


Unusual shallow-water boreal gastropod species associations at the Northern part of Arctic archipelago Novaya Zemlya

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Abstract

The fauna of the Barents Sea is the richest compared to other Arctic seas and is represented by a mixture of Arctic and boreal species, the distribution of which is believed to be due to the temperature conditions. In this study, this hypothesis was tested using data on the species composition of gastropods in the northern part of Novaya Zemlya, one of the coldest regions in the Barents Sea. Species associations with the predominance of the boreal species *Lacuna vincta* (Montagu, 1803) were found in the studied area; additionally, the fauna of gastropods was generally more similar to that of the boreal regions (White Sea and the Murman Coast) than the Arctic (fjords of Svalbard, Matochkin Shar (Novaya Zemlya), Franz Josef Land). The results obtained do not agree with the assumption about the effect of the temperature being the main factor determining the distribution of benthic communities in the Barents Sea. Two alternative hypotheses are proposed: either the influence of the Novaya Zemlya current as a corridor for the dispersal of species; or the existence of a glacier refugium off the coast of Novaya Zemlya where the shallow-water fauna could have survived the last glaciation.

Key words: Barents Sea; benthos; Kara Sea; temperature; glaciation.

Introduction

The fauna of the Barents Sea is the richest compared to other Arctic seas (Piepenburg *et al.*, 2011). This area is intersected by one of the generally accepted biogeographic boundaries: the border between the boreal and the Arctic regions, and also includes a number of local faunal divisions (Spalding *et al.* 2007; Jirkov 2013; Jørgensen *et al.* 2014). The benthic fauna of the southwestern Barents Sea is usually represented by boreal species shared with the shelf of the seas of northern Europe, while the northeastern Barents Sea is inhabited by the same communities as the northern areas of the shelf of the Siberian seas (Filatova 1957; Nekhaev & Krol 2020).

The generally accepted explanation for the heterogeneity of the distribution of benthic organisms is the heterogeneity of hydrological conditions. The southwestern part of the Barents Sea is strongly influenced by the relatively warm North Atlantic Current; in the central part of the Barents Sea, it encounters the Arctic water mass, which occupies the northern and northeastern part of the sea (Loeng 1991). It is assumed that the

main factor determining the patterns of large-scale distribution of benthic organisms is the heat content of water masses (Golikov 1989; Jørgensen *et al.* 2014; Zimina *et al.* 2015; Johannesen *et al.* 2017). Temperature also creates a major barrier that prevents boreal species and communities from entering the northern and eastern parts of the Barents Sea, as well as other areas of the Arctic (Galkin 1998; Renaud *et al.* 2015).

Coastal communities of the Arctic are more biologically diverse compared to the open sea and provide the most significant example of the heterogeneity of the fauna in the different regions of the Arctic (Golikov & Averintcev 1977; Golikov *et al.* 1990; Włodarska-Kowalczyk *et al.* 1998). In this study, I test the hypothesis that the faunas of regions similar in temperature conditions include a large number of common species than those from different time zones using the example of gastropods in the northern part of the Novaya Zemlya archipelago.

The northern part of Novaya Zemlya remains one of the least studied areas of the Barents Sea. In particular, information about the shallow-water mollusk fauna is still represented only by findings of two species by the Norwegian expedition of 1921 (Grieg 1924; Nekhaev & Krol 2017). The fauna of the open sea areas off the northern coast of the archipelago is described better and is represented by species common for Arctic (Frolova *et al.* 2011; Nekhaev & Krol 2017; Zimina *et al.* 2017).



Figure 1. Map of studied areas off Novaya Zemlya.

Materials and methods

Study area. Novaya Zemlya is an archipelago located on the border between the Barents and the Kara Seas. The northern part of Novaya Zemlya is strongly influenced by the cold Arctic waters. The average surface temperature in September does not exceed + 2°C (Ozhigin *et al.* 2011). About half of the area of the northern part of the archipelago is covered with glaciers, many of these are tidewater glaciers. The coastline is indented by numerous bays and inlets. The ice-free period along the open coast usually lasts from June-July to the beginning of October (Preobrazhensky 1947). The major portion of the archipelago is a part of the Russian Arctic National Park.

Samples were collected from the shallow-water part of the open sea off Cape Zhelania (мыс Желания), which is the northernmost part of Novaya Zemlya and from three bays in adjacent parts of the Barents and the Kara seas: Blagopoluchia Bay (залив Благополучия), Russkaya Gavan' Bay (залив Русская гавань), Ledyanaya Gavan' Bay (залив Ледяная гавань) (Figure 1). Russkaya Gavan' is a glacier fjord, while two other bays are influenced only by icebergs and drift ice during the summer period.

Sampling and sample processing. Materials were collected during the expedition of R/V Professor Molchanov from July 10 to August 2, 2018 over the course of the project "Arctic Floating University – 2018". Bottom sediments and kelps, which are a habitat for many gastropod species, were collected using a 0.1 Petersen grab (seven to ten replicates in each locality) and a dredge (three to five replicates in two-three localities in each locality) (Table 1).

Table 1. Sampling localities off Northern part of Novaya Zemlya.

Area	St.	Depth, m	Substrate	Date	Sampler	N	E
Russkaya Gavan	M2	10-15	Kelps	18/07/2018	Dredge	76.189583	62.606117
Russkaya Gavan	M3	10-15	Kelps	18/07/2018	Grab	76.191217	62.631467
Russkaya Gavan	M4	26	Silt, stones	18/07/2018	Grab	76.194750	62.625917
Blagopoluchiya	M5	10-15	Kelps	20/07/2018	Dredge	75.618533	63.82100
Blagopoluchiya	M6	58	Silt, Stones	20/07/2018	Grab	75.617950	63.861017
Ledyanaya Gavan	M7	7-10	Kelps	21/07/2018	Dredge	76.27267	68.28417
Ledyanaya Gavan	M8	4-7	Kelps	21/07/2018	Dredge	76.270617	68.283917
Ledyanaya Gavan	M9	22	Stones, silt	21/07/2018	Grab	76.274733	68.326817
Zhelaniya Cape	M10	22	Stones	22/07/2018	Grab	76.943950	68.574950
Zhelaniya Cape	M11	4-7	Kelps	22/07/2018	Dredge	76.943950	68.574950

The samples were sieved with a 0.5 mm sieve, specimens were collected from large stones and kelp fragments and fixed immediately onboard. The remainder of the bottom sediments were fixed and later surveyed under a stereomicroscope in the stationary laboratory. Species identification was mainly based on the shell characters and in some cases, radular morphology was additionally studied. Specimens in such a poor condition that they could not be identified to a species level were excluded. Taxonomy and nomenclature generally followed World Register of Marine Species (<https://www.marinespecies.org>) with the exception of "*Margarites striatus* – *Margarites groenlandicus*" group for the reasons described in Nekhaev (2014). When clarifying the taxonomic position of species from old publications, lists of synonyms from provided by Nekhaev (2014) and Nekhaev and Krol (2017) were used.

Data analysis. The obtained species list was compared with previously published data on the gastropod fauna for the following areas: Matochkin Shar, a shallow strait in the central part of Novaya Zemlya (Ushakov 1931); Northern Norway (Høisæter 2009), Murman Coast (Nekhaev 2014), the White Sea (Chaban 2001; Golikov *et al.* 2001), Franz Joseph Land (Nekhaev 2008), and two fjords in Svalbard: Kongsfjorden (Włodarska-Kowalczyk 2007) and Grønfjorden (Nekhaev 2012). For all coastal regions included in the comparison, the kelp associations were studied in detail. Shallow-water communities in three of these areas (Northern Norway, Murman Coast, and White Sea) are typically boreal, while the rest are Arctic (Filatova 1957; Jirkov 2013; Nekhaev 2014; Nekhaev & Krol 2020).

The Simpson index was used as a measure of the similarity of faunas (Baselga *et al.* 2007). This index is not sensitive to differences in the number of species between the regions being compared and is best suited for fragmentary data or comparison of the degree of similarity of local fauna with that of larger regions. Index values were calculated in PAST ver. 3.24 (Hammer *et al.* 2001).

All maps were created in QGIS ver. 3.6 with Natural Earth map kit.

Results

In the materials collected from the northern part of Novaya Zemlya, I found 28 gastropod species, four of them were represented only by empty shells (Table 2). All species, with the exception of *Lacuna vincta* and *Menestho albula*, were previously known for the fauna of the archipelago, but only *Cryptonatica affinis* and *Testudinalia testudinalis* (Grieg 1924; Nekhaev & Krol 2017) had been recorded directly in the shallow areas of the northern part of Novaya Zemlya.

Lacuna vincta and *Margarites helycinus* predominated in relation of the number of collected specimens (Table 2). These species were also the most frequently found (50% of all samples).

Species composition of gastropods from the northern part of Novaya Zemlya showed a high degree of similarity with the fauna of the Murman Coast and the White Sea (Fig. 2). On the contrary, the similarities with Matochkin Shar, Franz Joseph Land, and both fjords of Svalbard were low.

Discussion

The combination of species detected at the Northern part of Novaya Zemlya and their frequency of occurrence are not typical for coastal communities of the Arctic archipelagos. Similar communities with a pronounced predominance of *Lacuna vincta* and *Margarites helycinus* are characteristic for the shallow-water habitats of the photic zone of Northern Europe, including the Murman Coast and the White Sea (Matveeva 1974; Christie *et al.* 2003; Nekhaev 2014).

The temperature of the surface layer of water in the northern part of Novaya Zemlya during the warmest periods (August-September) does not exceed + 3°C and reaches negative values in winter; approximately the same temperature is characteristic for water surface at Franz Josef Land (Preobrazhensky 1947; Loeng *et al.* 1993). The average monthly temperature values in the fjords of West Spitzbergen are also low and reach +4°C (Svendsen *et al.* 2002). In the coastal areas of the Kola Peninsula and the White Sea, the water temperature during the warmest summer months (July-September) can get higher than +10 ... +15°C (Preobrazhensky 1947; Ilyin *et al.* 2016). The presence of boreal gastropod communities near the northern coast of Novaya Zemlya are not consistent with these patterns.

As alternative hypotheses for the formation of unusual species associations, I can suggest a) the influence of the coastal Novaya Zemlya current, or b) the existence of a refugium off the coast of Novaya Zemlya during the last glaciation.

The Novaya Zemlya current runs along the western coast of the archipelago from south to north (Ozhigin *et al.* 2011) and may be a corridor for dispersing species from more southern regions. In turn, the current itself is a continuation of the branch of the North Atlantic Current, which passes near the Kola Peninsula and Scandinavia, but the water temperature of the Novaya Zemlya current is low. This can explain the relatively high degree of difference between Svalbard fjords, Franz Joseph Land, and northern Novaya Zemlya. However, *Lacuna vincta*, which was dominant in my material, had not been found in the more southern coastal areas of the Novaya Zemlya, also influenced by the current similar to the Matochkin Shar, Chernaya Bay, and Pukhovaya Bay (Ushakov 1931; Nekhaev & Krol 2017).

Table 2. Species composition and number of collected individuals of gastropods off northern part of Novaya Zemlya.

Species	Station									
	M2	M3	M4	M5	M6	M7	M8	M9	M10	M11
<i>Admete viridula</i> (Fabricius, 1780)	1	2	4	-	-	-	-	-	-	-
<i>Alvania scrobiculata</i> (Møller, 1842)	-	-	-	-	-	-	-	S	-	-
<i>Boreotrophon clathratus</i> (Linnaeus, 1767)	-	-	-	-	1	-	-	-	-	-
<i>Boreotrophon truncatus</i> (Strøm, 1768)	-	-	-	-	-	-	-	1	-	-
<i>Buccinum ciliatum</i> (Fabricius, 1780)	-	-	-	-	-	-	1	-	-	-
<i>Buccinum glaciale</i> Linnaeus, 1791	-	-	-	1	-	-	-	-	-	-
<i>Cryptonatica affinis</i> (Gmelin, 1791)	1	-	-	-	-	-	-	-	-	-
<i>Curtitoma trevelliiana</i> (Turton, 1834)	1	-	-	-	-	-	-	-	-	-
<i>Curtitoma violacea</i> (Mighels et Adams, 1842)	-	-	2	-	-	-	-	-	-	-
<i>Cylichna alba</i> (Brown, 1827)	-	-	-	-	1	-	-	-	-	-
<i>Erginus rubellus</i> (Fabricius, 1780)	-	-	-	-	-	-	-	-	2	-
<i>Frigidoalvania cruenta</i> (Odhner, 1915)	-	-	-	-	6	-	-	-	-	-
<i>Frigidoalvania janmayeni</i> (Friele, 1878)	-	-	-	-	S	-	-	-	-	-
<i>Lacuna vincta</i> (Montagu, 1803)	10	4	-	-	-	4	5	-	-	233
<i>Lepeta caeca</i> (Müller, 1776)	-	-	18	-	-	-	-	-	-	-
<i>Margarites groenlandicus</i> (Gmelin, 1791)	-	-	-	7	-	-	-	-	-	-
<i>Margarites helycinus</i> (Phipps, 1774)	1	-	-	-	-	19	57	1	-	66
<i>Margarites striatus</i> (Leach, 1819)	-	-	1	-	-	-	-	-	-	-
<i>Menestho albula</i> (Fabricius, 1780)	-	-	S	-	-	-	-	-	-	-
<i>Menestho truncatula</i> Odhner, 1915	-	-	-	-	4	-	-	-	-	-
<i>Moelleria costulata</i> (Møller, 1842)	-	-	-	-	-	-	-	1	-	-
<i>Oenopota pyramidalis</i> (Strøm, 1788)	-	-	1	-	-	-	-	-	-	-
<i>Propebela arctica</i> (Adams, 1855)	1	2	-	-	-	-	-	-	-	-
<i>Propebela nobilis</i> (Møller, 1842)	2	-	-	-	-	-	-	-	-	-
<i>Propebela rugulata</i> (Møller in Reeve, 1846)	-	-	4	-	-	-	-	-	-	-
<i>Retusa obtusa</i> (Montagu, 1803)	-	-	-	S	-	-	-	-	-	-
<i>Tectura virginea</i> (Müller, 1776)	-	-	-	-	-	-	-	S	-	-
<i>Testudinalia testudinalis</i> (Müller, 1776)	-	-	-	5	-	-	3	-	-	-

Numerals indicate number of living specimens collected in the sampling site, “S” indicate that only empty shells were collected. Station codes the same as in the Table 1.

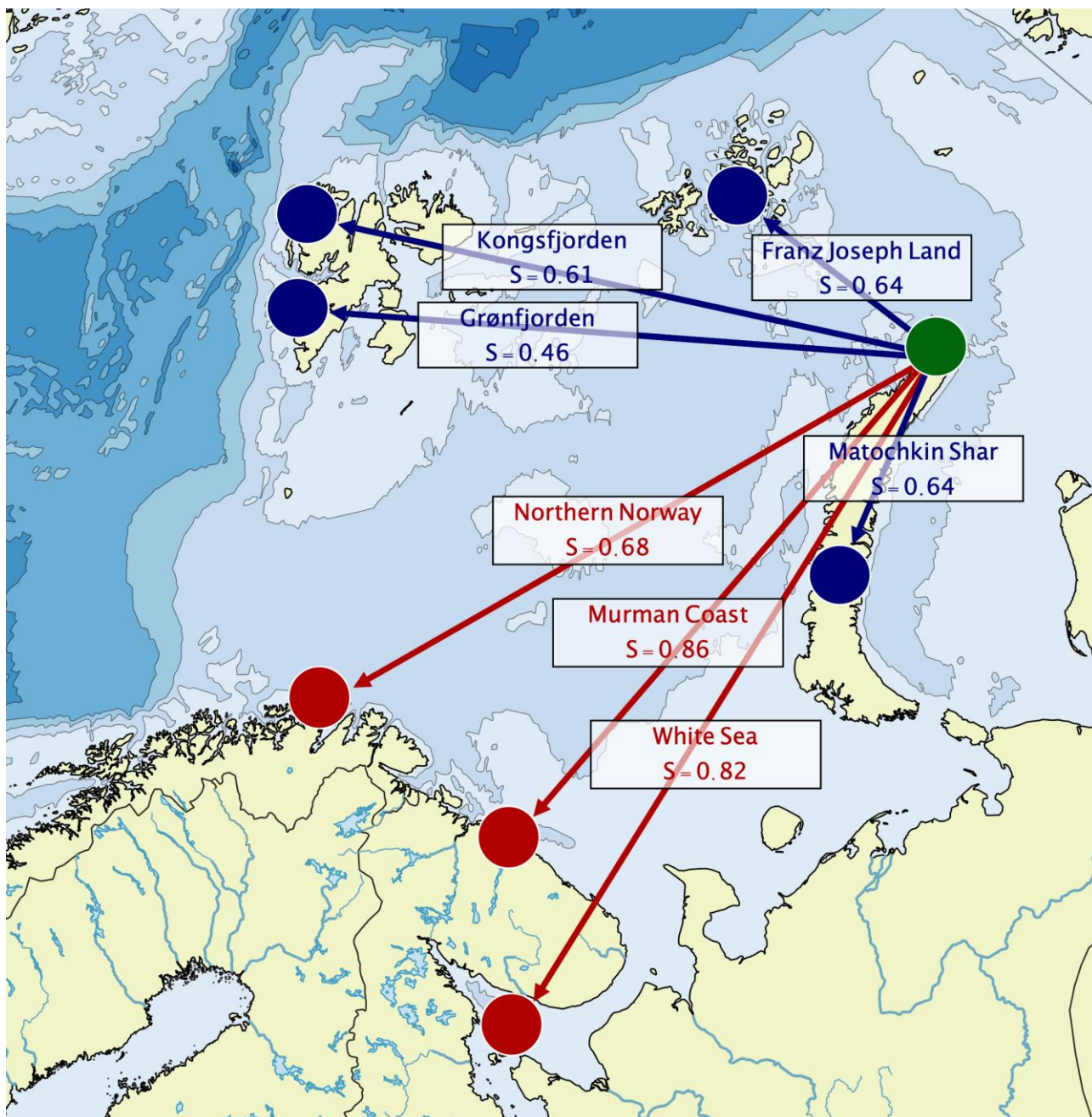


Figure 2. Relations between gastropod fauna of Novaya Zemlya (green circle) with shallow water boreal (red circles) and Arctic (blue circles) faunas. “S” indicates value of Simpson’s index.

The Barents Sea and adjacent areas were covered by an ice sheet in the Late Pleistocene. It is believed that marine fauna of the sea did not survive the glaciation and the Barents and the Western Kara seas were since recolonized by marine animals (Maggs *et al.* 2008). However, a significant part of the coast of Novaya Zemlya remained free of ice at least until the last glacial maximum, and marine benthic fauna existed in the region (26 ka BP) (Mangerud *et al.* 2008). During the last glacial maximum, the glaciation boundary, if not directly along the coast of Novaya Zemlya, was relatively close to it (Svendsen *et al.* 1999; Patton *et al.* 2017).

Some terrestrial animals living on Novaya Zemlya are known as relics that survived the last glaciation (Potapov *et al.* 2021; Spitsyn *et al.* 2021). The possibility of existence of a glacial refugia for the marine boreal and boreal-subarctic invertebrate species was also discussed but was rejected because climatic conditions in the subglacial regions were too severe for them (Strelkov *et al.* 2007). On the other hand, the modern climate of the northern part of Novaya Zemlya is close to the climate in other parts of the Barents

Sea during the last glaciation. It is possible that the resettlement of many shallow-water marine species that currently have a boreal type of distribution is limited not as much by the environmental conditions as by the impossibility of colonizing new areas. The assumption of the presence of a refugium, in my opinion, is the most likely, but it requires a more detailed analysis which cannot be performed using the existing faunistic data.

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