ISSN 0012-4966, Doklady Biological Sciences, 2023, Vol. 508, pp. 81–84. © Pleiades Publishing, Ltd., 2023.
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The Finding of Pogonophorans (Annelida, Siboglinidae) in the St. Anna Trough (Kara Sea) in an Area of Gas Hydrate Dissociation

N. N. Rimskaya-Korsakova[a], N. P. Karaseva[a], A. A. Osadchiev[b], I. P. Semiletov[c], M. M. Gantsevich[a,*], D. A. Yurikova[a,d], and Academician V. V. Malakhov[a]

Received August 30, 2022; revised October 15, 2022; accepted October 16, 2022

Abstract—Representatives of pogonophorans (Annelida, Siboglinidae), whose vital activity is provided by symbiotic chemoautotrophic bacteria that oxidize methane and hydrogen sulfide, were found in the St. Anna Trough at depths of 539 and 437 m. The finding of pogonophorans suggests high concentrations of methane, which might result from dissociation of bottom gas hydrates under the influence of the influx of warm Atlantic water into the Kara Sea along the St. Anna Trough.

Keywords: pogonophorans, methane, gas hydrates, St. Anna Trough, Kara Sea, Arctic warming, Siboglinidae
DOI: 10.1134/S001249662270020X

Pogonophorans are marine annelid worms of the family Siboglinidae and are characterized by a total reduction of the digestive tract. Vital activity of pogonophorans is completely sustained by symbiotic chemoautotrophic bacteria that oxidize hydrogen sulfide and methane [1–3]. The feature makes it possible to consider Siboglinidae as living indicators of subsea oil and gas fields [4, 5].

Huge deposits of oil, gas, and gas hydrates are thought to occur under water of the Russian shelf of the Arctic [6–10]. The Kara Sea surpasses all other seas of the Russian Arctic in hydrocarbon resources [11, 12]. The pogonophoran fauna of the Kara Sea remained virtually unexplored until recently. It was not until 2020 that two pogonophoran species were found in the Yenisey Gulf of the Kara Sea, both being unknown earlier [13–15].

Pogonophorans were found in the southern part of the St. Anna Trough at two stations during hydrobiological research of the 86th expedition onboard the research vessel *Akademik Mstislav Keldysh* (Fig. 1).

The coordinates of the stations and collection dates are summarized in Table 1.

[a] *Moscow State University, Moscow, Russia*
[b] *Shirshov Institute of Oceanology, Russian Academy of Sciences, Moscow, Russia*
[c] *Ilyichev Pacific Oceanological Institute, Far East Branch, Russian Academy of Sciences, Vladivostok, Russia*
[d] *Marine Research Center, Moscow State University, Moscow, Russia*
**e-mail: mgantsevich@gmail.com*

Benthic sediments were sampled using an Okean bottom grab with a sample area of 0.25 m^2. Once the sampler was raised to the deck, benthic samples were washed in a sieve with a hole size of 0.15 mm. The samples were examined with Mikmed (Russia) and Olympus SZX (Japan) stereo microscopes. Organisms were photographed using a LabCam (iDuOptics, USA) eyepiece adapter for iPhone 6S (Apple, United States). Material was fixed with 96% ethanol for further examination.

Three tubes, with live worms in two of them, were collected at a depth of 539 m at Station 7249. Two tubes without worms were found at a depth of 437 m at Station 7250. The worms were identified as belonging to different species of the family Frenulata. The worms are briefly described below. A detail morphological description, results of molecular genetic analysis, and species identification will be reported separately.

Frenulata gen. sp. 1 was the only worm found in a sample collected at Station 7249. The tube was 18 cm in length and approximately 0.2 mm in diameter, translucent, and whitish-yellow in color and lacked annulation throughout its length (Fig. 2, *tu*). A worm fragment was 6 cm in length. The cephalic lobe was conical (Fig. 2, *cl*). A single tentacle was observed (Fig. 2, *te*). A white glandular patch was distinct below

Table 1. Stations where pogonophorans were found

Station	N	E	Depth	Collection date
7249	77.0001	70.0021	539 m	Oct 22, 2021
7250	77.4999	68.9953	437 m	Oct 22, 2021

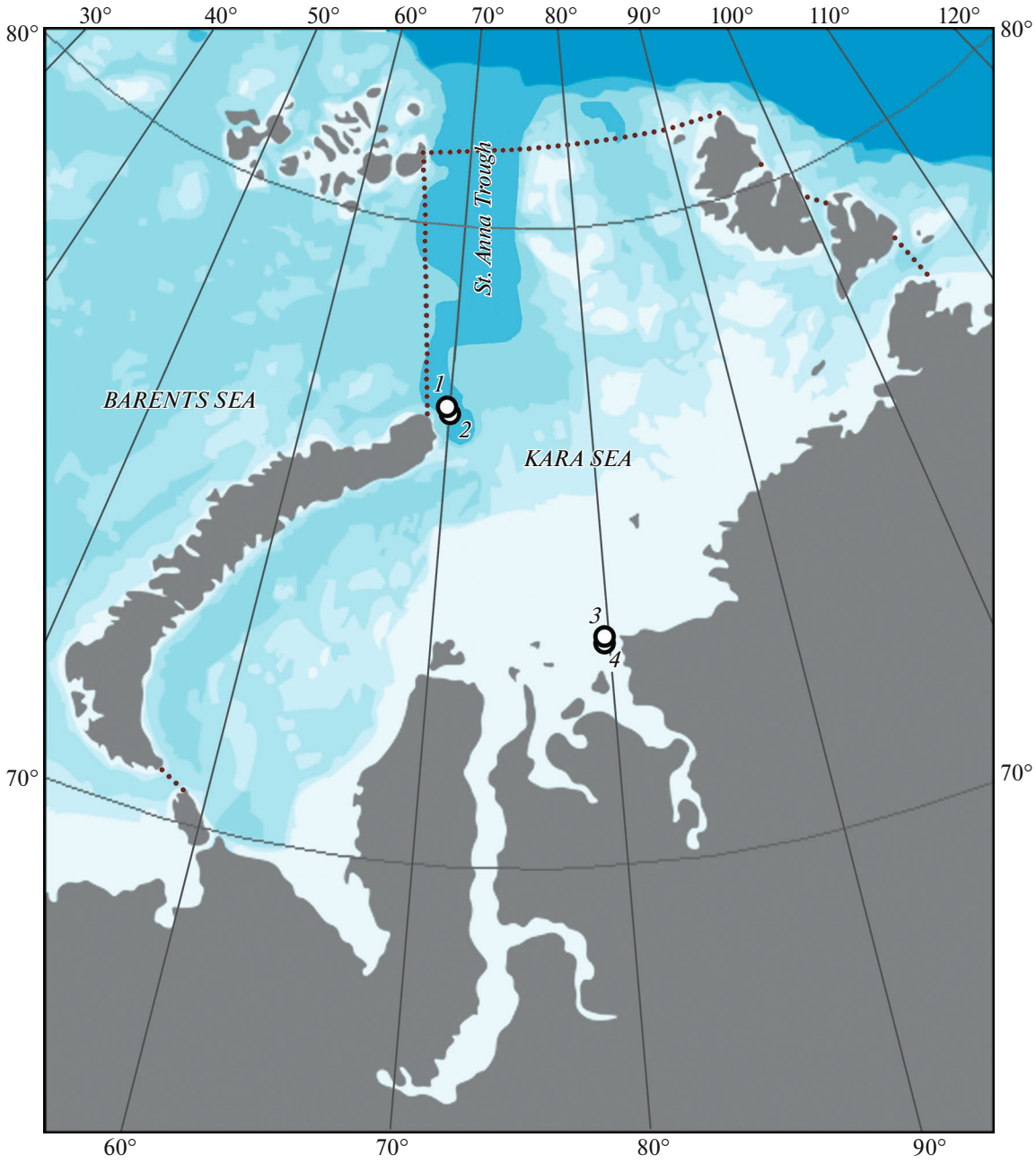

Fig. 1. Sites where pogonophorans were found in the Kara Sea: (*1*, *2*) sites in the St. Anna Trench and (*3*, *4*) sites in the Yenisey Gulf. A dashed line shows the geographical boundaries of the Kara Sea.

the bridle (Fig. 2, *gp*). The anterior part of the trunk had two rows of dorsal papillae (Fig. 2, *pa*). The worm was close to the genus *Siboglinum* by its morphological features, but differed in the structure of the tube, which was totally devoid of annulation.

Frenulata gen. sp. 2. was represented by two tubes found in a sample from Station 7249 and the two tubes found in a sample from Station 7250. The tubes were up to 17 cm in length and 0.15–0.2 mm in diameter. Tube annulation was distinct (Fig. 3, *tu*). A worm fragment of 5 cm in length was found in one of the tubes collected at Station 7249. The cephalic lobe was short and sharply conical (Fig. 3, *cl*). There were two tentacles (Fig. 3, *te*). The bridle was distinct; glandular patches were observed on the dorsal side below the bridle (Fig. 3; *br*, *gp*). Papillae formed two rows on the dorsal side of the trunk (Fig. 3, *pa*). Two larvae were found in the tube. The worm was similar to members of the genus *Nereilinum* by morphological features, but *Nereilinum* worms lack two rows of dorsal papillae on the trunk (and have rows of multicellular glands instead).

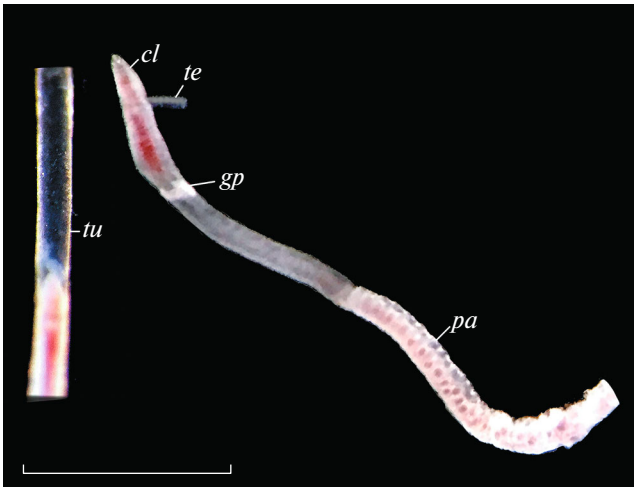

Fig. 2. Frenulata gen. sp. 1. Designations: *cl*, cephalic lobe; *gp*, glandular patches; *pa*, papillae; *te*, tentacle; *tu*, tube. Bar, 1 mm.

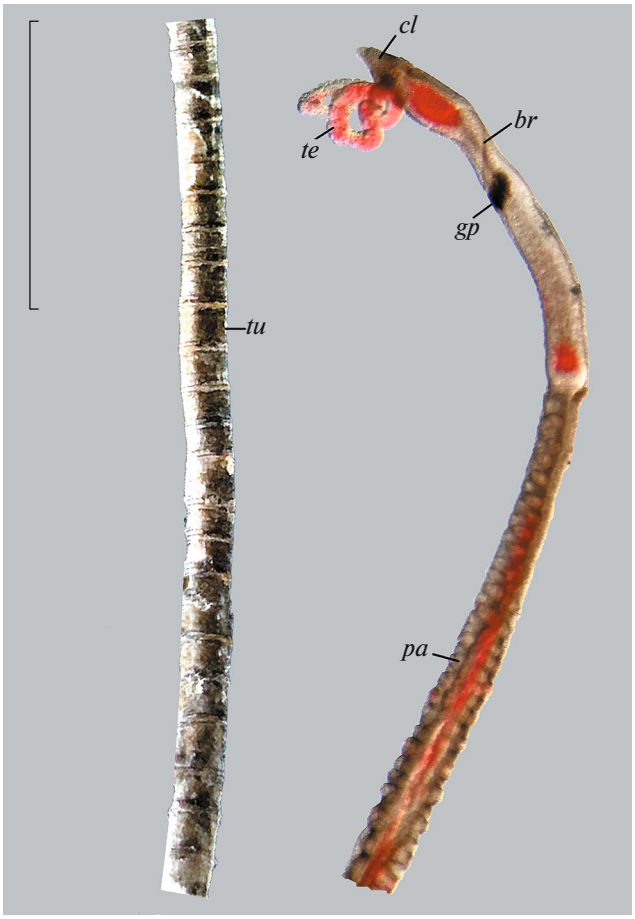

Fig. 3. Frenulata gen sp. 2. Designations: *br*, bridle; other designations are as in Fig. 2. Bar, 1 mm.

There are only two regions in the Kara Sea where pogonophorans have been found as of yet. One is between the Sibiryakov Island and the western coast of the Taymyr Peninsula in the Yenisey Gulf (Fig. 1). *Crispabrachia yenisey* has been found at a depth of 28 m [13, 15] and *Galathealinum karaense,* at a depth of 25 m [14]. High methane concentrations are characteristic of the sites where the two pogonophoran species have been found in the Yenisey Gulf because methane is produced as a result of permafrost degradation by the river flow [16].

Climate warming in the Arctic leads to gas hydrate dissociation not only in coastal regions, but also in deep-sea troughs [8, 17, 18]. As hydrological studies have shown, warm saline Atlantic water flows through the Fram Strait into the central deep of the Arctic Ocean and then enters the Kara Sea through the St. Anna Trough [19, 20]. Warm water entering the St. Anna Trough causes substantial dissociation of benthic gas hydrates according to modeling data [18]. The resulting methane flow acts as a source to sustain pogonophoran life.

FUNDING

This work was supported by the Russian Science Foundation (project no. 18-14-00141-P).

COMPLIANCE WITH ETHICAL STANDARDS

Conflict of interests. The authors declare that they have no conflicts of interest.

Statement on the welfare of animals. All applicable international, national, and/or institutional guidelines for the care and use of animals were followed.

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Translated by T. Tkacheva