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SHORT NOTE

Bathyphellia margaritacea (Cnidaria: Actiniaria): the most northern species of the world

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Abstract The sea anemone *Bathyphellia margaritacea* (Danielssen in Actinida. The Norwegian North-Atlantic expedition 1876–1878, Groendahl, Oslo, 1890) was collected by the research submersible MIR at the North Pole at a depth of 4,262 m and by the North Pole Drifting Station NP-22 in the American sector of Arctic Ocean covered by permanent ice. These widely separated records significantly increase the known geographic range of the species. *B. margaritacea* is highly plastic and has an ability to occupy different types of substrates. It appears to be the only species of sea anemone that is able to range in the high Arctic up to the North Pole and the only reliably identified species known from this part of the world.

Keywords *Bathyphellia* · North Pole · Drifting Station · Arctic Ocean · Sea anemone

Introduction

Several unusual deepwater benthic communities were discovered and explored by research submersibles during the last decades (Moskalev 2002; Sagalevitch 2002). However, the vast Arctic abyssal area situated under the polar ice was almost totally unexplored. No direct observation of sea bottom by research submersibles were performed before in this region hidden by permanent sea ice. Here we report results of the first and a very risky dive of the Russian manned submersibles MIR-1 and MIR-2 under the ice of the North Pole and, in addition, describe material collected by North Pole Drifting Station NP-22 in American sector of Arctic Ocean in 1977 and 1979.

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Materials and methods

The North Pole specimen of *Bathyphellia margaritacea* was collected at a depth of 4,262 m on 2 August 2007 in the upper layer of mud with the aid of a square langing-net attached to the arm of the submersible MIR-2. It is now deposited at the P.P. Shirshov Institute of Oceanology, Moscow. Detailed visual observations and a videotape were taken during the dive. The material from Drifting Station NP-22 contains 14 specimens from Station 24 (#9856–9869; 80°29′N, 129°57′W, 3,530 m, 12 July 1977, Small Sigsby trawl, initially preserved in alcohol), and one specimen from Station 112 (#9870; 75°15′N, 171°05′W, 450–460 m, 10–11 March 1979). These specimens are preserved in formalin and deposited in the Zoological Institute.

Our identification is based on the examination of morphology, cnidae distribution and size, and is confirmed by a re-examination of specimens collected by the Ingolf Expedition (Ingolf Expedition Station 113, 69°31′N, 07°06′W, 2,465 m, 21–22 September 1896, deposited at the Zoologisk Museum, Copenhagen). For all specimens, standard methodology was used to study anatomy of anemones: preserved specimens were examined whole and on longitudinal and transverse dissections. Nematocysts were examined on squash preparations. Cnidae terminology follows

Table 1 Size ranges (in microns) and distribution of cnidae of the studied specimens of *Bathyphellia margaritacea*

Body region	Cnidae	Specimen from North Pole	NP-22 Station 24	NP-22 Station 112	Ingolf expedition Station 113
Column	(a) Basitrichs 1 (common)	15–27 × 2–3	13–26 × 2.5–3	–	17–20 × 2.5–3
	(b) Basitrichs 2 (common)	7–14 × 1–2	5–15 × 1–2	–	7–9 × 1–1.5
	(c) p-mastigophores B1 (common)	18–25 × 2.5–3.5	15–26 × 2.5–3.5	–	16–20 × 3
Tentacles	(a) Gracile spirocysts (numerous)	29–62 × 3–6	24–61 × 3–6	18–32 × 2–4	21–42 × 2.5–5
	(b) Robust spirocysts (numerous)	26–74 × 4–9	21–74 × 3.5–9	18–33 × 4–6	21–56 × 4–10
	(c) Basitrichs 1 (common)	25–38 × 3–3.5	18–33 × 2–3	17–21 × 2–2.5	19–28 × 2.5–3
	(d) p-mastigophores B1 (common)	19–28 × 3–4	16–29 × 3–3.5	17–19 × 2.5–3.5	19–27 × 2.5–3
	(e) Basitrichs 2 (from endoderm, common)	11–22 × 1.5–2.5	(5)9–22 × 1.5–2	8–11 × 1.5–2	10–18 × 1.5–2
Pharynx	(a) Basitrichs 1 (common)	26–38 × 2.5–3	22–32 × 2.5–3	–	(20)24–27 × 2.5–3
	(b) p-mastigophores A (few)	30–37 × 5–7	25–33 × 4–6	22–26 × 4–4.5	25–28 × 4.5–5
	(c) p-mastigophores B1b (numerous)	20–33 × 3–4	20–30 × 3–4	–	17–26 × 3–4
	(d) Basitrichs 2 (few)	–	12–26 × 1.5–2	–	–
Filament	(a) Basitrichs (common)	11–20 × 1.5–2.5	9–16 × 1.5–2	–	11–16 × 1.5–2
	(b) p-mastigophores B1b (numerous)	21–31 × 3–3.5	20–28 × 2.5–4	–	15–22 × 3–4
Acontia	(a) Basitrichs 1 (numerous)	–	35–42 × 3–3.5	–	–
	(b) Basitrichs 2 (common)	–	12–18 × 1.5–2	–	–

Letters in brackets correspond to letters in Fig. 3. Size ranges of basitrichs and p-mastigophores B in column and tentacles of Ingolf specimens are not full because it was not always possible to differentiate between these capsules in this material

England (1991) with slight modifications (see Sanamyan and Sanamyan 2007); cnidae of all examined specimens are listed in Table 1 and depicted in Fig. 3.

Results and discussion

The family Bathyphellidae is traditionally placed in the infraorder Thenaria (anemones having a definite basal disk with special basilar muscles) and to the group of families characterized by the presence of acontia (Acontiaria)—special thread-like organs with numerous stinging capsules (nematocysts) used for defense. These features, basilar muscles and acontia, are traditionally considered important in taxonomy of the sea anemones and are basic features dividing the order Actiniaria into several main groups, although modern molecular studies do not support high value attributing to them (Daly et al. 2008). *B. margaritacea* is one of the few species in which these features may vary considerably. Although a number of the morphological features as well as the set of nematocysts of this species support its assignment to a group of the Thenaria, this species appears to lack basilar muscles (Riemann-Zürneck 1997). Development of acontia, another character regarded as taxonomically important at the family level also varies considerably in this species: some specimens have abundant acontia, while others lack them completely (Riemann-Zürneck 1997). Moreover, the cnidome of the acontia also varies: Riemann-Zürneck (1997) reported occasional additional *p*-mastigophores in acontia (although failed to give their size).

The polar specimens live on the soft bottom, with the lower, narrower portion of the trumpet-shaped column buried in the mud. This pedal disk anchors the specimen so tightly that even turbulence from the submersible does not cause them to move or shift. The expanded tentacular crowns of living specimens are up to 5 or 6 cm in diameter (Fig. 1a). The examined formalin-preserved specimen has 24 tentacles and is 25 mm high; its diameter is about 15 mm distally, the much narrower proximal part is only 5 mm near the limbus, and the diameter of the limbus is 6 mm (Fig. 1b). The pedal disk slightly concave and has cuticular covering with attached mud particles. The column is divided into scapus and scapulus: the scapus has tenaculi with partially abraded grayish cuticle incrusted by particles of sediment. Twenty-four mesenterial insertions are visible in the distal part of the scapus where the cuticle is abraded. The scapulus is naked, without cuticle and has 24 scapular ridges.

The strong, alveolar, non-stratified mesogloeal sphincter reaches bases of the tentacles distally and its narrowed proximal end enters to the scapus (Fig. 2b). The longitudinal muscles of the tentacles and radial muscles of the oral disc are ectodermal. Internally, two siphonoglyphs are supported by two pairs of directives. Two cycles of mesenteries are present throughout the column (Fig. 2a). The six pairs of mesenteries of the first cycle are perfect, fertile and have strong and restricted retractors. The six pairs of the

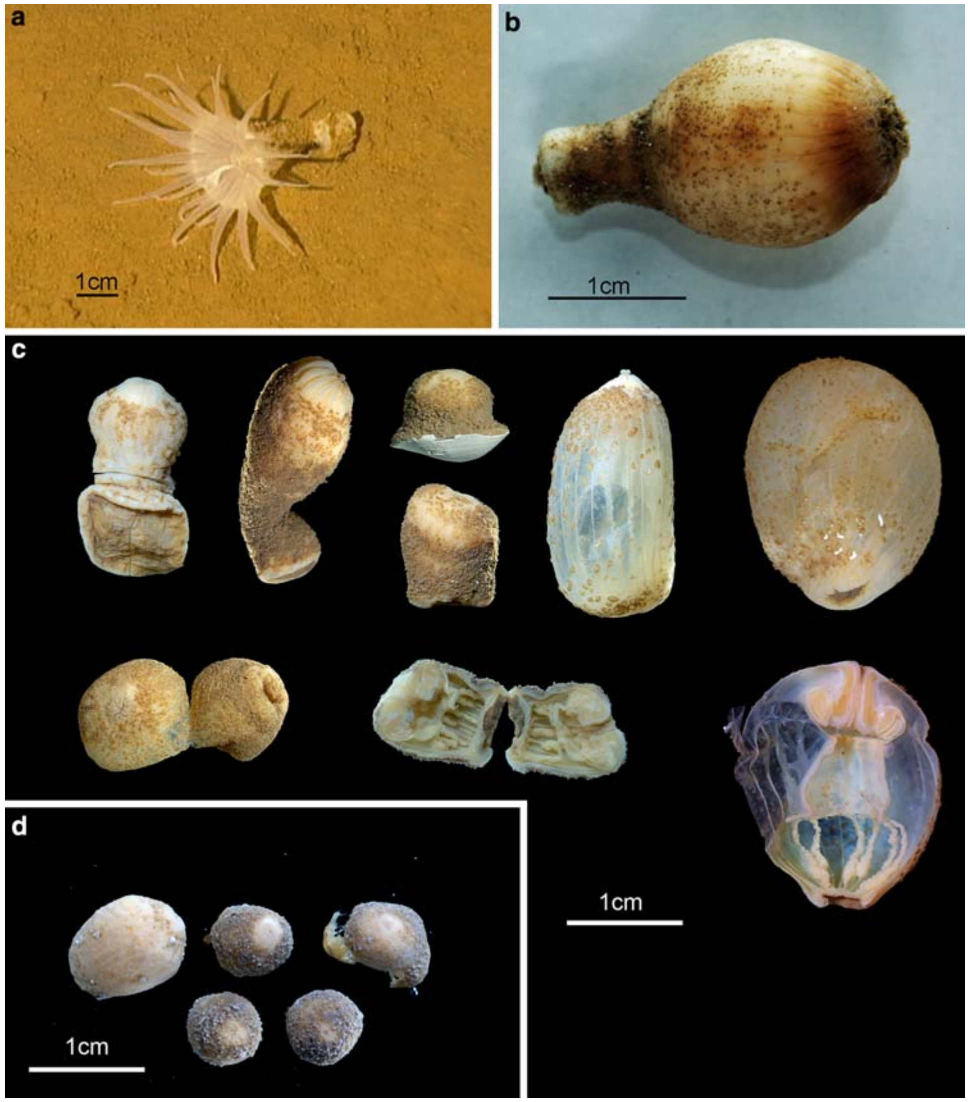

Fig. 1 **a–d** *Bathyphellia margaritacea*. **a** Living specimen on the bottom at the point of the North Pole. Photo taken by Russian submersible MIR-2, courtesy of P.P. Shirshov Institute of Oceanology RAS, Moscow, **b** Preserved specimen from the North Pole, **c** Specimens collected by North Pole Drifting Station NP-22: Station 24, **d** Specimens collected by Ingolf Expedition, Station 113

second cycle lack filaments and gonads and are never attached to the actinopharynx in any part of the body; they have weak and diffuse musculature, slightly concentrated into small retractors in the distal part of the mesenteries. Parietobasilar muscles are well developed only in lower part of column, near the bottom, where they have clear flap. We failed detect basilar muscles and any traces of acontia. The examined specimen was a female with eggs (0.2 mm in diameter) in the proximal part of macrocnemes.

The specimens from Drifting Station NP-22 Station 24 are 8–21 mm high to 18 mm diameter; the specimen from Station 112 is 1.5 mm high and 2 mm diameter. The shape of the body varies in these preserved samples from low with rather wide base (specimens #9860, 9863–9865) to more elongated, often with rather small concave base with attached particles of mud (specimens #9856–9859, 9861, 9862) (Fig. 1c). The number of tentacles varies from 24 to 28. As in the polar specimens, the scapus is covered by cuticle (partially abraded on some specimens) and has numerous tenaculi to which foraminifera and mud particles are attached. The smooth scapulus has from 12 to 24 rather distinct longitudinal thickenings. The sphincter muscle is strong, alveolar and not stratified. The musculature of the tentacles and oral disk is ectodermal. The mesenteries are arranged in two or three cycles. Regardless of the number of mesenteries, only those of the first cycle (six pairs) are perfect and have strong, restricted retractor muscles. Mesenteries of the second cycle are imperfect and have no filaments; the third cycle, when present, is incomplete, represented only by few pairs of very small, muscle and filament-less mesenteries, some of which are present only proximally. The parietobasilar muscles are weak, better developed in proximal part of the body where they may form a flap. Acontia were found only in one specimen (#9865; seven specimens sectioned). Acontia are 0.2 mm in diameter, two times thicker than the cnidoglandular tracts of the filaments.

There are no significant morphological differences among the specimens from American sector of Arctic

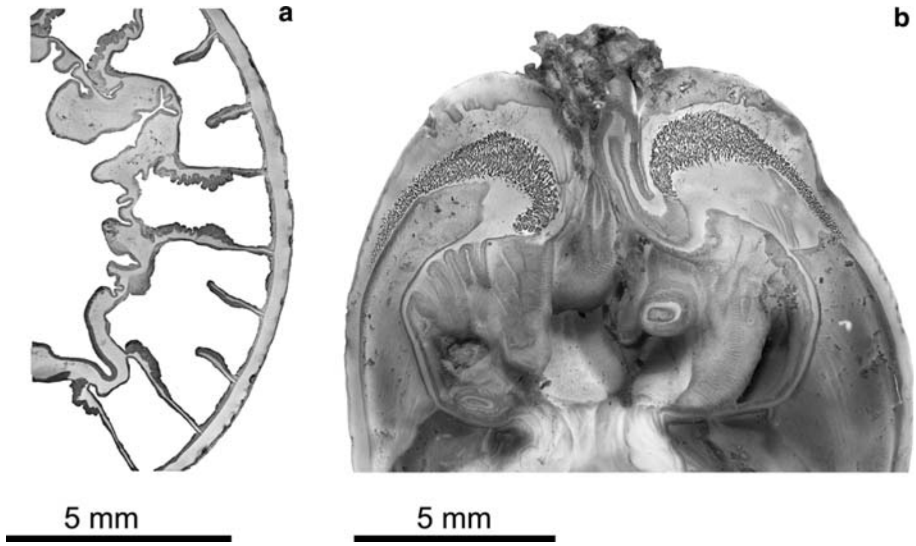

Fig. 2 **a**, **b** *Bathyphellia margaritacea*, specimen from the North Pole. **a** Mesentheries, **b** Longitudinal section showing the sphincter muscle

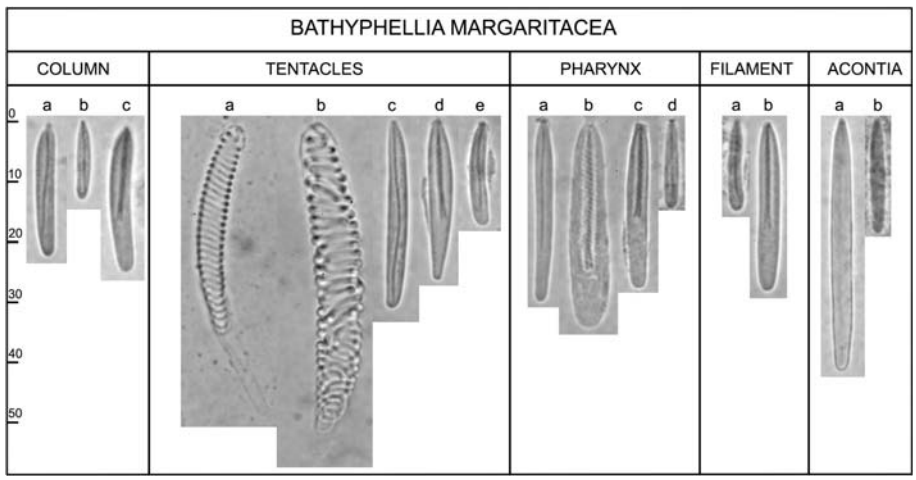

Fig. 3 Cnidae of *Bathyphellia margaritacea*

Ocean (NP-22). Six of seven sectioned specimens lack acontia (as is the case with the sectioned polar specimen), but one (#9865) has acontia with the large basitrichs characteristic for Bathyphellidae. Because the Drifting Station samples are obviously conspecifics, and because they share many other features (number of macrocnemes, presence and nature of cuticle and tenaculi, and cnidom) that unambiguously place the specimens in *Bathyphellia*, and because acontia are often degraded or absent in deep sea material, including some specimens of *B. margaritacea* (see Riemann-Zürneck 1997), the absence of acontia is not problematic in terms of identification.

We compared our material with specimens collected by Ingolf Expedition and identified as *B. margaritacea* by Carlgren (1942) and Riemann-Zürneck (1997). Among five specimens (5–8 mm) loaned by Zoologisk Museum, Copenhagen (Fig. 1d), one was already cut and we sectioned another specimen: both specimens lack acontia. Carlgren (1942) and Riemann-Zürneck (1997) failed to report *p*-mastigophores in the column and tentacles, however we have found thick-walled *p*-mastigophores in column and tentacles in Ingolf specimens. The material collected by Ingolf Expedition was initially preserved in alcohol, which obscured the internal structure of thick-walled nematocysts, making it very hard to distinguish between *p*-mastigophores B and basitrichs. These nematocysts co-occur in column and tentacle ectoderm and have almost the same dimensions. We confirm the presence of thin-walled p-mastigophores A (in actinopharynx only) reported by Riemann-Zürneck (1997) (see Table 1).

All examined specimens have two sorts of basitrichs and one p-mastigophore B1 in the ectoderm of all parts of the column (base, scapus, scapulus), although larger basitrichs are few in the scapus and p-mastigopheres B1 are rare in the scapulus. The ectoderm of the tentacles contains robust and gracile spirocysts, large basitrichs and p-mastigophores B1. Smaller basitrichs reported by Riemann-Zürneck (1997) for tentacles are seen on some squash preparations. They are contaminants from endoderm and actually are not present in ectoderm of the tentacles. Cnidae are not equally distributed along the tentacles. Robust spirocysts in the bases of the tentacles are of typical ‘Hormathiid’ type, they are thick and have unevenly packed threads. At the tips of the tentacles, robust spirocysts are longer and many have the thread packed regularly along most length of the capsule and the demarcation between robust and gracile spirocyst is not always obvious here. Robust spirocyst are more numerous than gracile spirocyst at tentacle tips, while in the bases of the tentacles, especially on their oral side, gracile spirocysts are more numerous. P-mastigophores B1 are numerous on aboral sides of tentacle bases but sparse in other parts of tentacles. The ectoderm of the pharynx of most examined specimens contains only three types of cnidae: one sort of basitrichs, p-mastigophores A and p-mastigophores B1b. An additional type of the rare thin basitrichs was found in three specimens from Station 24 (material NP-22). In the filaments, p-mastigophores B1b are present only in cnidoglandular tracts, where they are very numerous, and basitrichs are in the endoderm on the lamellar part of the mesentheries. In acontia, large basitrichs are very numerous on the sides of aconitum, and small basitrichs are common in its central part. The shaft in exploded p-mastigophores B1b has no “Falstück” and is 15–21 μm long and 1 μm thick, spines are 2–3 μm, and sometimes a short (5–40 μm) thread is visible.

The present material may shed some light on specimens from 400–410 m near the west border of the Barents Sea. Zhiubikas (1977) identified these samples as *Bathyphellia* sp., having documented features distinguishing his specimens from previously described specimens collected in deeper waters. Among the attributes he describes are better developed mesenteries of the third order and filaments and acontia on the mesenteries of the second cycle. However, as appears from his paper, he was not able to separate clearly acontia from filaments and lists nematocysts of these organs together. The cnidae reported by Zhiubikas (1977) is not complete, but size ranges of reported cnidae agree with our data. Because no specimens have been located, we associate this record tentatively with *B. margaritacea*, seeing no substantial differences between the report of Zhiubikas (1977) and the current circumscription of the species. This is the shallowest record of *Bathyphellia*, and the water temperature reported by Zhiubikas at the bottom was particularly high, +4.1°C, while all other records have been from waters with temperatures less than 0°C.

Although most of the length of the body of *B. margaritacea* is covered by cuticle encrusted with mud particles, the upper third or quarter is free of this cuticle and mud. Riemann-Zürneck (1997) speculated that in extremely poor nutrient environments this nude upper part of the body may play a role in the nutrition of the species by trapping small organisms in the mucous surface of the scapulus. Videotape taken during the dive of the manned submersibles at the North Pole shows the animals in situ: the base and part of the column are immersed into the mud, with the tentacles and distal 2–3 cm of column exposed. The widely expanded tentacles form a large (5–6 cm) ‘catching surface’ outside of the expanded oral disk and also shelter the naked scapulus, so it is unlikely that the scapulus plays a role in nutrition of this species.

Visual observations made in region of North Pole by pilots of research submersibles and videotape show plain muddy bottom and very poor macrofaunal composition. *B. margaritacea* and the occasional small, rapidly moving crustacean (shrimps and amphipods) are the only discernable organisms. The sea anemones occur in small groups, with about 20 m between the groups and separated from each other by 1–5 m within groups. The temperature at the bottom was −1.5° C. The rock formations underlying the sediment were not detected. The entire bottom at the point of the North Pole was covered by a thick layer of yellowish mud so fine that its superficial layer roiled from the slightest movement of the submersible or even just its arm. The total lack of water current prevented the fog from disappearing and made visual observations and all other submersible work very difficult. This habitat differs significantly from those observed during another dive of the MIR submersibles at the ice border near the Franz Josef Land (83°N) at a depth of 1,300 m, where the sediment on the bottom was lighter, coarser, and not as easily roiled as at the North Pole. The fauna near Franz Josef Land was much more diverse than the fauna of the North Pole; the dominant groups were brittle stars (Ophiuroidea), sea lilies and feather stars (Crinoidea), and fishes lying on the bottom (probably of the genus *Lycodes*), none of which were seen by the pilots or on the video footage from the North Pole.

The previously known distribution of *B. margaritacea* was the Greenland and Norwegian Seas (Danielssen 1890; Carlgren 1928, 1932, 1942; Riemann-Zürneck 1997), from the Faroe Islands on the south (Fautin et al. 2005) to the border of Barents Sea on the east (Zhiubikas 1977). The southern and eastern outermost points of the range are represented by most shallow-water records: 600–700 m at Faroe Islands and 400–410 m near the west border of the Barents Sea. All other records for this species are much deeper ranging from 1,600 to 3,770 m. The species has also been recorded from the North Atlantic by Doumenc (1975), but this record is dubious (see Riemann-Zürneck 1997). The specimen collected from the North Pole is the deepest reliable record of this species. The specimens collected in the American sector of Arctic Ocean significantly increase known range of geographic distribution of the species.

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