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Escape from troubled shores: finding of a shallow-water boreal gastropod *Onoba aculeus* on the high Arctic shelf

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Abstract

The species composition and distribution of marine invertebrates varies greatly in different bathymetric regions. Nevertheless, the process of exchange between faunas of different depths has occurred repeatedly throughout the evolution of marine biodiversity. In high latitudes, this process should occur most actively due to absence of strong temperature stratification. The presence of physiological adaptations that allow northern shallow-water organisms to live at greater depth has been demonstrated in a series of experiments. However, known cases of recent colonization by species confined to a highly productive shallow-water zone in unusually deeper Arctic habitats are almost absent. The present study describes finding of population of the gastropod *Onoba aculeus* (Gould, 1841) in two samples from the lower continental shelf of the Arctic Ocean. *Onoba aculeus* is a shallow-water amphiatlantic species widely distributed in the temperate regions. The finding reported here is at the same time, the northernmost, easternmost, and most remote from the coast location. We assume that the detection of molluscs indicates the presence of an abundant isolated population in the region.

Introduction

The species composition and distribution of marine invertebrates varies greatly in different bathymetric regions. This is due to many environmental factors and physiological limitations that make vertical migrations of animals difficult. Nevertheless, the process of exchange between faunas of different depths has occurred repeatedly throughout the evolution of marine biodiversity (McClain & Hardy, 2010). In high latitudes, this process should occur most actively. The temperature stratification here is much weaker and does not create significant obstacles to the vertical migration of organisms. Many species common on the abyssal or continental slope in temperate and subtropical latitudes may also occur on the continental shelf in the Arctic seas (Bouchet & Warén, 1993; Zimina *et al*., 2017; Nekhaev, 2018; Nekhaev & Krol, 2020*a*).

On the other hand, deep-sea marine ecosystems, including the lower part of the continental shelf, are characterized by low productivity and low biological diversity compared with coastal communities. On the scale of geological time, shallow-water ecosystems are considered as the main sources of formation of deep-sea fauna (Thuy *et al*., 2012). The presence of physiological adaptations that allow northern shallow-water organisms to live at high hydrostatic pressure corresponding to abyssal and ultra-abyssal depths under similar temperature conditions has been demonstrated in a series of experiments (Tyler & Young, 1998; Mestre *et al*., 2009; Smith & Thatje, 2012). However, known cases of recent colonization by species confined to a highly productive shallow-water zone in unusually deeper Arctic habitats are rare and are still confined to coastal regions (Sukhotin *et al*., 2008).

The aim of the present paper is to describe the finding of the gastropod *Onoba aculeus* (Gould, 1841) on the lower continental shelf of the Arctic Ocean. *Onoba aculeus* is abundant in shallow waters along both shores of the Atlantic Ocean: from the latitude of southern France to New England, Scandinavia, Greenland and Svalbard (Nekhaev *et al*., 2014) (Figure 1). The finding reported here is at the same time, the northernmost, easternmost, and most remote from the coast location.

Materials and methods

The material was collected during the cruise of RV 'Dalniye Zelentsy' in October–November 2019 to the areas of the Barents Sea and the Arctic Ocean between the Novaya Zemlya and Franz Josef Land archipelagos (Figure 1). Samples of the bottom fauna were taken at 12 stations using a 0.1 m^2 van Veen grab. Three samples were taken at each station. Immediately after collecting the samples were washed in a 0.5 mm sieve and then fixed with 4% buffered formalin. The samples were sorted manually in the stationary laboratory with use of a stereo microscope.

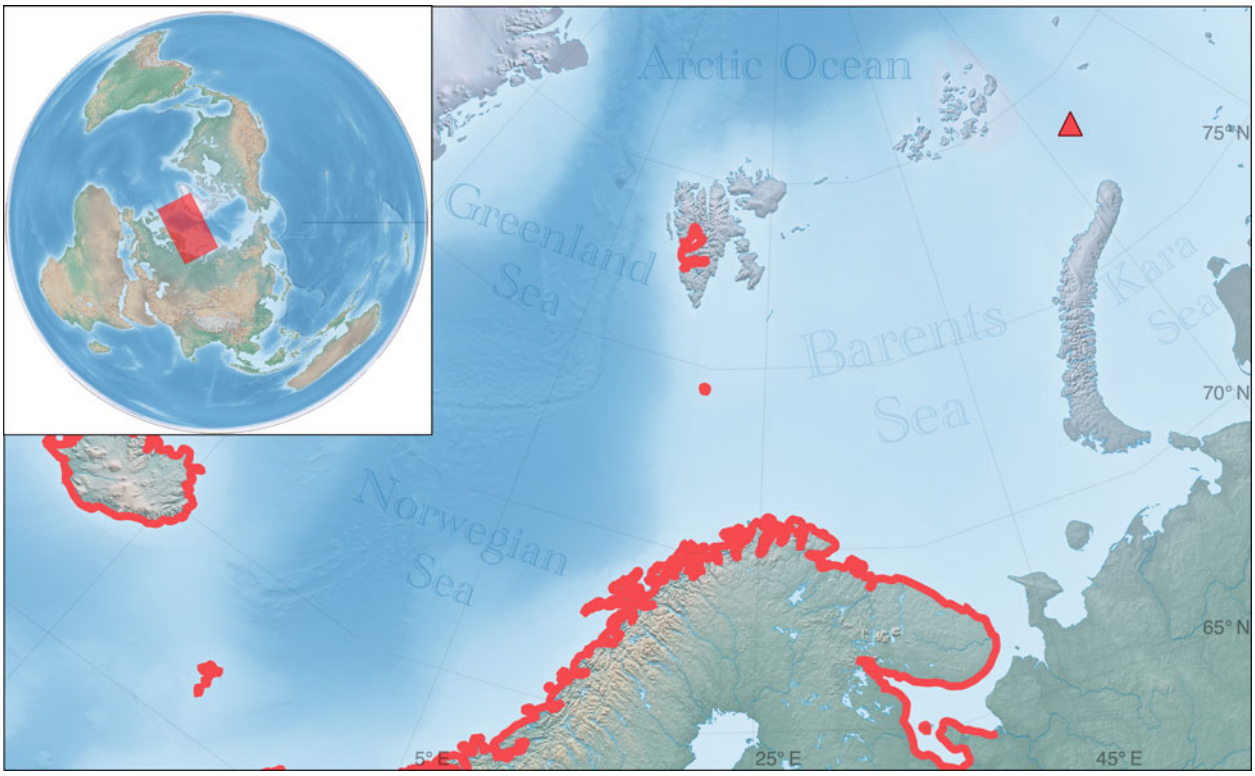

Fig. 1. Distribution of *Onoba aculeus* in the North-eastern Atlantic and the Arctic Ocean. Coastal regions where the species is distributed are highlighted by red. Triangle indicates locality in the Arctic shelf reported here.

The specimens of *Onoba aculeus* were collected on 2 November at the station with coordinates 78°44.734′N 69° 42.679′E and a depth of 343 m from the bottom with brown silt, clay and sand. The temperature recorded at the time of collection was −0.2 °C, the salinity was 34.9 PSU. The seafloor community was dominated by polychaete *Spiochaetopterus typicus* M Sars, 1856 and brittle star *Ophiacantha bidentata* (Bruzelius, 1805). For comparison we used material described by Nekhaev *et al.* (2014). Also, we had studied collections of the Zoological Institute of Russian Academy of Sciences (Saint Petersburg, Russia), Natural History Museum of Denmark (Copenhagen, Denmark) and Swedish Museum of Natural History (Stockholm, Sweden).

Shell measurements were taken according to the scheme by Nekhaev (2019).

Results

Onoba aculeus were found in two samples out of three collected at the station (3 and 2 specimens, respectively). The shells of collected snails are slender, conic with moderately flattened whorls covered with yellowish or brownish periostracum (Figure 2A, B). The shell surface with numerous thin spiral ribs, the axial sculpture is absent. Aperture drop-shaped, outer lip in side view is rounded, almost straight. The protoconch is relatively large, lecithotrophic, its surface was eroded in all five specimens. The measurements of the largest specimen (Figure 2A) are: shell height = 3.23 mm, aperture height = 1.13 mm, body whorl height = 2.03 mm, shell width = 1.48 mm, whorls number = 4.75.

The combination of morphological features listed above makes us confident in the correctness of the species identification of the discussed snails. Apart from *Onoba aculeus*, five more species of the genus are known from the Eastern Arctic seas (Warén, 1996; Nekhaev *et al.*, 2014; Nekhaev & Krol, 2020*b*). *Onoba mighelsi* (Stimpson, 1851), *O. improcera* (Warén, 1996) and *O. torelli* (Warén, 1996) differ from *O. aculeus* by less slender shell covered with lesser number (~10 *vs* ~20 in *O. aculeus*) of coarse spiral ribs (Warén, 1996; Nekhaev *et al.*, 2014). *Onoba semicostata* is the only representative of the genus in the region with planktotrophic protoconch (Nekhaev *et al.*, 2014). Shell shape and sculpture of *Onoba leptalea* (Verrill, 1884) is the most similar to *Onoba aculeus*. The former species can be distinguished by larger size convex whorls, more prominent spiral ribs and prosocline aperture in side view (Nekhaev *et al.*, 2014). Three adult specimens *Onoba leptalea* (Figure 2E) were found at the same sample with *Onoba aculeus*.

Apart from two *Onoba* species, two more gastropod species, *Punctulum wyvillethomsoni* (Friele, 1877) and *Propebela harpularia* (Couthouy, 1838), were identified from the same station.

Onoba aculeus is a rather variable species throughout its range. Spiral sculpture is more pronounced in molluscs from southern populations, whereas in snails from northern regions it is poorly marked. The sculpture of the studied specimens corresponds to individuals from Svalbard and the Murman coast of the Barents Sea (Figure 2C, D).

Discussion

In our opinion, the finding of living specimens of *Onoba aculeus* in two samples at the same station cannot be an accident that occurred during the collection or processing of samples. In the southern part of the Murmansk harbour, at the place of permanent moorage of the R/V 'Dalnie Zelentsy', *Onoba aculeus* is absent, like many other marine species due to low salinity (Derjugin, 1915; personal observation). Before the cruise in which the molluscs were collected, the ship did not leave the harbour for a long time, and the sampling gear also was not in use for a long period before. The sorting of samples from this expedition in the laboratory was carried out separately from the processing of benthic collections from other areas.

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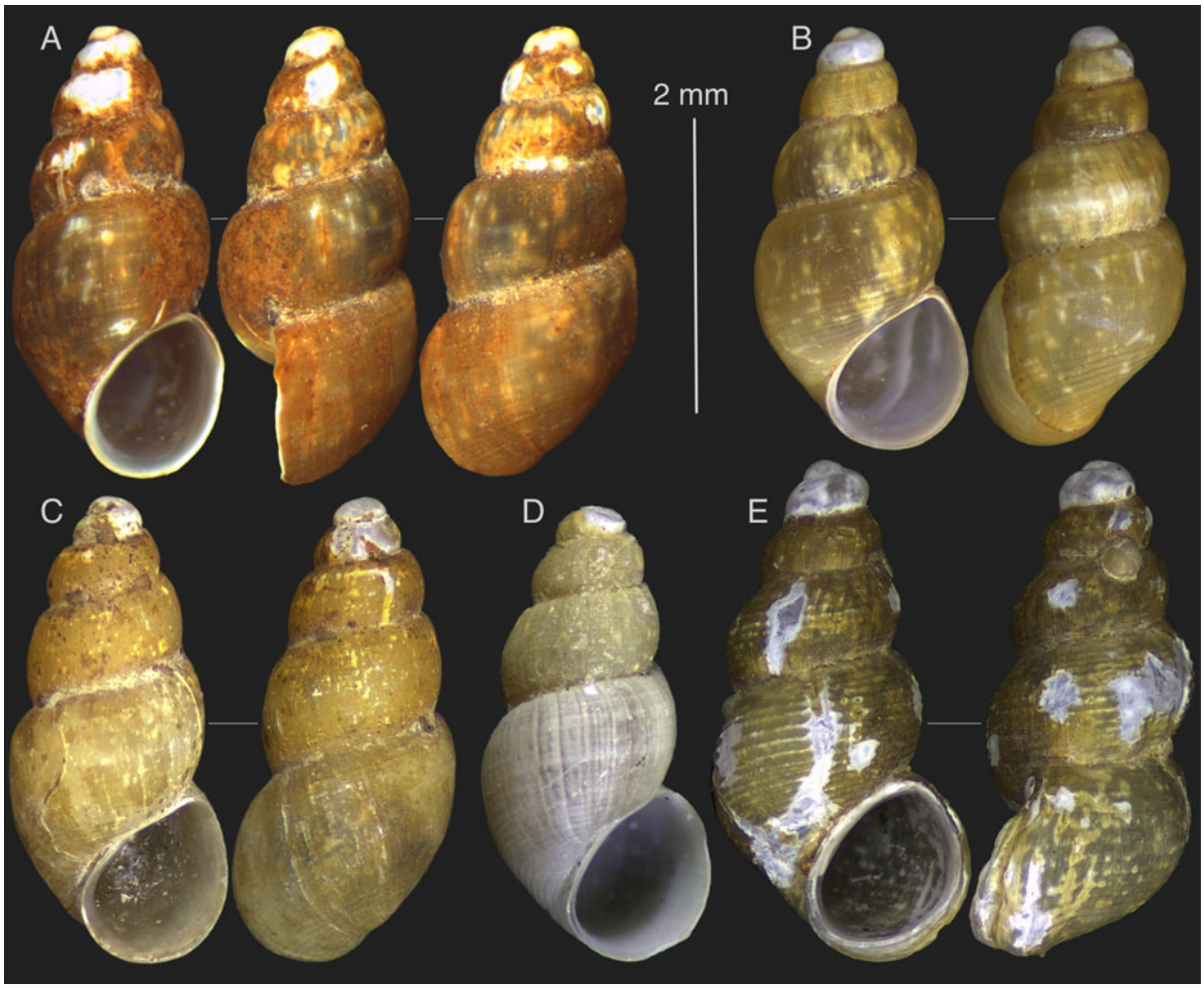

Fig. 2. Shells of *Onoba aculeus* (A–D) and *Onoba leptalea* (E). (A and B) Arctic Ocean, 78°44.734′N 69°42.679′E, 343 m; (C) Svalbard, Grønfjorden, 77°59.25′N 14°12′E, littoral; (D) South-western Barents Sea, Murman Coast, 68°17.67′N 38°37.93′E, 3 m; (E) Arctic Ocean, 78°44.734′N 69°42.679′E, 343 m (same locality with A and B).

Onoba aculeus is a typically shallow-water boreal mollusc confined to the littoral and seaweed zone (Matveeva, 1974; Warén, 1996; Nekhaev *et al.*, 2014; Nekhaev & Krol, 2020*b*). Finds of this species at depths exceeding 40–50 metres are isolated and confined to the inner fjord waters (Thorson, 1944; Nekhaev *et al.*, 2014). In fjords, due to the features of a sharp bottom slope, partial isolation, water circulation and sedimentation, the species composition is more homogeneous compared with the outer coastal regions and shallow-water fauna can often be found outside its usual bathymetric range (Buhl-Jensen, 1986; Buhl-Mortensen & Høisæter, 1993).

Onoba aculeus is not known directly from the regions of the high Arctic but is found in some regions transitional between the Arctic and temperate biogeographic realms: New England, south-western Greenland, western Svalbard, northern Scandinavia, Kola Peninsula and the White Sea (Warén, 1996; Nekhaev, 2014; Nekhaev *et al.*, 2014) (Figure 1). These areas are influenced by the warm branches of the North Atlantic current, which allows reduced boreal communities to exist there (Loeng *et al.*, 1997; Spalding *et al.*, 2007; Solyanko *et al.*, 2011; Nekhaev & Krol, 2020*b*).

The northernmost previous locality of *Onoba aculeus* was western Svalbard at 78°N. There molluscs live on the littoral even in winter and almost do not occur below the tide level (Rozycki, 1993; Nekhaev *et al.*, 2014; Zimina & Meshcheryakov, 2017). Mild temperature and ice conditions for this latitude allow relatively rich communities to exist on the littoral, which include several tens of macrofaunal species (Weslawski *et al.*, 1993; Zimina & Meshcheryakov, 2017). In general, the shallow-water communities of the area also abound with a large number of boreal species (Włodarska *et al.*, 1996; Laudien *et al.*, 2007; Malavenda, 2021).

Onoba aculeus has not been reliably recorded from the coastal communities of the Franz Josef Land archipelago and the northern part of Novaya Zemlya with severe habitat conditions. Previously published findings of the species on Franz Josef Land are based on incorrectly identified specimens of *Onoba leptalea* (see Nekhaev *et al.*, 2014). The finding of *Onoba aculeus* published in the south of Novaya Zemlya (~ 71°N 52°E) needs confirmation (Nekhaev & Krol, 2017).

The finding locality of *Onoba aculeus* reported here is in the Arctic Ocean at ~1200 km eastward to the nearest previous locality in Svalbard. The molluscs are found at a great distance from the shore at an unusual depth for this species. Bottom communities in the area where the samples with *Onoba aculeus* originates include species complexes typical of the lower Arctic shelf (Frolova *et al.*, 2011; Nekhaev & Krol, 2017; Zimina *et al.*, 2017). No other species unusual or new to the region were found in the samples.

The specimens found were adults, and the methods used for collection did not allow us to detect juvenile specimens that could be washed away through the sieve. Therefore, we cannot check whether the detection of *Onoba aculeus* indicates the presence of a self-reproducing population. In any case, the snails are

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involved in the bottom food chains of this region, and their actual distribution may not be limited directly to the place of collection.

The locality of *Onoba aculeus* lies between two areas of transport of warm Atlantic water to the Arctic. The first of them is the Murman Current, one of the branches of the North Atlantic Current, which reaches the northern part of Novaya Zemlya (Loeng *et al.*, 1993; Ozhigin *et al.*, 2011). Another flow of Atlantic water is the surface circulation of the Fram Strait branch current in the St. Anna Trench (Osadchiev *et al.*, 2022). Both currents can serve as effective transport corridors for southern species. Snails, however, do not have pelagic larvae that could serve to spread them with the ocean current (Matveeva, 1974). Most likely, they were brought into the region with drifting algae, wood and litter that are transported by the current (Grøsvik *et al.*, 2018).

Apart from physical environment, a significant limitation for the spreading of many coastal species at depths exceeding several tens of metres may be their association with seaweed as a food source or shelter. This is unlikely in the case of *Onoba aculeus*, which is detritophagus and is not strictly confined to macrophyte thickets in shallow water (Matveeva, 1974; Tsikhon-Lukanina, 1987; Nekhaev & Krol, 2020*b*).

Thus, we assume that the discussed finding of *Onoba aculeus* indicates the presence of a population of the species in this area. Since *Onoba aculeus* has not been found elsewhere on the High Arctic shelf, we suggest that the discovered molluscs indicate a presence of an isolated 'population island'. This type of distribution is typical for many species outside their main range (Harrison, 1991; Grimm *et al.*, 2003; Nekhaev *et al.*, 2020). Population islands, as a rule, exist for a relatively short time, but may mean the permanent presence of the species in the macroregion (Collins & Glenn, 1991). In this case, there is a permanent disappearance of some populations with subsequent colonization of the territory by the species. The formation of population islands can also be a stage in the settlement of a species and precede the formation of its permanent population.

Recently, the migration of shallow-water species has been demonstrated in a temperate environment, probably due to climatic shifts, which make deep-sea areas warmer (Tyler & Young, 1998; Perry *et al.*, 2005). The decrease in the thermal content of waters in the Arctic is especially noticeable (Boitsov *et al.*, 2012). However, it is impossible to determine whether the appearance of *Onoba aculeus* in this part of the Arctic shelf is the result of a recent introduction because there are no baseline data for previous decades.

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Author contributions. Ivan O. Nekhaev – conceptualization, preparation of text and artworks, examination of main material and comparative collections, Zinaida Yu Rumyantseva – fieldwork, preliminary examination, and identification of the material, comments to manuscript.

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Conflict of interest. The authors declare no conflict of interest.

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