УДК 574.34

БИОТОПИЧЕСКОЕ РАСПРОСТРАНЕНИЕ ИНВАЗИВНОГО ВИДА – *DREISSENA POLYMORPHA* (MOLLUSCA, BIVALVIA) В ОЗЕРЕ НАРОЧЬ (БЕЛАРУСЬ) В 2016–2017 ГГ.

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Исследование состояния популяции *Dreissena polymorpha* (Pallas, 1771) в оз. Нарочь было выполнено в летние месяцы 2016–2017 гг. Для оценки распределения популяции дрейссены на различных глубинах оз. Нарочь было обследовано 9 трансект, на которых дрейссена обнаружена в пробах, отобранных на глубинах от 0,5 до 8 м. По результатам исследования было выявлено, что максимальных величин плотности и биомассы в расчете на 1 м^2 площади дна дрейсена достигала на глубинах 2–6 м в пробах, где макрофитом-субстратом была хара. Вероятно, это связано с особенностями развития харовых водорослей (неполное отмирание в зимний период), их морфологией (сильная разветвленность таллома и, как следствие, большая площадь поверхности для прикрепления), тем фактом, что харовые водоросли являются активными карбонатоосадителями (шероховатая поверхность облегчает прикрепление велигеров к растению). Установлено, что средняя индивидуальная масса особей дрейссены, развивающихся на грунте

Образец цитирования:
Крюк ДВ, Жукова АА. Биотопическое распространение инвазивного вида – *Dreissena polymorpha* (Mollusca, Bivalvia) в озере Нарочь (Беларусь) в 2016–2017 гг. *Журнал Белорусского государственного университета. Экология.* 2021;4:28–35 (на англ.).
https://doi.org//10.46646/2521-683X/2021-4-28-35

For citation:
Kryuk DV, Zhukava HA. Biotopic distribution of invasive species – *Dreissena polymorpha* (Mollusca, Bivalvia) in lake Naroch (Belarus) in 2016–2017. *Journal of the Belarusian State University. Ecology.* 2021;4:28–35.
https://doi.org//10.46646/2521-683X/2021-4-28-35

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в прибрежной зоне, оказалась существенно больше, чем у особей, которые развиваются на макрофитах. После сравнения полученных нами данных с данными предыдущих исследований можно заключить, что за последние два десятилетия величины плотности и биомассы дрейссены в оз. Нарочь существенно не изменились.

Ключевые слова: *Dreissena polymorpha*; биотопическое распределение; плотность популяции; оз. Нарочь; погруженные макрофиты.

Благодарность. Авторы материала выражают благодарность дайверам международной категории В. В. Катулько и А. А. Солдатенкову за неоценимый вклад в сбор полевого материала.

BIOTOPIC DISTRIBUTION OF INVASIVE SPECIES – *DRESSENA POLYMORPHA* (MOLLUSCA, BIVALVIA) IN LAKE NAROCH (BELARUS) IN 2016–2017

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The study of the population of *Dreissena polymorpha* (Pallas, 1771) in the Naroch Lake was carried out in 2016–2017. The distribution of the Dreissena's population at different depths of Lake Naroch was examined at 9 transects. Dreissena was found in samples taken from 0.5 to 8 m depths and reached its maximum densities at depths of 2–6 m. As the result of the investigation, we found that the main substrate for the development of Dreissena in the lake are submerged macrophytes. The highest values of Dreissena's abundance were observed in the samples, where Chara algae was the main substrate. This is probably due to the peculiarities of the charophyta development (incomplete dying off in winter), their morphology (strong branching of the thallus and, as a consequence, a large surface area for attaching of dreissena) and the fact that Chara algae are active carbonate precipitators (a rough surface of the thallus facilitates attachment to the plant). At the same time, the average mass of individuals of Dreissena developing on the bottom in near-shore zone was significantly greater than that of the individuals developing on macrophytes. After comparing the obtained data with the data of previous studies, it can be concluded that over the past two decades, the values of the weighted average density and biomass of Dreissena in Lake Naroch have not changed significantly.

Keywords: *Dreissena polymorpha*; biotopic distribution; population density; Naroch Lake; submerged macrophytes.

Acknowledgments. The authors express their gratitude to the divers of the international category V. V. Katulko and A. A. Soldatenkov for their contribution to the collection of field material.

Introduction

Dreissena polymorpha (Pallas) is a small invasive bivalve mollusk, capable of living at different depths of water bodies. Getting into suitable habitats, Dreissena quickly forms extremely dense settlements and often turns into the absolute dominant in benthic and periphytic communities both in terms of abundance and biomass. The active resettlement of Dreissena on the territory of Belarus took place at the end of the 20th century.

It has been shown that, getting into suitable water bodies, zebra mussel over several years becomes a driving factor in changing the habitats for native species. The influence of zebra mussel is primarily associated with its filtration type of nutrition, due to which this mollusk intercepts and deposits in its tissues a significant part of organic matter and nutrients, preventing their deposition and burial in bottom sediments [2; 3]. From a practical human point of view, the introduction of zebra mussel can be also positive. In particular, an improvement in water quality and, in some cases, an increase in the productivity of benthos-feeding fish. At the same time there are negative traits. For example, overgrowing underwater constructions and mass developing in pipelines leads to serious difficulties in water supply. In addition, the sharp edges of the shells at the bottom in littoral can create inconvenience for swimming people, and it is very noticeable for the reservoirs that are actively used for recreational purposes, such as, for example, Lake Naroch.

In Lake Naroch – the largest reservoir of the Republic of Belarus – Dreissena was first recorded in the late 1980s (according to other data, Dreisena was found in 1985–1986) [1; 4]. Regular hydrobiological studies carried out at Lake Naroch for over 60 years have made it possible to identify and describe quantitatively a number of consequences of the introduction of Dreissena, the main of which was the switching of matter and energy flows from planktonic communities to benthic and periphytic ones (while maintaining the same production level of the whole ecosystem). This process was named «bentification» [5; 6] or «contourization» [4] in the scientific literature.

The first estimates of the Dreissena population density after its introduction into Lake Naroch were carried out by A.Yu. Karataev and L.E. Burlakova [1; 2]. So, in 1990, Dreissena in Naroch was examined for the first time only in the area of the confluence of the River Skema from the lake Myastro (which confirmed its entry into Naroch from above located Lake Myastro), the main substrate for it at that time were the shells of Unionids, submerged macrophytes and stones. In terms of the entire lake bottom area, the density and biomass of Dreissena in 1990 in Naroch were small and constituted 7.4 ± 3.0 ind./m^2 and 1.5 ± 0.6 g/m^2. However, in the next few years, as it is typical for many invasive species, there was an "explosive" increase in the population of zebra mussel, and by 1993 the population density of the mollusk in Naroch had increased by 103 times, and the biomass by 68 times, amounting 763 ± 149 ind./m^2 and 99 ± 30 g/m^2 on average for the lake. Dreissena by this time inhabited all suitable substrates, mainly developing on submerged macrophytes, and moved deeper into the lake up to 8 m. Since 1995, the total population of Dreissena in lake Naroch stabilized and, according to [2], remained the same until 2002. In 2005, according to the data of bottom grab samples in May and October, the weighted average values of Dreissena's density and biomassin the lake were 1508 ± 221 ind./m^2 and 158.4 ± 17.9 g/m^2, respectively [7], which is also similar to the data obtained in the late 1990s – early 2000s.

Materials and methods

In June–August 2016 and June–September 2017 we estimated the density and biomass of Dreissena in Lake Naroch with the help of divers who used underwater photography and manual collection for sampling mollusks from macrophytes and bottom. This study, carried out after a rather long break in accordance with the scheme of previous years [2], made it possible to assess the current state of the Dreissena population in the lake and compare the obtained results with that of 20 years ago. In total, in 2016–2017 we examined 9 half-sections extending from the shore line to the maximum depths of submerged macrophytes distribution in the lake (fig. 1): transects 1–3 were located in the Small stretch of the lake, transects 4–9 were in the Large stretch.

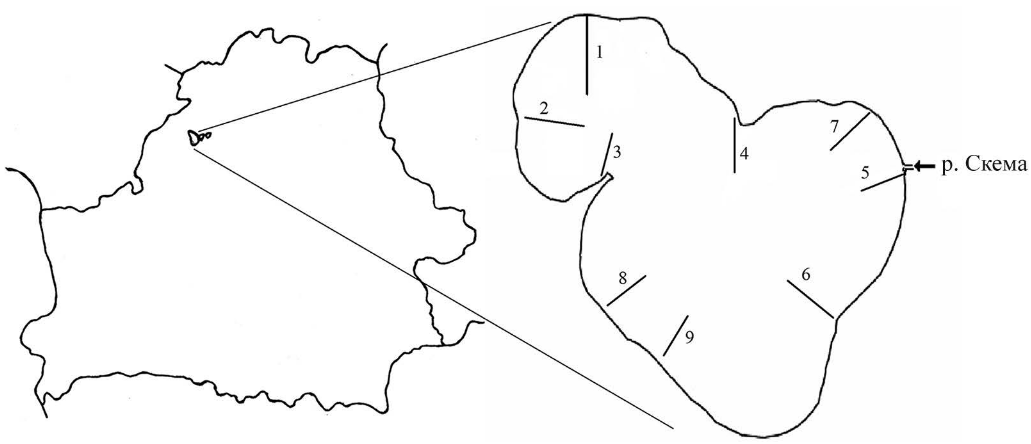

Fig. 1. The location of the Naroch lake on the map of Belarus and the layout of the transects along which the zebra mussel samples were taken in the lake Naroch in 2016–2017 (similar to those where dreissena was sampled in 1999–2002)

Dreissena and submerged macrophytes were collected manually using a 0.5×0.5 m frame (as shown in fig. 2) along the transects when submerging for each meter of depth or when plant associations were changing.

Fig. 2. Sampling of zebra mussel and accompanying samples of bottom sediments and macrophytes in Lake Naroch in 2016

Results and discussion

During the period of work in the summer months of 2016–2017 9 transects were examined. Transects were located along the periphery of the lake and covered depths in the range of 0.5–8 m (to the lower boundary of the submerged macrophytes distribution in the lake). The main results of the study of quantitative counts of Dreissena, as well as the description of soil type and submerged macrophytes (which are the substrate for the Dreissena attachment), are presented in table 1.

Table 1

Density of zebra mussel at different depths of the lake Naroch (weighted averages are presented)

Transect number (see fig. 1)	Sampling depth, m	Soil type of bottom	Macrophyte species	Number of collected frames (0.25 m²)	*Dreissena polymorpha* density, ind./m²	Biomass* *Dreissena polymorpha*, g/m²
1	0.5–0.6	Silty sand	Chara, potomogeton	15	4	0.6
	0.8–1.0	Silty sand	Chara	3	1033	874.5
	1.9	Silty sand	Chara	1	1708	626.5
	2.5	Silty sand	Chara	1	5492	408.6
	3.0	Silty sand	Stratiotes, ceratophillum, elodea	1	2892	726.0
	3.1	Silty sand	Chara, stratiotes	1	9716	479.4
	3.1	Silty sand	No macrophytes	1	0	0.1
	4.7	Silty sand	Chara	1	568	87.3
2	0.5	Sand	Chara, nitellopsis	10	147	93.9
	1.5	Sand	Chara	1	5680	416.3
	2.1	Silty sand	Elodea	1	364	78.4
	2.2	Silty sand	Chara, ceratophillum, fontinalis	1	36	5.8
	2.2	Silty sand	Chara, stratiotes	1	168	25.7
	2.2	Silty sand	Chara	1	1332	108.8
	2.5	Silty sand	Potomogeton, ceratophillum, elodea	1	1288	128.8
	3	Silty sand	Chara	1	1080	297.8
	4.7	Silty sand	Chara	1	2840	258.2
	5.5	Silty sand	Potomogeton, chara	1	376	60.9
	6.6	Silty sand	Elodea	1	652	87.4
3	0.5–0.8	Sand	No macrophytes	15	131	70.8
	0.5–0.8	Sand	Potomogeton	10	0	0.1
	1.6	Silty sand	Elodea, ceratophillum	1	852	119.3
	1.8	Sand	Chara	1	336	150.6
	4.6	Silty sand	Chara	1	872	167.8
4	0.5	Sand and stones	Chara	3	149	21.6
	0.5	Sand and stones	No macrophytes	3	936	207.5
	1.6	Silty sand	Chara, ceratophillum, fontinalis	1	4472	418.2
	1.7	Silty sand	Chara, elodea, fontinalis	1	1836	205.7
	2.1	Silty sand	Ceratophillum	1	792	55.2
	2.4	Silty sand	Elodea	1	72	7.9
	3	Silty sand	Chara, elodea, ceratophillum	1	984	159.5

Ending table 1

Transect number (see fig. 1)	Sampling depth, m	Soil type of bottom	Macrophyte species	Number of collected frames (0.25 m^2)	*Dreissena polymorpha* density, ind./m^2	Biomass* *Dreissena polymorpha*, g/m^2
5	0.4–0.6	Sand	No macrophytes	20	18	15.3
	0.4–0.6	Sand	Chara	1	144	37.2
	0.4–0.6	Sand	Chara	1	1452	507.6
	0.4–0.6	Sand	Potomogeton	3	7	0.9
	3.8	Silty sand	Chara, fontinalis	1	344	150.8
	4.5	Silty sand	Chara	1	1536	239.8
	7	Silty sand	Chara, potomogeton	1	428	86.8
	7.4	Silt	Chara	1	1052	43.6
6	0.5	Sand and stones	Chara	5	97	88.8
	0.5	Sand and stones	Chara	5	14	5.6
	2.0	Silty sand	Chara	1	3144	1155.6
	3.5	Silty sand	Chara	1	4792	824.6
	5.0	Silty sand	Chara	1	956	123.6
	7.5	Silty sand	Chara	1	252	53.2
7	0.4	Silty sand	Chara	20	0	0.1
	2.2	Silty sand	Potomogeton, chara, filamentous algae	1	304	282.0
	4.3	Silty sand	Chara, stratiotes	1	1572	390.2
	8.0	Silty sand	Nitellopsis, ceratophillum	1	4	0.5
8	0.6–0.7	Sand	Chara	15	23	5.7
	3.0	Silty sand	Chara	1	1736	387.1
	4.0	Silty sand	Chara, potomogeton, elodea	1	2296	350.0
	5.5	Silty sand	Ceratophillum, stratiotes, elodea, potomogeton, fontinalis	1	3352	424.6
	6.8	Silty sand	Ceratophillum, elodea, potomogeton	1	136	27.2
9	0.5	Sand	Chara	10	44	21.1
	1	Sand	Chara	5	90	30.3
	3.0	Silty sand	Chara	1	676	82.3
	4.2	Silty sand	Chara, elodea, potomogeton	1	164	61.8
	5.4	Silty sand	Ceratophillum, elodea	1	376	105.8
	6.3	Silty sand	Ceratophillum, elodea	1	784	210.1
	8.0	Silt	Elodea, chara	1	748	87.7

Note. *Wet weight was measured after drying the zebra mussel on filter paper.

The results of the study showed that the main substrate for the development of Dreissena in the lake remain submerged macrophytes (as in was in the late 1990s – early 2000s), the densest thickets of which currently occupy depths from 2 to 6 m. Accordingly, in this range of depths the zebra mussel also reaches its maximum densities, like it has been noted earlier [1]. The distribution of spatial distribution of density and biomass at different depths is graphically depicted at the figures 3 and 4.

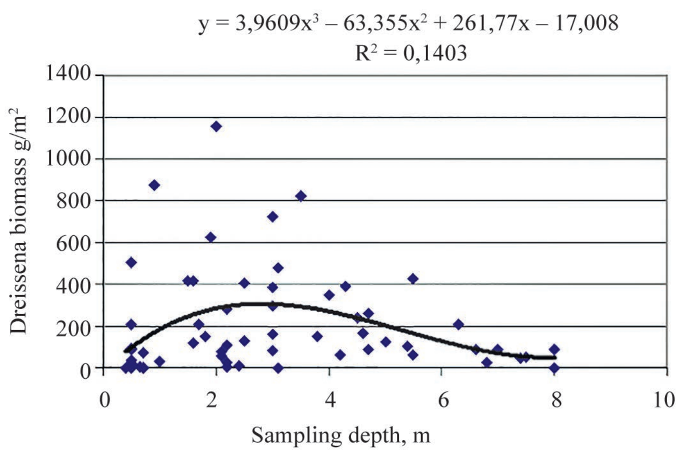

Fig. 3. Distribution of the zebra mussel biomass by depth in the Naroch lake in samples 2016–2017

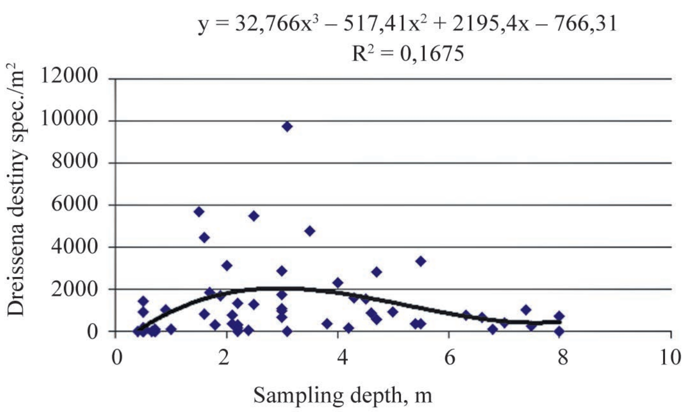

Fig. 4. Distribution of the zebra mussel density by depth in the Naroch lake in samples 2016–2017

The graphs show that there is no clear correlation between the abundance/biomass of Dreissena and depths of sampling. The maximum biomass values are within the depth values from 1 to 4 m, and the maximum density values from 1.5 m to 3.5 m. With increasing depth, the values of both parameters decrease. Probably, these results indirectly indicate the dependence of the Dreissena population on the intensity of the bottom overgrowth with macrophytes, which, in turn, is limited not only by the depth, but also by the type of soil, currents, etc. Moreover, at medium depths chara and ceratophillum are more common, when at depths over 6–7 m elodea is mare common (which is a less convenient substrate for attachment in comparison with chara algae, which mainly occupy shallower areas of the lake). The distribution of the zones of overgrowth with submerged macrophytes over the various depths of the lake are presented in more details in [8]. In the presence of a suitable plant substrate (chara algae), mollusks can be found in a fairly large number also at depths over 6 m.

Due to the fact that different types of submerged macrophytes in the lake have different ratios of surface area to mass and their own morphological features, the relationship between the air-dry mass of macrophytes and the abundance/biomass of dreissena collected from the same site has not been revealed. According to Spearman's rank correlation analysis the data on the biomass of dreissena didn't show dependence with air-dry mass of macrophytes ($n = 36$, $r = -0.028$), as well as for the abundance of dreissena and air-dry mass of macrophytes ($n = 36$, $r = 0.063$). It was noted that the most favorable substrate for the development of Dreissena in Lake Naroch is chara algae, since their morphological structure and features of the life cycle allow dreissena to fix successfully on the thallus in large numbers. First of all, this is facilitated by the strong branching of the thallus and, as a consequence, a large surface area for attachment, as well as the fact that chara algae are active carbonate precipitators (a rough surface facilitates attachment to the plant). Also chara thallus shows the incomplete dying off in winter (and due to calcification of cell membranes, even dying parts of the thallus decompose more slowly), which allows zebra mussel to develop on chara algae for more than one vegetative season [9].

Also it has been shown that dreissena individuals that develop at shallow depths on sandy soil (usually they form drusen or attach to stones and snags) have a higher specific weight in comparison with that developing on macrophytes. This is mainly due to the seasonal development of most water plants , which also leads to dying off the mollusks attached to them in winter when they submerge in silt at the bottom. Therefore, for samples collected in 2016–2017 on macrophytes, the average weight of one zebra mussel (±standard error of the mean) turned out to be significantly less than that for mollusks collected in shallow water on a sandy substrate (0.24 ± 0.02 and 0.80 ± 0.05 g, respectively). Differences between the individual weights of individuals found on the two substrates were higly significant (Mann-Whitney U-test, $p = 0.0003$, $n = 15$). The similar situation was observed in the lake earlier: the average weight of mollusks on macrophytes in 1993–1995 and 1997 was equal to 0.07 ± 0.01 and 0.10 ± 0.01 g, and on a sandy substrate – 0.35 ± 0.07 and 0.3 ± 0.05 g respectively (calculated based on the archival data of L. E. Burlakova).

The collected data from 9 investigated transects where superimposed on the bathymetry of the lake and the weighted average values of the density and biomass of Dreissena in the lake were calculated. Data of the present study were compared with the data of previous. The results are shown in table 2.

Table 2

Long-term dynamics of the *Dreissena polymorpha* population in Lake Naroch

Years of research	Number of observations (sample size)	Density, sp./m^2	Biomass, g/m^2	Source
1990	54	7,4 ± 3	1,5 ± 0,6	[2]
1993	49	763 ± 149	99 ± 30	
1994	126	758 ± 240	115 ± 30	
1995	116	1521 ± 451	107 ± 44	
1997	285	922 ± 238	99 ± 20	
2002*	37	757 ± 198	256 ± 78	Archival data of L. E. Burlakova
2005**	177	1508 ± 221	158 ± 18	[7]
2016–2017	188	1202 ± 128	199 ± 18	Our data

Note. *Samples were taken at depths up to 2 m; **according to bottom grab samples.

The data obtained in 1995–1997 are the most comparable with the data of our study, because they were sampled according to the same scheme. Other data can be considered as indicative, since the number of collected samples and the depth of their sampling varied. So, in 2002, zebra mussel samples were collected only in shallow areas of the littoral zone, mainly on sandy soil, which led to lower average density values with a higher biomasses; in 2005, bottom areas were examined at depths from 0.8 to 8 m using a bottom grab [7].

If we compare our data with the data of previous studies, especially paying attention to that in 1995 and 1997 when the population of Dreissena in Lake Naroch reached a plateau and the research scheme was the same, it can be concluded that over the past two decades, the mean values of dreissena's density and biomass in the lake had not changed significantly.

Conclusion

In 2016–2017 after almost 20 years break, a large survey of the lake Naroch was carried out in order to assess the population density and spatial distribution of Dreissena polymorpha. It had been shown that the main substrate for the development of dreissena in the lake remain submerged macrophytes, mainly chara algae, which develop mostly in the depth range 2–6 m. Our results indicate that in recent 20 years the population of Dreissena in Lake Naroch is in a stationary state, keeping the values of the weighted averages of density and biomass close to those observed at the end of the 1990s. Dreissena on submerged macrophytes in the lake is mainly represented by annual individuals that die when macrophytes die off in winter. The part of the population located in shallow water area is represented by mollusks of different ages (this is confirmed by the higher values of individual weight and size characteristics of individuals), which form a reproductive reserve for the population in the lake ecosystem that ensures the colonization of a new generations of zebra mussels on submerged macrophytes in the next growing season.

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Статья поступила в редколлегию 08.11.2021.
Received by editorial board 08.11.2021.