The first record of *Gyraulus* cf. *acronicus* (Gastropoda, Heterobranchia, Planorbidae) in waterbodies of the Novaya Zemlya Archipelago

Nadezda B. Ovchankova[1,2] and Andrey B. Krasheninnikov[3]

Ovchankova NB and Krasheninnikov AB. 2023. The first record of *Gyraulus* cf. *acronicus* (Gastropoda, Heterobranchia, Planorbidae) in waterbodies of the Novaya Zemlya Archipelago. Fauna norvegica 42: 1-5.

The knowledge on diversity of freshwater molluscs in the Arctic islands of the Russian Federation remains incomplete. The present study provides the first record of the North Palaearctic species *Gyraulus* cf. *acronicus* (Férussac, 1807) on the Novaya Zemlya Archipelago. It is also the first finding of freshwater gastropods on the archipelago and the northernmost record for *Gyraulus* in the Palaearctic Region. The questions still remain: whether our finding belongs to a recent or a subfossil or fossil population, and how gastropods could colonize the Arctic islands. Several possibilities of dispersal are discussed: the former land-bridge once connecting the archipelago islands to the mainland, and the dispersal of snails with other animals after the Ice Sheet retreat.

doi: 10.5324/fn.v42i0.4917. Received: 2002-05-24. Accepted: 2022-10-22. Published online: 2023-02-28.
ISSN: 1891-5396 (electronic).

Keywords: Gastropoda, Planorbidae, Heterobranchia, the Novaya Zemlya Archipelago, the Yuzhny Island.

1. Zoological Institute of the RAS, 199034, Universitetskaya Emb., 1, Saint Petersburg, Russia
2. Laboratory of Macroecology and Biogeography of Invertebrates, Saint-Petersburg State University, 199034, Universitetskaya Emb., 7–9, Saint-Petersburg, Russia
3. Institute of Biological Problems of the North FEB RAS, 685000, Portovaya st., 18, Magadan, Russia

Corresponding author: Nadezda B. Ovchankova
E-mail: nephilain@gmail.com

INTRODUCTION

The Novaya Zemlya Archipelago is the largest European Arctic archipelago, which primarily consists of the South (Yuzhny) and North (Severny) islands, separated by the narrow Matochkin Strait (Stokes 2011). These islands represent a linear fold system surrounded by the Barents and Kara seas shelves. Geologically, they represent a northern extension of the Ural-Paikhoi folded region of the Palaeozoic age (600-250 million years). The area of the archipelago is 81,280 km^2; it is characterized by a rugged mountain terrain with a maximum elevation of 1547 m above sea level and with large parts of the coastline incised by fjords (Anokhin 2009; Grant *et al*. 2009; Stokes 2011). Studying high-latitude freshwater faunas on islands is difficult due to the hard accessibility of these places. Much regarding their faunas is therefore still poorly understood, including how biogeography and faunogenetic processes works in isolated archipelagos. Solving these questions is only feasible through a combined study of their biodiversity, biogeography, and ecology.

The first data on the fauna of freshwater invertebrates from Novaya Zemlya was obtained in the second half of the 19th century by A. E. Nordenskiöld during the 1875 Swedish expedition (Vekhoff 1998), and after that during the 1887 Danish expedition (Hansen 1887). Further studies were conducted in the first half of the 20th century by the 1921 Norwegian expedition to the Novaya Zemlya Archipelago (Holtedahl 1928) the results of which were published in a series of articles (Alexander 1922; Kieffer 1922; Lenz & Thienemann 1922; Morton 1923; Odhner 1923; Ulmer 1925; and others). In the same years, two expeditions to the Archipelago were organized by the Soviet Union: the expedition of the Floating Marine Scientific Institute (Sidorov 1925) and the Northern Scientific and Commercial expedition (Gorbunov 1929). Then, any hydrobiological research on the Archipelago ceased until 1986. Bespalaya *et al*. (2021) have presented a detailed overview of research on freshwater invertebrates from Novaya Zemlya.

The data on species diversity, ecology, and reproduction of freshwater molluscs of the Novaya Zemlya Archipelago can be found in a series of publications (Odhner 1923; Sidorov 1925; Bespalaya *et al*. 2015a, 2015b, 2017, 2019, 2021). In total, three species of bivalve molluscs are found in fresh waters of the Archipelago: *Pisidium conventus* Clessin, 1877, *Pisidium waldeni* Kuiper, 1975, and *Pisidium globularis* Westerlund, 1873 (Odhner 1923; Sidorov 1925; Bespalaya *et al*., 2017; Bespalaya *et al*., 2021). No representatives of freshwater Gastropoda have ever been reported from the Archipelago.

In the present study, we discuss the finding of an aquatic gastropod on the Yuzhny Island, which was identified as *Gyraulus* cf. *acronicus* (Férussac, 1807). So far, this finding is the first representative of freshwaters gastropods reported from the archipelago.

MATERIAL AND METHODS

The freshwater zoobenthos were sampled in June 30 and August 5, 2015, in two unnamed watercourses flowing from the lakes in the area at Cape Sakhanin on the South part of the Yuzhny Island (Figure 1). The samples were taken using a Bogatov bentometer and were fixed with 4% formalin.

The first station is a stream flowing from a swampy lake (Figure 2A). The dominant taxonomic groups were represented by Chironomidae, Enchytraeidae and Nemouridae. Representatives of the families Tipulidae, Empididae, Capniidae and Baetidae were noted singly. The species *Tvetenia duodenaria* Kieffer, 1922 was the most abundant among chironomids. The Baetidae family was represented by species *Baetis macani* Kimmins, 1957, the Capniidae family – *Mesocapnia variabilis* (Klapálek, 1920). Species *Branchinecta paludosa* (O.F. Müller, 1788) and *Lepidurus arcticus* (Pallas, 1793) occurred in the water column of the lake. Moss covered 50 % of the bottom of the lake. The substrate was pebbly and gravelly. The total number of benthic organisms was 18,055 specimens per m^2 and the biomass was 7.5 g/m^2.

The second station is a stream situated above the bird market (Figure 2B). The substrate was pebbly and gravelly with small clamps of algae. Species *Arabis alpina* L. grew on the banks of the stream. Enchytraeids and chironomids predominated. Representatives of Limnephilidae, Baetidae, Planariidae, Hydracarina, Coleoptera and Tipulidae were noted singly. The total number of benthic organisms was 12,544 specimens per m^2 and the biomass was 6.5 g/m^2.

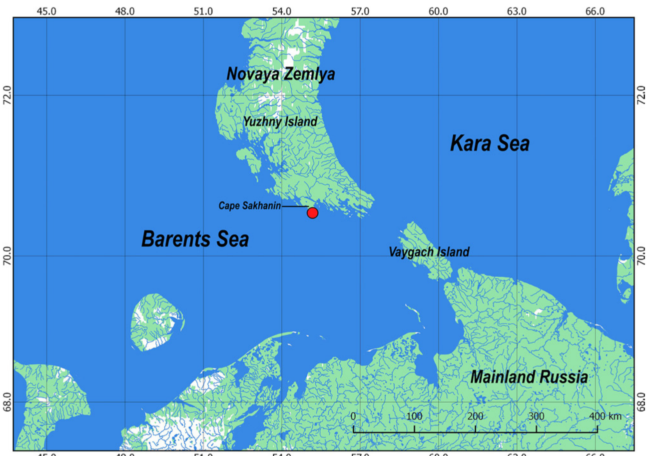

Figure 1. Map of the Novaya Zemlya Archipelago, showing the sampling stations with *Gyraulus* cf. *acronicus* (Férussac, 1807).

Taxonomic identification of the collected molluscs was based on shell shape and sculpture using the keys of Glöer & Meier-Brook (2003), Khokhutkin & Vinarski (2013), Glöer (2015) and Kijashko et al. (2016). The shell shape and structure were used during identification. Shell photographs were obtained using a Hitachi TM3000 scanning electron microscope with a BSE (back-scattered electron) detector at 15 kV accelerating voltage (Perm State University). The size and clarity of images were adjusted by using the Adobe Photoshop CS6 Version 13.0 software. Mapping of sampling sites of molluscs was realized using software QGIS 2.18.25 «Las Palmas» on the cartographic basis taken from https://vsegei.ru/ru/. The studied samples are stored in the senior author's collection.

RESULTS

Two broken specimens (empty shells) of freshwater gastropods belonging to the family Planorbidae were found in the unnamed watercourses. Based on conchological characters, we identified these shells as belonging to *Gyraulus* cf. *acronicus* (Férussac, 1807) (Figure 3). A more exact determination is impossible due to the poor preservation of shells and the absence of soft tissue.

The shells collected on Yuzhny Island are morphologically similar to shells of *G.* cf. *acronicus* from other regions of Europe and the Urals as they are described by Glöer & Meier-Brook (2003), Khokhutkin & Vinarski (2013), Glöer (2015) and Kijashko *et al*. (2016). Based on dimensions and proportions, the collected molluscs were juvenile. On the apical surface of the larger specimen (Figure 3A) the whorls are evenly growing. On the basal shell surface of the second specimen (Figure 3B) only the juvenile whorls were observed, the other whorls were not preserved. The height of whorls of the larger specimen increases slowly and its whorls are submerged weakly. The initial whorls of our specimens are somewhat sunk from both the apical and basal shell surfaces. The shell sculpture consists of thin axial lines, with spiral striation. According to Kijashko *et al*. (2016) shells can be matte on one and shiny on the other. The shell sculpture is observed from both surfaces of matte specimens, and predominantly from basal surface of shiny specimens. In a number of European populations shells are sometimes slightly keeled, which makes them similar to *Gyraulus stroemi* (Westerlund, 1881). However, we suggest that our specimens are *G.* cf. *acronicus* for two reasons: last whorl rounded at periphery, not keeled or angulated, and this species could potentially migrate to the Yuzhny Island from Vaigach Island where it was found in lakes (Bespalaya *et al*., 2021).

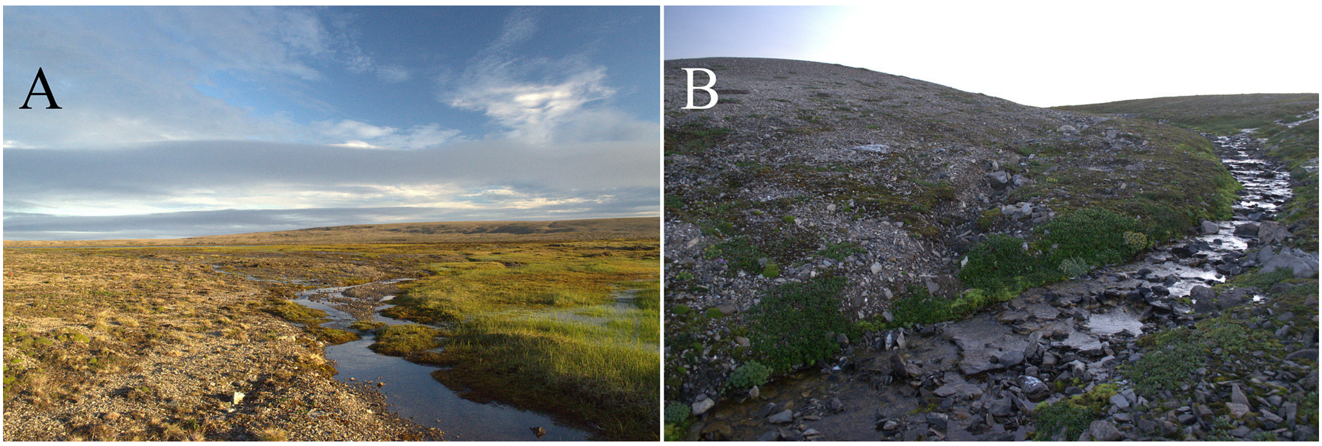

Figure 2. Photos of the sampled waterbodies of the Novaya Zemlya Archipelago: A – stream flowing from a swampy lake; B – stream situated above the bird market.

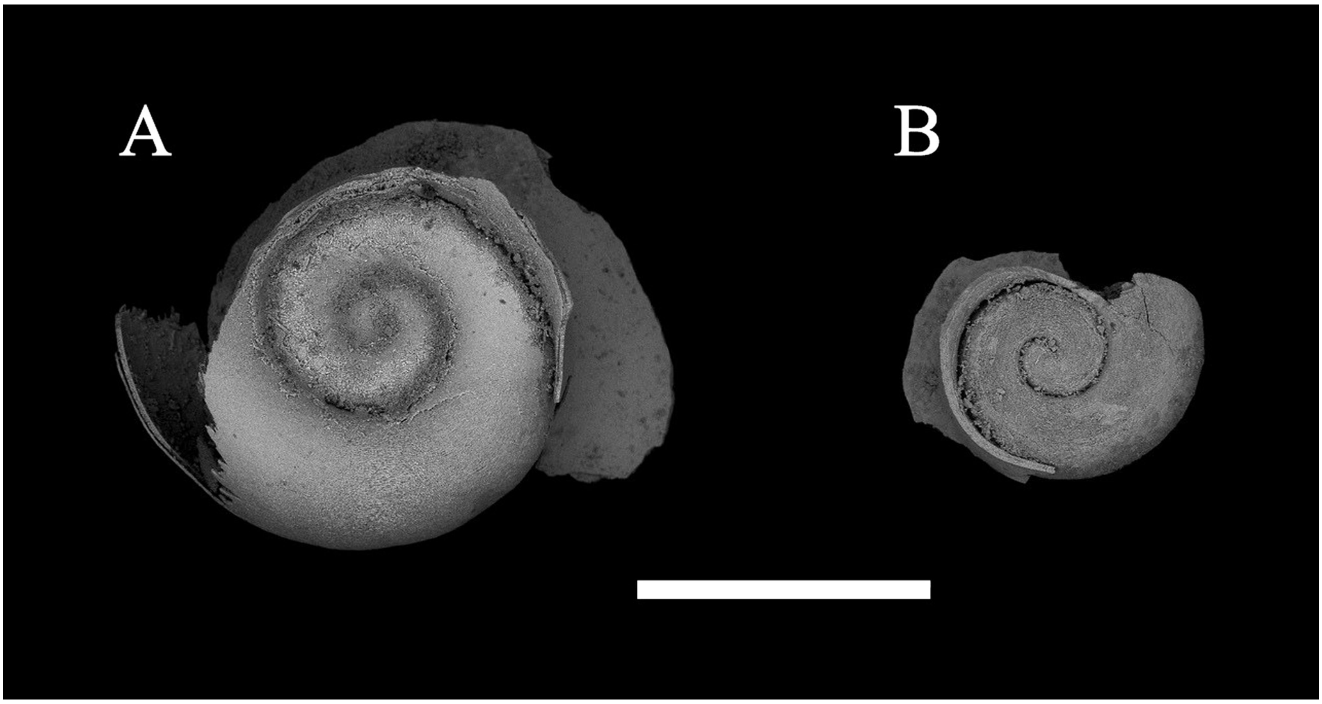

Figure 3. *Gyraulus* cf. *acronicus* (Férussac, 1807): A – the apical shell surface of adult specimen, B – the basal shell surface of juvenile specimen (scale bar 1 mm).

DISCUSSION

According to the catalogue of Vinarski & Kantor (2016), the species *G. acronicus* is distributed in the Northern Palaearctic, including Central and Northern Europe and Siberia. Our finding is the first record of freshwater Gastropoda on the Novaya Zemlya Archipelago and the northernmost record of a *Gyraulus* species in the Palaearctic Region.

In Northern Europe, *G. acronicus* lives in permanent waters on algae and soft substrates with vegetation (Starobogatov *et al*., 2004; Kijashko *et al*. 2016). The river network of the Yuzhny Island consists of rather short rivers flowing from mountains and uplands. These rivers have ravines and rapids. For about 9 months rivers are covered with ice and freeze to the bottom in winter. Many of these rivers are intermittent. Open water appears during warmer weather, when the melting of ice and snowfields intensifies (Olenev, 1965). We assume that finding live gastropods in such conditions are most improbable. Thus, it is likely that the collected shells are subfossil or even fossil. They could have been preserved in the sediments of river valleys or swampy lakes and washed out, and then mixed with the contemporary freshwater fauna of watercourses. It appears more likely because living conditions in the sampling localities are not corresponding to environmental preferences of the species. A similar phenomenon was observed in some watercourses of the Middle Urals (unpublished data).

Freshwater molluscs are known to disperse in several ways. According to Bespalaya *et al*. (2017) the contemporary fauna of invertebrates including freshwater molluscs of the Novaya Zemlya Archipelago has originated from recent immigration processes after the Last Glacial Maximum (Brochmann *et al*. 2003; Coulson *et al*. 2014, cit.; Bespalaya *et al*. 2017). Herewith, some authors suggest the existence of ice-free refugia for some plants or animals with the ability to survive as relicts, for example, on Vaygach Island (Makhrov & Bolotov 2006; Coulson *et al*. 2014). We suppose the shells, discussed in this paper, can be from a population that once existed in such a refugium, located on the archipelago even during the coldest Pleistocene intervals (Serebryanny & Malyasova 1998). According to these authors none of Pleistocene glaciations covered all the surface of Novaya Zemlya. Ice-free areas functioned as refugium under the most unfavorable ecological conditions and served as central nuclei of organism's dispersal during deglaciation intervals. However, the question is how they originally got to the archipelago still remains open. For example, land-bridges with freshwater systems that existed during the last glacial period could contribute to their dispersal. The timing of deglaciation on Novaya Zemlya is not well dated, but it is supposed that from the southwestern coast deglaciation occurring before c.18 ka (Hughes *et al*. 2016). Probably, the land-bridge connecting the mainland with the islands appeared during the Ice Sheet retreat and contributed to migration of pulmonate molluscs to freshwater systems of archipelago. However, transition from one freshwater-ways to another was made possible by other organisms.

An alternative option is a relatively recent oversea dispersal of the *Gyraulus* species from Vaigach Island, which was the closest place to the studied region where five species of pulmonate molluscs were found, including *Gyraulus acronicus* (Férussac 1807) (Bespalaya *et al*. 2019). The dispersal of pulmonate snails to the Yuzhny Island over sea by aquatic birds is a possibility. The Kara Gates Strait, which is about 55 km wide, separates the Yuzhny Island from Vaigach Island. Though rare, cases of birds carrying pulmonate snails on long distances (more than 1000 km) to remote oceanic islands are known (Gittenberger *et al*. 2006; Kappes & Haase 2012). Probably, aquatic birds are the only appropriate vectors to transport snails from Vaigach Island and the mainland. That freshwater snails can migrate in this way is well established (Malone 1965; Rees 1965; Russell-Hunter 1978; Boag 1986; Wesselingh *et al*. 1999; Wada *et al*. 2011). This possible way of dispersal of freshwater-molluscs to Arctic islands was also discussed by Vinarski *et al*. (2015, 2017). In the last article sea currents (including drifting ice and wood) are considered as another mechanism of molluscs migration. Anyway, the appearance of molluscs on Wrangel Island, Greenland, Vaigach Island and Novaya Zemlya is associated with the immediate vicinity of the mainland.

In contrast, dispersal of snails was impossible to Svalbard and Franz Josef Land due to isolation of the archipelagos from the mainland and larger land masses of other archipelagos.

The literature indicates that molluscs can be transferred by means of other animals, for example, fish (Brown 2007) or large flying insects (Walther *et al*. 2008).

These ways appear very unlikely in the case of *Gyraulus* species for a variety of reasons. Experimental studies shown that pea clams (Sphaeriidae) and valve snails (Valvatidae) are mainly capable of surviving complete fish gut passage (Brown 2007). Their number reached over 400 and 800 specimens, respectively, whereas a surviving pond snail was found in a single specimen. This can be explained by the fact that soft body of pulmonate snails is more susceptible to digestion because it has no protection against the effects of fish gastrointestinal tract. Whereas sphaeriids are protected by tightly closing the shell valves and the operculum provides protection to the valvatid snails during fish gut passage. Furthermore, pond snail survived gut passage times of at least only 12 hours which could indicate that this migration way takes place within a single freshwater system.

The dispersal of freshwater molluscs by large flying insects is considered on the example of the limpets in the family Ancylidae (Walther *et al*. 2008). It is known that these molluscs are firmly attached to the dytiscid and gyrinid beetles. Due to the streamlined shape of the shells limpets stay on the substrate for a long time. Planorbid molluscs rather could not stay on the body of an insect for such a long time to migrate long distances.

In our case we suppose that the most likely way of all the above mentioned is the dispersal by birds because it may be a common cause for long-distance dispersal. Moreover, we cannot exclude that colonizing went through several stages. Molluscs were probably dispersed within a single freshwater system on the former land-bridge. However, it would need to be transported by animals, for example, the same birds, to get to another freshwater system.

ACKNOWLEDGEMENTS

Fieldwork was conducted within the framework of Open Ocean: Arctic Archipelagos – 2015 expedition and supported by the Association “Maritime Heritage: Explore & Sustain”. The authors thank the Russian Scientific Fund for the financial support of this research (project No. 19-14-00066). We are grateful to Dr. M. V. Gavrilo for the expedition’s organization and Dr. Maxim Vinarski (Saint-Petersburg State University) for his valuable comments on the manuscript.

REFERENCES

Alexander CP. 1922. The crane-flies (superfamily Tipuloidea, order Diptera). In: Holtedahl O (ed.), Report on the scientific results of the Norwegian expedition to Novaya Zemlya 1921, no. 5. Oslo (Kristiania). A.W. Brøggers Bogtrykkeri. pp 1-16.

Anokhin VM. 2009. Physical and geographical characteristics of the archipelago. Geological structure. In: Boyarsky P.V. (ed.), Islands and archipelagoes of the Russian Arctic. Novaya Zemlya. pp 257-275. (In Russian).

Bespalaya Y, Bolotov I, Aksenova O, Kondakov A, Gofarov M, Paltser I. 2015a. Occurrence of a *Sphaerium* species (Bivalvia: Sphaeriidae) of Nearctic origin in European Arctic Russia (Vaigach Island) indicates an ancient exchange between freshwater faunas across the Arctic. Polar Biology 38: 1545-1551. doi: 10.1007/s00300-015-1656-5.

Bespalaya Y, Bolotov I, Aksenova O, Kondakov A, Paltser I, Gofarov M. 2015b. Reproduction of *Pisidium casertanum* (Poli, 1791) in Arctic lakes. The Royal Society Open Science 2:140-212. doi: 10.1098/rsos.140212.

Bespalaya Y, Bolotov I, Aksenova O, Kondakov A, Spitsyn V, Kogut Y, Sokolova S. 2017. Two *Pisidium* species inhabit freshwater lakes of Novaya Zemlya Archipelago: the first molecular evidence. Polar Biology 40: 2119-2126. doi: 10.1007/s00300-017-2119-y.

Bespalaya Y, Joyner-Matos J, Bolotov I, Aksenova O, Gofarov M, Sokolova S, Shevchenko A, Travina O, Zubriy N, Aksenov A, Kosheleva A, Ovchinnikov D. 2019. Reproductive ecology of *Pisidium casertanum* (Poli, 1791) (Bivalvia: Sphaeriidae) in Arctic lakes. Journal of Molluscan Studies 85: 11-23. doi: 10.1093/mollus/eyy050.

Bespalaya Y, Przhiboro A, Aksenova O, Berezina N, Gofarov M, Kondakov A, Kurashov E, Litvinchuk L, Sokolova S, Spitsyn V, Shevchenko A, Tsiplenkina I, Travina O, Tomilova A. 2021. Preliminary study of the benthic fauna in lakes of the Novaya Zemlya Archipelago and Vaigach Island (the Russian Arctic). Polar biology 44: 539-557. doi: 10.1007/s00300-021-02817-4.

Boag DA. 1986. Dispersal in pond snails: potential role of waterfowl. Canadian Journal of Zoology. 64: 904-909. doi: 10.1139/z86-136.

Brochmann C, Gabrielsen TM, Nordal I, Landvik JY, Elven R. 2003. Glacial survival or tabula rasa? The history of the North Atlantic biota revisited. Taxon 52: 417-450. doi: 10.2307/3647444.

Brown RJ. 2007. Freshwater mollusks survive fish gut passage. Arctic 60(2): 124-128. doi: 10.14430/arctic237.

Clessin S. 1877. Die Mollusken der Tiefenfauna unserer Alpenseen. Malakozoologische Blätter 24: 159-185.

Coulson SJ, Convey P, Aakra K, Aarvik L, Ávila-Jiménez ML, Babenko A, Biersma EM, Boström S, Brittain JE, Carlsson AM, Christoffersen K, De Smet WH, Ekrem T, Fjellberg A, Füreder L, Gustafsson D, Gwiazdowicz DJ., Hansen LO, Holmstrup M, Hullé M, Kaczmarek Ł, Kolicka M, Kuklin V, Lakka H-K, Lebedeva N, Makarova O, Maraldo K, Melekhina E, Ødegaard F, Pilskog HE, Simon JC, Sohlenius B, Solhøy T, Søli G, Stur E, Tanasevitch A, Taskaeva A, Velle G, Zawierucha K, Zmudczyńska-Skarbek K. 2014. The terrestrial and freshwater invertebrate biodiversity of the archipelagoes of the Barents Sea; Svalbard, Franz Josef land and Novaya Zemlya. Soil Biology and Biochemistry 68: 440-470. doi: 10.1016/j.soilbio.2013.10.006.

Férussac JBL. 1807. Essai d’une méthode conchyliologique appliquée aux Mollusques terrestres et fluviatiles. Paris: de l’Imprimerie de Delange, xvi+142 p.

Gittenberger E, Groenenberg DSJ, Kokshoorn B, Preece RC 2006. Molecular trails from hitch-hiking snails. Nature 439: 409. doi: 10.1038/439409a.

Glöer P, Meier-Brook C. 2003. Süsswassermollusken. Ein Bestimmungschlüssel für die Bundesrepublik Deutschland. 13 Auflage. Hamburg. Deutscher Jugendbund für Naturbeobachtung. 134 p.

Glöer P. 2015. Süßwassermollusken. Ein Bestimmungsschlüssel für die Bundesrepublik Deutschland. 14 Auflage. Hamburg. Deutscher Jugendbund für Naturbeobachtung. 136 p.

Gorbunov GP. 1929. Preliminary report of investigations in term fresh and brackish-waters of the Novaya Zemlya in 1923, 1924 and 1925. Trudy Instituta po izutcheniyu Severa 40: 147-154. (in Russian with German summary).

Grant KL, Stokes CR, Evans IS. 2009. Identification and characteristics of surge-type glaciers on Novaya Zemlya, Russian Arctic. Journal of Glaciology 55: 960-972. doi: 10.3189/002214309790794940.

Hansen HJ. 1887. Oversigt over de paa Dijmphna-Togtet indsamlede Krebsdyr. In: Lütken CF (ed.), Dijmphna-Togtets Zoologisk-Botaniske Udbytte. pp 183-286.

Holtedahl O (ed.). 1928. Report of the scientific results of the Norwegian expedition to Novaya Zemlya. Kristiania. A.W. Broggers Bogtrykkeri, Oslo.

Hughes ALC, Gyllencreutz R, Lohne ØS, Mangerud J, Svendsen JI. 2016. The last Eurasian ice sheets – a chronological database and time-slice

reconstruction, DATED-1. Boreas 45: 1-45. doi: 10.1111/bor.12142.
Kappes H, Haase P. 2012. Slow, but steady: dispersal of freshwater molluscs. Aquatic Science 74: 1-14. doi: 10.1007/s00027-011-0187-6.
Khokhutkin IM, Vinarski MV. 2013. Molluscs of the Urals and the adjacent areas. The families Acroloxidae, Physidae, Planorbidae (Gastropoda, Pulmonata, Lymnaeiformes). Fasc. 2. Yekaterinburg, Goshchitskiy Publishers. 184 p. (In Russian).
Kieffer JJ. 1922. Chironomides De La Novuvelle-Zemble. Report of the scientific results of the Norwegian expedition to Novaya Zemlya 1921, no. 2. Kristiania, A.W, Brøggers Bogtrykkeri, Kristiansand, Oslo: 1-24.
Kijashko PV, Soldatenko EV, Vinarski MV. 2016. Class of gastropods – Gastropoda Cuvier, 1797. In: Tsalolikhin SY (ed.) Key for the freshwater zooplankton and zoobenthos of European Russia. V. 2. Zoobenthos. KMK Scientific Press, Moscow–St. Petersburg. pp 335-438. (In Russian).
Kimmins, D. E. 1957. A new Ientic species of the genus *Baetis* (Ephemeroptera) from North Finland. Notulae Entomologicae 37: 27-29.
Klapálek F. 1920. Neue Plecopterenarten aus der Familie Capniidae. Časopis, České Spolecnosti Entomologické 17: 3-6.
Kuiper JGJ. 1975. Zwei neue boreale *Pisidium* Arten: *P. hinzi* und *P. waldeni*. Archiv für Molluskenkunde 106(1/3): 27-37.
Lenz F, Thienemann A. 1922. Chironomidenlarven aus Nowaja Semlja. In: Holtedahl O (ed.). Report on the scientifc results of the Norwegian expedition to Novaya Zemlya 1921, no. 3. Kristiania. A.W. Brøggers Bogtrykkeri, Oslo. pp 1-8.
Linnaeus C. 1758. Systema Naturae per Regna Tria Naturae, secundum Classes, Ordines, Genera, Species, cum Characteribus, Differentiis. Synonymis, Locis. Tomus I. Editio Decima, Reformata. Holmiae. iv + 824 p.
Makhrov AA, Bolotov IN. 2006. Dispersal routes and species identification of freshwater animals in northern Europe: a review of molecular evidence. Russian Journal of Genetics 42: 1101-1115. doi: 10.1134/S1022795406100036.
Malone CR. 1965. Dispersal of aquatic gastropods via the intestinal tract of water birds. Nautilus 78: 135-139.
Morton KJ. 1923. Plecoptera. In: Holtedahl O (ed.). Report on the scientifc results of the Norwegian expedition to Novaya Zemlya 1921, no. 16. Oslo Kristiania. A.W. Brøggers Bogtrykkeri. pp 1-19.
Müller O.F. (ed.) 1788. Zoologiae Danica seu Animalium Daniae et Norvegiae rariorum ac minus notorum. Descriptiones et historia. Vols I and II (reissue). N. Müller et filii: Havniae (Copenhagen).
Odhner NH. 1923. Mollusca *Pisidium conventus* Clessin (*P. clessini* Surbeck, partum). In: Holtedahl O (ed.). Report on the scientific results of the Norwegian expedition to Novaya Zemlya 1921, no. 6. Oslo Kristiania. A.W. Brøggers Bogtrykkeri. pp 3-6.
Olenev AM. 1965. Ural and the Novaya Zemlya. Feature article of nature. Moscow. 215 p. (In Russian).
Pallas PS. 1793. Voyages de M. P. S. Pallas 4: 1-722.
Rees WJ. 1965. The aerial dispersal of Mollusca. Proceedings of the Malcological Society of London 36: 269-282. doi: 10.1093/oxfordjournals.mollus.a064955.
Russell-Hunter WD. 1978. Ecology of freshwater pulmonates. Pulmonates: Systematics, Evolution and Ecology. London etc: Academic press V. 2A: 335-383.
Serebryanny L, Malyasova E. 1998. The quaternary vegetation and landscape evolution of Novaya Zemlya in the light of palynological records. Quaternary International 45/46: 59-70. doi: 10.1016/S1040-6182(97)00007-4.
Sidorov SA. 1925. The question about freshwater molluscs species *Pisidium* on Novaya Zemlya. Trudy Plavuchego Morskogo Nauchnogo Instituta 12: 103-104. (in Russian).
Starobogatov YaI, Prozorova LA, Bogatov VV, Saenko EM. 2004. Mollusks. In: Tsalolikhin SYa (ed.). Key to freshwater invertebrates of Russia and adjacent lands. Vol. 6. Molluscs, polychaetes, nemerteans. SPb: Nauka: 9-491.
Stokes CR. 2011. Novaya Zemlya. In: Singh VP, Singh P, Haritashya UK (eds). Encyclopedia of snow, ice and glaciers. Encyclopedia of earth sciences series. Springer, Dordrecht: 781.
Ulmer G. 1925. Ephemeropteren und Trichopteren von Nowaja Semlja. In: Holtedahl O (ed.). Report on the scientifc results of the Norwegian expedition to Novaya Zemlya 1921, no. 29. Oslo Kristiania, A.W. Brøggers Bogtrykkeri. pp 1-4.
Vekhoff [Vekhov] NV. 1998. Invertebrates of inland waterbodies (Novaya Zemlya, Arkhangelsk region). In: Trudy morskoi arckticheskoi kompleksnoi ekspeditsii. Novaya Zemlya. Nature. History. Archaeology. Culture. pp 182-193. (in Russian).
Vinarski MV, Kantor YI. 2016. Analytical catalogue of fresh and brackish water mollusks of Russia and adjacent countries. Moscow: A.N. Severtsov Institute of Ecology and Evolution of RAS: 544 p.
Vinarski MV, Palatov DM, Novichkova AA. 2015. The first freshwater molluscs from Wrangel Island, Arctic Russia. Polar Research 34: 23889: 1-4. doi: 10.3402/polar.v34.23889.
Vinarski MV, Bolotov IN, Schniebs K, Nekhaev IO, Hundsdoerfer AK. 2017. Endemics or strangers? The integrative re-appraisal of taxonomy and phylogeny of the Greenland Lymnaeidae (Mollusca: Gastropoda). Comptes Rendus Biologies 340: 541-557. doi: 10.1016/j.crvi.2017.09.005.
Wada S, Kawakami K, Chiba S. 2011. Snails can survive passage through a bird's digestive system. Journal of Biogeography 39(1): 69-73. doi: 10.1111/j.1365-2699.2011.02559.x.
Walther AC, Benard MF, Boris LP, Enstice N, Tindauer-Thompson A, Wan J. 2008. Attachment of the freshwater limpet *Laevapex fuscus* to the hemelytra of the water bug *Belostoma flumineum*. Journal of Freshwater Ecology 23: 337-339. doi: 10.1080/02705060.2008.9664207.
Wesselingh FP, Cade´e GC, Renema W. 1999. Flying high: on the airborne dispersal of aquatic organisms as illustrated by the distribution histories of the gastropod genera *Tryonia* and *Planorbarius*. Geologie en Mijnbouw 78: 165-174. doi: 10.1023/A:1003766516646.
Westerlund CA. 1873. Fauna molluscorum terrestrium et fluviatilium Sueciae, Norvegiae et Daniae. 2. Sötvatten Mollusker. Stockholm, O.W. Backmann, 1-5: 297-651.
Westerlund CA. 1881. Malakologiska bidrag. II. För Vetenskapen nya Land- och Sötvatten Mollusker. Öfversigt af Kongliga Vetenskaps Akademiens Förhandlingar 4: 50-70.

Editorial responsibility: Torkild Bakken.