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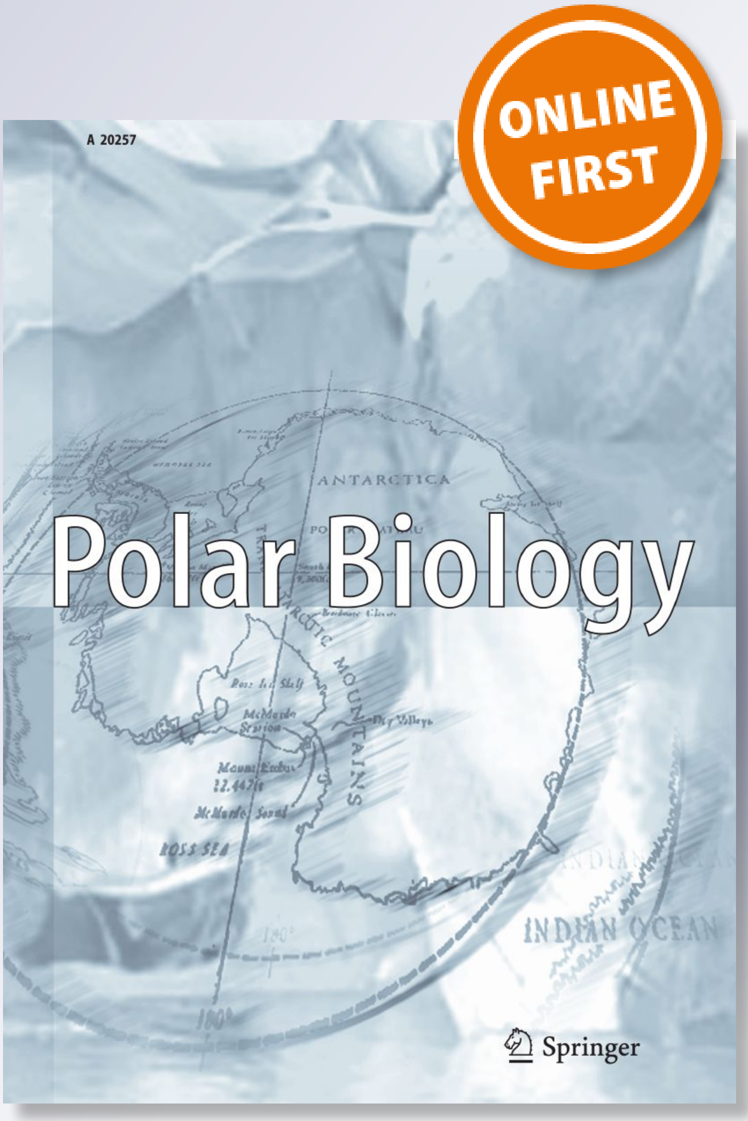

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ORIGINAL PAPER

Diversity of shell-bearing gastropods along the western coast of the Arctic archipelago Novaya Zemlya: an evaluation of modern and historical data

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Abstract Accurate estimation of biodiversity is necessary to provide a baseline for further ecosystem investigations and protection of High Arctic regions. Novaya Zemlya is a large Arctic archipelago located on the border between the Barents and Kara Seas. Despite a long history of investigation, data on species composition along the coast of Novaya Zemlya are presented only in sources from the initial period of investigation in the late 19th to early 20th century. We estimate herein the diversity of shell-bearing Gastropoda found along the western coast of Novaya Zemlya, based on both published sources and our original identification of material collected between 1985 and 2008. The total species list contains 86 species, 24 of which were identified only from the recent material, while 28 were only reported in literature. Our results demonstrate that modern and historical data are significantly different. However, these differences do not indicate any changes in species composition in the region during the last century, but rather arise for methodological reasons. Even combined, the two types of data do not provide complete coverage of the fauna. We also carried out a preliminary comparison between local coastal gastropod faunas from various parts of the Barents Sea (including Novaya Zemlya).

Keywords Arctic · Barents Sea · Gastropoda · Species diversity · Novaya Zemlya · Historical data

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Introduction

Arctic marine ecosystems are believed to have been transformed recently due to the influence of multiple factors, including climatic changes, pollution, effects of fisheries, and invasive species (Britaev et al. 2010; Jørgensen et al. 2015). One of the most important metrics of these changes is alteration in taxonomical diversity over time, as revealed by comparing modern and earlier investigations. Such differences are often interpreted as substantial changes of the ecosystem structure influenced by local and/or global factors (Britaev et al. 2010; Lyubina et al. 2014). However, this approach has a significant drawback: Real changes may be overestimated if the results of either of the studies are incomplete (Nekhaev 2016). Given the limited baseline knowledge regarding the Arctic fauna and ecosystems in many regions, such incompleteness of biodiversity studies may be even harder to identify, and the practical limitations of poor accessibility of many Arctic regions make frequent and regular monitoring studies difficult.

Only some large High Arctic marine shallow-water ecosystems, especially coasts of Svalbard and Western Greenland, undergo more or less regular hydrobiological examination (Hop et al. 2002; Palerud et al. 2004; Beuchel and Gulliksen 2008; Yesson et al. 2015). Both sites are located in the Atlantic Ocean and are influenced by the tails of the warm North Atlantic Current. By contrast, knowledge about bottom fauna of other Eurasian Arctic archipelagos, such as Severnaya Zemlya, the New Siberian Islands, Franz Josef Land, and Novaya Zemlya, is considerably poorer and limited to only occasionally collected data (Gorbunov 1949; Golikov and Scarlato 1977; Denisenko et al. 1995). More detailed and accurate estimation of biodiversity in these regions is necessary to provide a baseline for further ecological research.

Gastropoda is one of the key groups of marine benthic invertebrates. Aside from great taxonomical diversity and abundance, gastropods demonstrate a wide spectrum of life strategies and ecological preferences: from short-lived algae eaters to long-lived predators or even parasites. Also, some gastropod species are relatively easy to recognize using simple shell characteristics. This makes gastropods suitable as indicators of environmental conditions and popular objects for monitoring studies in various environments (Golikov 1968; Zvonareva et al. 2015). Novaya Zemlya is one of the largest but most poorly studied Arctic archipelagos of Eurasia, located on the border between the Barents and Kara Seas. Investigations of its environment and fauna started in the early 18th century. The first report on mollusks inhabiting the waters around the archipelago was presented by Middendorff (1849) based on samples collected during Baer's expedition in 1837. Later, species lists of mollusks from various parts of Novaya Zemlya were published after the 1875–1876 and 1878–1879 cruises by N.A.E. Nordenskiöld (Leche 1878; Aurivillius 1885).

Another survey of the archipelago was carried out in 1908; based on the material collected by this expedition, a new species, *Natica tenuistriata* Dautzenberg et Fischer, 1911 (now *Euspira tenuistriata*), was described and an annotated list of molluskan taxa published (Dautzenberg and Fischer 1911). Dautzenberg also identified a small collection of mollusks taken in a Russian survey in 1910 (Ivanov 1910). Substantial zoological material, including marine invertebrates, was collected during the Norwegian expedition to Novaya Zemlya in 1921, and a report on mollusks was published by Grieg (1924).

The next stage of studies of Novaya Zemlya started in the 1920s as part of investigations of the environment along the Northeastern Passage, a shipping route between the Atlantic and Pacific Oceans. Detailed species lists of benthic animals and descriptions of the environmental conditions were published for three studied areas: Moller Bay, Chernaya Inlet, and Matochkin Shar Strait (Ushakov 1927; Gurjanova and Ushakov 1928; Ushakov 1931). Additionally, the new species *Trichotropis herzensteini* Derjugin et Gurjanova, 1926 (now synonymized with *Trichotropis borealis* Broderip et Sowerby, 1829) was described (Derjugin and Gurjanova 1926).

Publications based on later surveys of the region are surprisingly scarce, and often present only brief ecological summaries (e.g., Golikov and Averintcev 1977; Denisenko et al. 1995; Pogrebov et al. 1997). Material collected during this period for the most part was not properly preserved and is now not available for reexamination. However, some portions of it are dispersed between taxonomic museum collections or remain unidentified. Careful examination of these samples may complement older data obtained during the initial phase of investigation, although the latter still remain the most useful source of faunistic information on the Novaya Zemlya region.

The main objective of this study is to estimate the species diversity of shell-bearing gastropod mollusks along the western coast of Novaya Zemlya based on available original material, taken during the cruises of past decades, and published sources. We also compared the two datasets, i.e., modern and historical, to determine whether either dataset separately or both of them together can provide reliable information regarding the fauna of the archipelago.

Materials and methods

Study area

The Arctic archipelago Novaya Zemlya (Новая Земля, Novaja Semlja) is located between the Barents and Kara Seas and consists of two major islands—Southern and Northern—and several hundred smaller islands around them. The Southern and Northern islands are divided by a very narrow (1–2 km) strait called Matochkin Shar. The shoreline of the archipelago is indented by numerous fjords and inlets. Some of them, especially in the north, are influenced by tidewater glaciers. The typical depth along the coast of Novaya Zemlya does not exceed 250 m. The western coast in particular is influenced predominantly by Arctic waters, although Atlantic ones also have some effect in the extreme north of the region (Ozhigin et al. 2011). Average water temperature at sea bottom, measured in September, the warmest month, is about 0–1 °C (Loeng 1991; Ozhigin et al. 2011). The temperature range observed during our recent investigation was from −1.83° to +2.25 °C (Online Resource 1). The salinity of the coastal waters was remarkably stable at about 34.8–34.9 psu with nonsignificant variation (Ozhigin et al. 2011). At least two regions of Novaya Zemlya (Matochkin Shar and Chernaya Inlet) were used as nuclear weapon test sites during the second part of the 20th century. However, dedicated study revealed no significant effects of radioactive pollution on macrobenthic communities (Pogrebov et al. 1997).

To describe the geographical distribution of gastropods along Novaya Zemlya, we divided its coast into the following seven regions (Fig. 1): A—extreme north of the archipelago southward to 75°50′N; B—coastal areas from

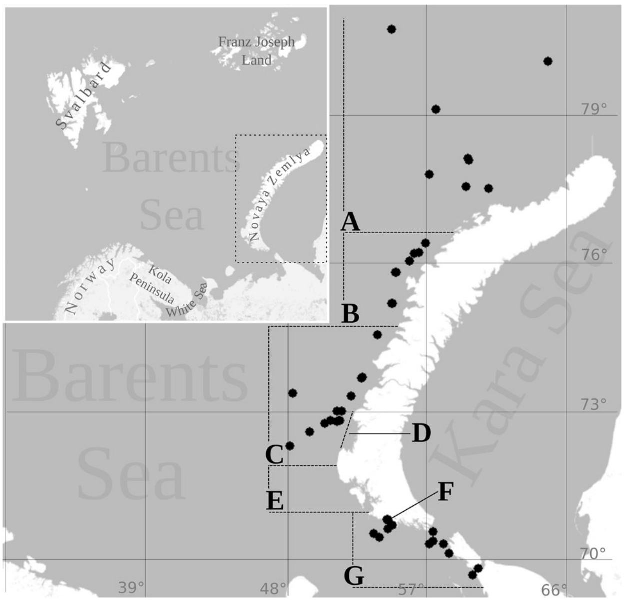

Fig. 1 Map of study area, showing sample sites of material used (*black circles*). Letters *A*–*G* indicate regions of previous and modern investigations: *A*—extreme north of the archipelago southward to 75°50′N; *B*—coastal areas from 75°50′ south to 74°20′N; *C*—central part of the archipelago from 74°20′N to 71°50′N except Moller Bay and Besimyannaya Bay; *D*—Moller Bay and Besimyannaya Bay; *E*—Kostin Shar Strait and its vicinities; *F*—Chernaya Inlet; *G*—extreme south of Novaya Zemlya southward to 70°50′N including Yugorskiy Shar Strait

75°50′ south to 74°20′N; C—central part of the archipelago from 74°20′N to 71°50′N except Moller Bay (залив Моллера) and Besimyannaya Bay (Безымянная губа); D—Moller Bay and Besimyannaya Bay; E—Kostin Shar Strait (Костин шар) and its vicinities; F—Chernaya Inlet (Чёрная губа); G—extreme south of Novaya Zemlya southward to 70°50′N including Yugorskiy Shar Strait (Югорский шар). This division corresponds with sampling areas of various surveys, both past and recent.

Matochkin Shar Strait was not included as a separate research area in our study. A large amount of published and original data on the distribution of seafloor fauna in the strait was already summarized by Ushakov (1931). No additional information has been reported since then, and our recent samples also did not cover this area.

Sampling and sample processing

Material used for the present study had been collected in the numerous cruises of RV Dalnie Zelentsy carried out during the period of 1985–2008. Surveys covered the areas along the western coast of Novaya Zemlya (A, B, C), inner parts of Chernaya Inlet and Yugorskiy Shar Strait (F and G; Online Resource 1), and some adjacent areas of the Barents Sea (Fig. 1). Moller Bay and Kostin Shar (regions D and E on Fig. 1) were not examined.

Material was taken from 4 to 14 sampling stations within each region. Typically, seafloor sediments were collected using grab samplers (0.1 m^2 van Veen or 0.25 m^2 Petersen) in three replicates, except for four stations in Chernaya Inlet, where five replicates were taken with 0.1 m^2 van Veen grab. Five additional samples were taken with Sigsbee Trawl from regions B and C (Online Resource 1).

Collected bottom sediments were sifted through 1-mm-mesh sieve onboard and immediately fixed with 4 % formalin. After sorting in the laboratory under stereomicroscope, the material was transferred into 75 % ethanol. Currently, samples are kept in the Laboratory of Macroecology and Biogeography of Invertebrates, Saint Petersburg State University (Saint Petersburg, Russia).

We found that the majority of the gastropods were live, but occasional empty shells were also present. We did not discard these data, and whenever information on empty shells is used, it is specifically pointed out. Specimens in such a poor state that they could not be identified to species level were not considered.

For species identification, we examined shell characteristics and compared our data with modern taxonomical literature on Northern Atlantic and Arctic gastropods (Galkin 1955; Bouchet and Warén 1980, 1986, 1993; Golikov 1980, 1987; Golikov and Sirenko 1988; Bogdanov 1990; Warén 1996; Chaban 1996; Kantor and Sysoev 2006; Ohnhesiser and Malaquias 2013). Prior to this study, original species descriptions and reference museum collections, including type series, stored in several European museums [Swedish Museum of Natural History (Stockholm, Sweden), Natural History Museum of Denmark (Copenhagen, Denmark), Zoological Institute of Russian Academy of Sciences (Saint Petersburg, Russia), University Museum at the University of Oslo (Norway), and University Museum of Bergen (Norway)] were examined by the first author.

The taxonomical system generally follows that of MolluscaBase (http://www.molluscabase.org) with some remarks discussed in Nekhaev (2014). We did not apply a definitive species identification for *Anatoma* Woodward, 1859, because this genus, which currently contains a single arctic species, requires taxonomical revision (Høisæter and Geiger 2011). In classification of cephalaspid genera *Cylichna* and *Retusa*, we follow Chaban (2004) and Kantor and Sysoev (2006).

All results obtained from these recent surveys were combined to produce a single dataset of new information on presence/absence of various species across the study area.

Analysis of published sources

We created a combined dataset of presence/absence of all species recorded by seven publications, each of them a faunistic report from a single survey. Four expeditions covered large areas (Leche 1878; Ivanov 1910; Dautzenberg and Fischer 1911; Grieg 1924), while the rest examined smaller locations: Yugorskiy Shar Strait (Aurivillius 1885), Chernaya Inlet (Gurjanova and Ushakov 1928), and Moller Bay (Ushakov 1927). Only studies containing species lists with detailed information on material and collection sites were included.

To resolve synonymy, we predominantly used two online taxonomical databases: MolluscaBase (http://www.molluscabase.org) and CLEMAM (http://www.somali.asso.fr). However, not all of the species names used by previous authors are present in these databases. Moreover, names are sometimes erroneously used in a single publication. In these cases, we adopted detailed lists of synonyms from the nomenclatural catalogs and taxonomical revisions (Galkin 1955; Bogdanov 1990; Kantor and Sysoev 2006). Associations of all names used by previous authors with the valid species synonyms are given in Online Resource 2.

On several occasions, species listed in the published sources were not included in our analysis. First, since the taxonomical status of some species of Mangeliidae reported by previous authors is often confused, we only included species reported for this region of the Barents Sea by Bogdanov (1990). We also omitted several species from other families, if their occurrence in the study area was in doubt (see "Results" section for further information).

Data analysis

Multidimensional scaling (MDS) together with clustering were applied for comparison between known gastropod fauna of Novaya Zemlya with other local gastropod faunas of the Barents and Norwegian Seas. The unweighted pair-group average algorithm was used for dendrogram formation.

To estimate significance of differences between modern and published data and between regions, analysis of similarities (ANOSIM) was carried out. ANOSIM, MDS, and clustering were based on the Dice similarity index, which corresponds to the Bray-Curtis index widely used for binary data in ecological studies. Expected species number for modern data was calculated by using nonparametric Chao 2 and Jacknife 1 estimators (Colwell and Coddington 1994). Only data on grab samples were used for such estimation. All statistical analyses were carried out using the PAST 2 statistical package (Hammer et al. 2001).

Results

Examination of recent material

We identified a total of 58 species of shell-bearing gastropod (Table 1), with 3 species (*Trichotropis bicarinata*, *Colus gracilis*, and *Retusa pertenuis*) represented exclusively by empty shells. All recorded species but one are already known from the Barents Sea and adjacent Arctic waters (Sirenko 2001; Kantor and Sysoev 2006; Nekhaev 2014). The exception was a single specimen of *Admete* Kröyer in Møller, 1842, which we provisionally identified as *Admete* cf. *solida*. This individual had 26-mm-high shell and corresponded well to the description and published figure of the holotype of *A. solida* (Aurivillius 1885) (Sysoev and Kantor 2002). However, in the Russian Arctic, it has been reported only from the northern part of the Bering Sea (Kantor and Sysoev 2006), a location significantly removed from our study area. It is also possible that some undescribed species with similar shell morphology may be present in the study area (Sirenko 2015).

The highest numbers of species were detected in regions C and G (37 and 28, respectively) (Table 1). Both areas are located in the south of Novaya Zemlya (Fig. 1). The number of species in the northern regions A and B was two times smaller: 13 and 15 species. Surprisingly, only 17 species were recorded in the Chernaya Inlet, although it is located in the south of the archipelago. The most common species were *Cylichna alba* (39 %), *Frigidoalvania cruenta* (28 %), and *Solariella obscura* (15 %).

The suggested number of species estimated by Chao 2 estimator was 77.2 with variance of 3.5, while the Jacknife 1 estimator value was lower at 67.5. These data as well as the species accumulation curve (Fig. 2) show that the real species diversity of the region was underestimated during recent studies.

Analysis of published sources

A total of 62 species were detected during previous investigations along the western coast of Novaya Zemlya (Table 1). Nine more species [*Onchidiopsis glacialis* (Sars, 1851), *Tachyrhynchus erosus* (Couthouy, 1838), *Neptunea despecta* (Linnaeus, 1758), *Buccinum hydrophanum* Hancock, 1846, *Curtitoma novajasemljensis* (Leche, 1878), *Frigidoalvania cruenta* (Odhner, 1915), *Eumetula arctica* (Mörch, 1857), *Aartsenia candida* (Møller, 1842), and *Cylichna densistriata* (Leche, 1878)] were reported exclusively from Matochkin Shar Strait (Ushakov, 1931) and were not included in the total species count. Also, a number of accounts were not added to the species list due to their questionable reliability. We excluded three species

Table 1 Species composition of shell-bearing Gastropoda along the western coast of Novaya Zemlya

	Region						
	A	B	C	D	E	F	G
Patellogastropoda							
Acmaeoidea Forbes, 1850							
Lepetidae Gray, 1850							
Lepeta caeca (Müller, 1776)	L	L	L, 1	6	1	L, 7	L
Lottiidae Gray, 1840							
Tectura virginea (Müller, 1776)						L	
Erginus rubellus (Fabricius, 1780)				6	1	7	
Testudinalia testudinalis (Müller, 1776)	5	5	1, 3	6	1, 4		1
Vetigastropoda							
Scissurelloidea Gray, 1817							
Anatomidae McLean, 1989							
Anatoma sp.						L	
Fissurelloidea Fleming, 1822							
Fissurellidae Fleming, 1822							
Puncturella noachina (Linnaeus, 1771)				6	1	7	
Trochoidea Rafinesque, 1815							
Margaritidae Thiele, 1924							
Margarites costalis (Lovén in Gould, 1841)	L	5	L, 1, 3	1	1, 4	L, 7	L, 2
Margarites groenlandicus (Gmelin, 1791)			L	6	1, 4	7	
Margarites helicinus (Phipps, 1774)			1, 3	1, 6	1, 4	7	
Margarites olivaceus (Brown, 1827)		5	L	6, 5	4	7	
Margarites striatus (Leach, 1819)		5		1, 6, 5	1	7	
Solariellidae Powell, 1951							
Solariella obscura (Couthouy, 1838)		5	L, 1	1, 6, 5		L	L, 1
Solariella varicosa (Mighels et Adams, 1842)			L, 1	1	1		L, 1
Turbinoidea Rafinesque, 1815							
Colloniidae Cossmann, 1917							
Moelleria costulata (Møller, 1842)			L			L, 7	L
Caenogastropoda							
Capuloidea Fleming, 1822							
Capulidae Fleming, 1822							
Trichotropis bicarinata (Sowerby, 1825)		S					
Trichotropis borealis (Broderip et Sowerby, 1829)		L	L, 1	1, 6	1	7	1
Trichotropis conica Møller, 1842			L				
Neoiphinoe kroeyeri (Philippi, 1849)							1
Littorinoidea Children, 1834							
Littorinidae Children, 1834							
Littorina obtusata (Linnaeus, 1758)				1			
Littorina saxatilis (Olivi, 1792)				6		7	
Naticoidea Guilding, 1834							
Naticidae Guilding, 1834							
Amauropsis islandica (Gmelin, 1791)				6			L, 2
Cryptonatica affinis (Gmelin, 1791)	S, 5	L, 5	L, 1, 3	1, 6, 5	1, 4, 5	7	L, 1, 2
Pseudopolinices nanus (Møller, 1842)							L
Euspira pallida (Broderip et Sowerby, 1829)			L, 1, 3	1, 6, 5	1	7	L, 1
Euspira tenuistriata (Dautzenberg and Fischer 1911)					4		
Rissoidea Gray, 1847							

Table 1 continued

	Region						
	A	B	C	D	E	F	G
Rissoidae Gray, 1847							
Alvania scrobiculata (Møller, 1842)			L			L	
Boreocingula castanea (Møller, 1842)			L	6			
Frigidoalvania cruenta (Odhner, 1915)		L	L			L	L
Frigidoalvania janmayeni (Friele, 1878)	L		L			L	
Pusillina tumidula (G.O. Sars, 1878)							L
Onoba improcera Warén, 1996			L			L	
Velutinoidea Gray, 1840							
Velutinidae Gray, 1840							
Limneria undata (T. Brown, 1839)		5		6		7	1
Piliscus commodus (Middendorff, 1851)			L				
Onchidiopsis groenlandica Bergh, 1853							1
Velutina velutina (Müller, 1776)		5				7	
Muricoidea Rafinesque, 1815							
Muricidae Rafinesque, 1815							
Boreotrophon clathratus (Linnaeus, 1767)			S, 3				L, 1
Boreotrophon truncatus (Strøm, 1768)		5				7	
Buccinoidea Rafinesque, 1815							
Buccinidae Rafinesque, 1815							
Buccinum polare Gray, 1839			1				
Buccinum angulosum Gray, 1839	S		L	1	4	7	1
Buccinum ciliatum (Fabricius, 1780)			1		1	7	1, 2
Buccinum cyaneum Bruguière, 1792	5	5	3	6, 5	4	7	1, 2
Buccinum fragile Verkruzen, 1878			L				
Buccinum glaciale (Linnaeus, 1761)	5	5	L, 1	1	1	L	1, 2
Buccinum maltzani Pfeffer, 1886			1	1		7	1, 2
Buccinum scalariforme Møller, 1842			L, 1		4		1
Buccinum undatum (Linnaeus, 1758)				6			
Colus gracilis (da Costa, 1778)			S				
Colus holboelli (Møller, 1842)	L	L					
Colus islandicus (Mohr, 1876)			1			7	
Colus sabini (Gray, 1824)						7	
Neptunea communis (Middendorff, 1848)	S		L				
Neptunea ventricosa (Gmelin, 1791)					4		
Pyrulofusus deformis (Reeve, 1847)			1				
Retifusus roseus (Dall, 1877)			L				
Columbellidae Swainson, 1840							
Astyris rosacea (Gould, 1840)			1	6, 5	4	7	2
Cancellariidae Forbes et Hanley, 1851							
Admete cf. *solida*							L
Admete viridula (Fabricius, 1780)		L	L, 1	6	1	L, 7	L, 1
Conoidea Fleming, 1822							
Mangeliidae P. Fischer, 1883							
Curtitoma trevelliana (Turton, 1834)		L	L				
Curtitoma violacea (Mighels et Adams, 1842)			1	1, 6	1, 4	7	L, 1, 2
Obesotoma simplex (Middendorff, 1849)							L
Obesotoma woodiana (Møller, 1842)		L	L, 1	1			1

Table 1 continued

	Region						
	A	B	C	D	E	F	G
Oenopota harpa (Dall, 1884)			1			7	L, 1
Oenopota impressa (Beck in Mιrch, 1869)	5		L, 1	1, 6	4		L
Oenopota pyramidalis (Strøm, 1788)			L, 1	1	1, 4	L, 7	1
Propebela arctica (Adams, 1855)							2
Propebela exarata (Møller, 1842)			1	1	1	7	1
Propebela harpularia (Couthouy, 1838)				6		7	
Propebela nobilis (Møller, 1842)		5	L	1, 6, 5	4		1, 2
Propebela rugulata (Møller in Reeve, 1846)		L	L			7	
Propebela scalaris (Møller, 1842)			1		1		
Propebela spitzbergensis (Friele, 1886)				6		7	
Heterobranchia							
Mathildoidea Dall, 1889							
Mathildidae Dall, 1889							
Turritellopsis stimpsoni Dall, 1919				6			L
Pyramidelloidea Gray, 1840							
Pyramidellidae Gray, 1840							
Menestho truncatula Odhner, 1915	L	L	L, 1	1		7	
Liostomia eburnea (Stimpson, 1851)			L				
Cephalaspidea							
Diaphanoidea Odhner, 1914							
Diaphanidae Odhner, 1914							
Diaphana glacialis Odhner, 1907			L	6		7	
Diaphana hiemalis (Couthouy, 1839)		L					L
Diaphana minuta Brown, 1827				6		7	L
Toledonia limnaeoides (Odhner, 1913)			L				L
Philinoidea Gray, 1850							
Cylichnidae H. et A. Adams, 1854							
Cylichna alba (Brown, 1827)	L	L	L, 1	1, 6	1, 4	L, 7	L, 1, 2
Cylichna occulta (Mighels et Adams, 1842)	L		1	1	1		L, 1
Cylichna scalpta (Reeve, 1855)	L	L		6		L, 7	L
Philinidae Gray, 1850							
Laona finmarchica (M. Sars, 1859)	L						
Philine lima (Brown, 1827)				6		L, 7	L
Philine quadrata (S. Wood, 1839)	L	L					
Retusidae Thiele, 1925							
Retusa pertenuis (Mighels, 1843)							S, 1
Retusa turrita Møller, 1842				6		L	L
Found in original material	13	15	37			17	28
Recorded in literature	5	12	30	43	30	30	13
Total	17	26	51	43	30	46	45

"L" indicates presence of living specimens in the material seen, "S" indicates that only empty shells were found in our material; numbers indicate records in literature sources: *1*, Leche 1878; *2*, Aurivillius 1885; *3*, Ivanov 1910; *4*, Dautzenberg and Fischer 1911; *5*, Grieg 1924; *6*, Ushakov 1927; *7*, Gurjanova and Ushakov 1928. Letters A–G indicate regions of previous and modern investigations: *A*, extreme north of the archipelago southward to 75°50′N; *B*, coastal areas from 75°50′ south to 74°20′N; *C*, central part of the archipelago from 74°20′N to 71°50′N except Moller Bay and Besimyannaya Bay; *D*, Moller Bay and Besimyannaya Bay; *E*, Kostin Shar Strait and its vicinities; *F*, Chernaya Inlet; *G*, extreme south of Novaya Zemlya southward to 70°50′N including Yugorskiy Shar Strait

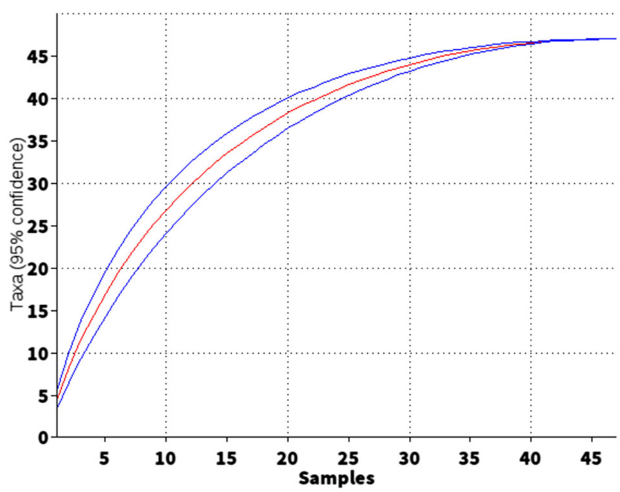

Fig. 2 Species accumulation curve for grab samples

[*Onoba aculeus* (Gould, 1841), *Peringia ulvae* (Pennant, 1777), and *Rissoella globularis* (Jeffreys in Forbes et Hanley, 1852] recorded by Ushakov (1927) and Gurjanova and Ushakov (1928) because their known distribution in the Barents Sea is limited to its southwestern part (Nekhaev 2014; Nekhaev et al. 2014), which is strongly influenced by the warm North Atlantic Current. Their presence along Novaya Zemlya requires confirmation. We reexamined all available samples of *Onoba aculeus*, *Peringia ulvae*, and *Rissoella globularis* taken by Gurjanova and Ushakov during various expeditions and stored in the collections of the Zoological Institute of RAS (Saint Petersburg), but none originated from coastal waters of Novaya Zemlya. Five mangelid species reported by previous authors [*Curtitoma decussata* (Couthouy, 1839), *Obesotoma gigantea* (Mörch, 1869), *Oenopota elegans* (Møller, 1842), *Propebela cancellata* (Mighels et Adams, 1842), and *P. angulosa* (G.O. Sars, 1878)] but not listed for this part of the Arctic by Bogdanov (1990) were also excluded.

The highest number of species (46) was registered by Leche (1878) along the southern part of Novaya Zemlya. Ushakov (1927) and Gurjanova and Ushakov (1928) presented extensive species lists containing 36 gastropod species for Chernaya Inlet and 31 for Moller Bay. Species lists given by other authors contained from 6 to 18 species.

Four species (*Testudinalia testudinalis*, *Cryptonatica affinis*, *Buccinum cyaneum*, and *B. glaciale*) were recorded in all geographical regions (Table 1). There was a moderate degree of repeatability of the species records across seven previous surveys: *B. cyaneum* and *C. affinis* were found in all studies, while 20 species were only mentioned once. The highest species richness was also observed in the southern part of the study area (region D—43 species, regions E and G—30 species).

Analysis of species lists from recent and previous surveys

The combined total of species of shell-bearing gastropod, identified in both our material and published sources, reached 86. Only 35 species are shared between both datasets (Dice similarity distance = 0.56). By contrast, 24 species were found exclusively in the recent material and 28 species were reported from previous surveys alone.

Analysis of similarities shows clear separation between species lists obtained during our study and compiled from previous investigations in all regions (ANOSIM, $R = 0.57$, $p = 0.02$). By contrast, geographical regions along the coast of Novaya Zemlya did not differ based on both datasets (ANOSIM, $R = -0.2$, $p = 0.82$). Modern and historical data demonstrated unequal proportions of species numbers in different superfamilies (Fig. 3). While whelks and top snails were frequently reported by previous authors, representatives of the small-sized superfamilies, e.g., Rissoidea and Philinoidea, were more common in the recent material.

Discussion

Comparison of modern and historical data

We present herein the first assessment of the species diversity along Novaya Zemlya based on both newly collected and previously published data. These datasets overlap only partially and both provide incomplete faunistic information (as the theoretical estimates of species richness attest). We believe that differences between the two datasets do not indicate changes in species composition of the region during the last century, since neither recently obtained material nor published sources alone can fully describe the diversity of gastropods along the coast of Novaya Zemlya. Previous studies, as well as our work, are

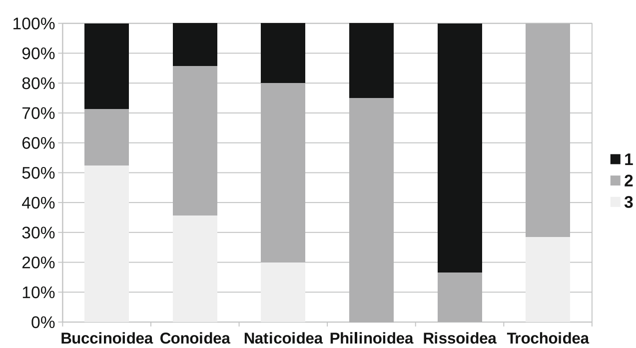

Fig. 3 Proportions of species number in main superfamilies of shell-bearing Gastropoda found only during the recent investigations (*1*), only known by historical data (*3*), and shared by both datasets (*2*)

based on a limited number of benthic sampling stations. None of the surveys aimed specifically at detection of taxonomical diversity along the coast of Novaya Zemlya. Moreover, some data used here were obtained accidentally during investigations of adjacent areas. For instance, Nordenskiöld's expeditions (Leche 1878; Aurivillius 1885) primarily explored Siberian seas. Similarly, the majority of the recently collected material identified during this study was taken incidentally in the course of ecological surveys of neighboring regions of the Barents Sea. There were only three dedicated expeditions examining the species composition of benthic invertebrates, including gastropods, and each was focused on a relatively small area: Moller Bay, Matochkin Shar Strait, and Chernaya Inlet (Ushakov 1927; Gurjanova and Ushakov 1928; Ushakov 1931). Predictably, the highest species diversity was recorded in these areas (Table 1). Nonetheless, we identified nine more species from Chernaya Inlet found during the 2000 survey and not mentioned by Gurjanova and Ushakov (1928). Overall, the fauna of the northern part of the archipelago was poorly sampled and still remains one of the least understood areas of the Barents Sea.

Researchers from the late 19th to early 20th century used trawls or dredges to sample bottom fauna. Samples were usually sorted immediately after collection, so many small mollusks were often overlooked, while larger animals were overrepresented. Conversely, during the last decades, samples were collected almost exclusively by grabs. This method underestimates the diversity of large mollusks (e.g. Buccinidae, Mangeliidae, and Velutinidae), although it allows accurate assessment of small animals. A similar effect of sampling gear on the outcome of benthic studies was reported from surveys of the Gorlo Strait, White Sea (Solyanko et al. 2010). Another important reason for the differences between recent and previously published data lies in unequal coverage of coastal versus offshore areas during investigations. Most of the historical material comes from near-shore sites: Chernaya Inlet, Moller Bay, and numerous smaller bays and inlets. By contrast, the bulk of the recent samples were collected much farther away from the coastline (usually 3–20 km). Since in the recent surveys there were no samples from shallow waters, we were unable to find several typical coastal species, such as *Testudinalia testudinalis*, *Margarites helicinus*, and *Littorina* spp.

Relationships with adjacent faunas

The fauna of the Barents Sea is heterogeneous and consists of two main zoogeographical groups: boreal and Arctic. The boreal communities generally occur in the southwestern part of the sea, which is influenced by temperate Atlantic water masses. Arctic fauna, associated with cold waters, is common in the north and east of the Barents Sea (Golikov 1989; Jirkov 2013; Jørgensen et al. 2014). Some areas, e.g., the Murman Coast and Svalbard, are considered to have mixed fauna. Altogether, up to eight biogeographical units of the Barents Sea have been defined, based on the local distribution of benthic species (e.g., Jirkov 2013).

The number of species of shell-bearing gastropod in the Barents Sea is no less than 200 (Sirenko 2001; Kantor and Sysoev 2006; Nekhaev 2014), therefore the 86 species known from Novaya Zemlya amount to about 40 % of the gastropod fauna in the whole sea. Similar species-level diversity was reported in the entirely of the White Sea and in the waters surrounding Franz Josef Land: 86 and 83 species, respectively (Sirenko 2001; Golikov and Scarlato 1977; Nekhaev 2008).

Figure 4 compares the species composition of shell-bearing gastropods from Novaya Zemlya presented here with those for Franz Josef Land (Golikov and Scarlato 1977; Nekhaev 2008), Svalbard (Palerud et al. 2004), Northern Norway (Høisæter 2009), the Murman Coast (Nekhaev 2014), and the White Sea (Sirenko 2001). The

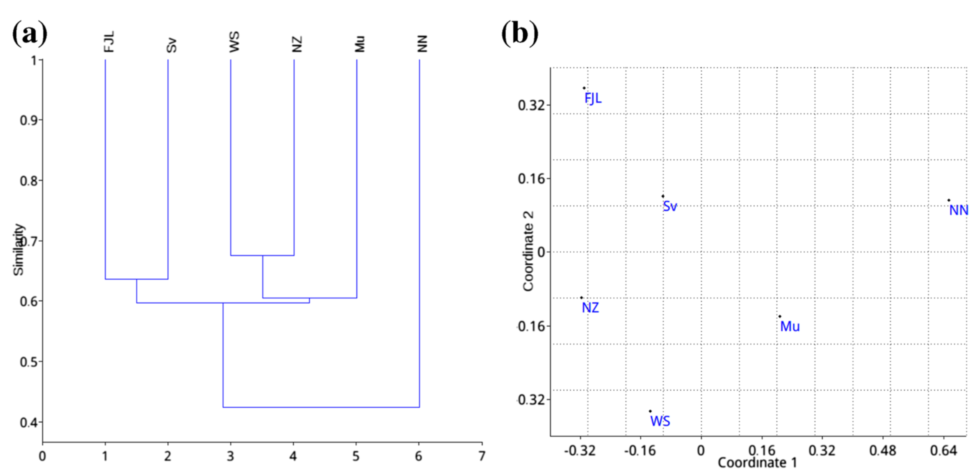

Fig. 4 Dendrogram (**a**) and MDS plot (**b**) comparing taxonomical composition of shell-bearing Gastropoda of Franz Josef Land (FJL), Murman Coast (Mu), Novaya Zemlya (NZ), Northern Norway (NN), Svalbard (Sv), and White Sea (WS)

fauna of Northern Norway was the richest, and most distant from all others. Similarity distances between coastal regions of the Barents Sea, including Novaya Zemlya, were similar and formed no defined grouping within this cluster. Our findings support the view that these regions are occupied by somewhat differing faunistic complexes (Jirkov 2013; Jørgensen et al. 2014). Surprisingly, here we found no differences between sites from boreal (Northern Norway, Murman, Svalbard) and Arctic (Novaya Zemlya, Franz Josef Land, and the White Sea) biogeographical regions, although in previous studies these two regions were distinguished by occurrence of species with different types of distribution (Filatova 1957; Jirkov 2013). This analysis represents only a preliminary comparison between the most studied local gastropod faunas of the Barents Sea and the adjacent areas. More detailed investigations are still needed.

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