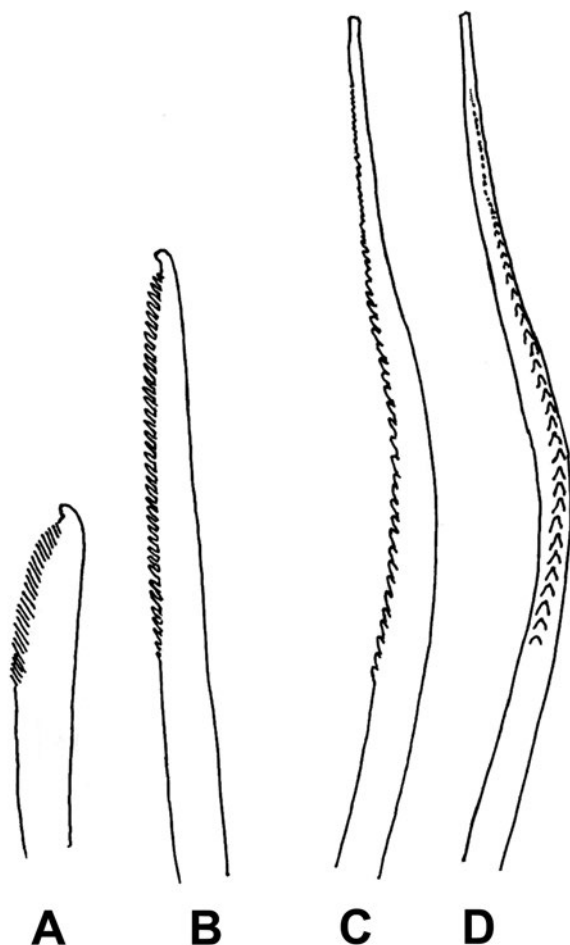


Fig. 3. *Raricirrus arcticus* sp. nov. A, B – short and long pectinate falcigers; C, D – long serrate neurochaetae with thin straight tips.

demonstrates great morphological similarity with the geographically nearest *R. beryli*. These species are likely most closely related sharing the absence of a modified region with enlarged spines and the presence of distinct ventral ciliary fields in the area of the mouth and the neural ciliary band on a few anterior segments. The new species resembles *R. beryli* and *R. maculatus* in the possession of uniform filamentous branchiae, asexual reproductive mode, and the absence of notopodial pectinate falcigers. *Raricirrus variabilis* appears to be unique among the congeners in the absence of asexual reproduction, the presence of branchiae with club-like ends, pectinate falcigers in notopodia, and the presence of reproductive stylet and a seminal vesicle.

*Raricirrus arcticus* sp. nov. differs from *R. beryli* in the structure of nuchal organs, which cannot be differentiated from wide patches of cilia on the dorsolateral sides of the prostomium. Probably similar nuchal organs are described in *R. maculatus*, but photo is absent (Hartman 1961; Petersen and George 1991).

Thus, the following morphological characters are useful in distinguishing species within the genus *Raricirrus*: 1) Position of the heart body; 2) Presence or absence of notopodial pectinate falcigers; 3) Presence or absence of long serrate chaetae with thin straight tips in neuropodia; 4) Presence or absence of a modified region with large hooked spines; 5) Number of segments in the modified region; 6) Presence/development of ciliary patches on the prostomium and peristomium, and ventral ciliary band on anterior segments; 7) Structure of the nuchal organs; 8) Structure of the branchiae; 9) Presence or absence of an asexual reproductive mode; 10) Relative length of capillaries in epitokous worms.

**Distribution.** Laptev Sea, Arctic Ocean (1992–1993 m depth).

#### Key to the species of the genus *Raricirrus*

- 1a. Branchiae with clublike ends. Pectinate falcigers in notopodia. Only sexual reproductive mode ... *R. variabilis*
- 1b. Branchiae cylindrical. No pectinate falcigers in notopodia. Sexual and asexual reproduction ... 2
- 2a. Distinct ventral ciliary fields near mouth and neural ciliary band on a few anterior segments. No modified region with enlarged spines ... 3
- 2b. Ventral ciliation absent, or not clearly discernible. Modified region with large hooked spines in some specimens ... *R. maculatus*
- 3a. Heart body begins from chaetiger 2. Nuchal organs inconspicuous among anterolateral patches of cilia ... *R. arcticus*
- 3b. Heart body begins from chaetigers 7–10. Nuchal organs areas without cilia, surrounded by ciliary fields ... *R. beryli*

#### DISCUSSION

The new species undoubtedly belongs to the family Ctenodrilidae, though the differentiation of Ctenodrilidae and Cirratulidae is uncertain. The ctenodrilids have an evident resemblance with cirratulids, but differs from them by absence of grooved tentacles. Thus, it is possible to take some

juvenile cirratulids (still without the tentacles) for ctenodrilids. Hartmann-Schröder (1971, 1996) and Magalhães et al. (2011) treated them as distinct in the morphological studies, and Salazar-Vallejo et al. (2008) in a restricted phylogenetic analysis considered the family Ctenodrilidae monophyletic, but at least some molecular studies placed them within cirratulids (e.g. Rousset et al. 2007). Weidhase et al. (2016) further reported that *Raricirrus* and *Ctenodrilus* species were nested within Cirratulidae, with *R. beryli* as a sister taxon to a clade comprising the multi-tentaculate cirratulid genera. The molecular data might reflect the classification of the Ctenodrilidae in two subfamilies by Petersen and George (1991): Ctenodrilinae, including *Ctenodrilus ser-ratus* (Schmidt, 1857), and Raphidrilinae, including *R. beryli*, rather than support the monophyly of the family Ctenodrilidae. Also stout serrated chaetae found in all ctenodrilid species, including the new species described here, imply the possibility of progenetic evolution: these chaetae are similar to those in juveniles of cirratulids (Weidhase et al. 2016). Additionally, in the ontogeny of some multitentaculate cirratulids, the branchiae, which are also present in *Raricirrus* and *Raphidrilus*, are developed prior to the tentacles (Claparède and Meczniow 1869; Wilson 1936; Okuda 1946). Given the close relationship of *Raricirrus* to multitentaculate cirratulids and the hypothesized progenetic evolution of this taxon, Weidhase et al. (2016) suggested that the absence of tentacles represents a juvenile character. Furthermore, the two genera of ctenodrilids with branchiae and long bodies, *Raricirrus* and *Raphidrilus* comprising the subfamily Raphidrilinae, are initially very morphologically close and have many overlapping features. Nevertheless, the genera were confirmed to be distinct by Petersen and George (1991) based on the position of the heart body, the structure of the nuchal organs and the head region. Dean (1995) considered the first two features to be a species level based on variability among species of *Raricirrus*, and suggested that the distinctness between *Raricirrus* and *Raphidrilus* are due to the chaetal characteristics and the head structure. Magalhães et al. (2011) further elucidated the diagnostic features of *Raphidrilus*, and reported the presence of at least one dorsally biannulated achaetous segment between the peristomium and first chaetiger, and an indistinct posterior region in all *Raphidrilus* species, thus confirming that the two genera are close but not identical. The

present study of *R. arcticus* sp. nov. reveals the occurrence of the heart body most anterior among all previously described species of both *Raricirrus* and *Raphidrilus*, which confirms the species level value of this character. In addition, the indistinct nuchal organs in *R. arcticus* sp. nov., possibly similar to those of *R. maculatus*, but unlike the nuchal organs of other ctenodrilids, imply the great variability of this character within the genus *Raricirrus*, while the structure of the head and caudal region, and the arrangement of the chaetae are indeed useful for distinguishing *Raricirrus* and *Raphidrilus*.

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