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Infestation of Bivalvia by *Dreissena polymorpha* (Pallas, 1771) in thermally polluted lakes

by

Anna Marszewska*,
Kamila Kopczyńska,
Anna Cichy,
Elżbieta Żbikowska

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Department of Invertebrate Zoology, Faculty of Biology and Environment Protection, Nicolaus Copernicus University in Toruń, ul. Lwowska 1, 87-100 Toruń, Poland

Abstract

Unionid mussel species belong to one of the most threatened invertebrate groups on Earth. Biological invasions, especially those by filtering species, are particularly harmful to native Unionidae species. In Poland, a significantly disturbing situation of native Unionidae is observed in thermally polluted aquatic ecosystems. Such water bodies have favorable conditions for the settlement of alien mollusks, including *Sinanodonta woodiana* or *Corbicula fluminea*, whose shells can potentially be a beneficial substrate for *Dreissena polymorpha*. The objective of the presented research was to check whether zebra mussels can hinder the invasion of alien species of bivalve mollusks in thermally polluted waters. Our results indicate that with the increase in thermal pollution associated with the growing invasion of alien species of bivalves, *D. polymorpha* infestations of clams decrease considerably, which leads to the conclusion that *D. polymorpha* does not pose a significant natural threat to bivalves in the lakes under study.

Key words: zebra mussel, native unionid, alien clams, thermal pollution, Poland

* Corresponding author: *anna.marszewska@umk.pl*

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African, North American and European waters are inhabited by almost 700 species belonging to the Unionidae family (Walker et al. 2001). Unionids play an important role in freshwater ecosystems (Ökland 1963; Lewandowski & Stańczykowska 1975; Strayer et al. 1994; Piechocki 1999; Dillon 2000; Vaughn & Hakenkamp 2001; Ożgo 2010). Six species are native to Poland, and half of them are statutorily protected (Piechocki & Wawrzyniak-Wydrowska 2016). A decline in Unionidae populations is a phenomenon observed all over the world (Ożgo 2010; Lopes-Lima et al. 2017) and results from many anthropogenic and/or natural factors (Augspurger et al. 2007; Cope et al. 2008; Grizzle & Brunner 2009; Ożgo 2010; Bódis et al. 2014). One of the factors that affects the future of native bivalves are biological invasions (Colomba et al. 2013; Bódis et al. 2014).

Hundreds of freshwater species have been introduced outside their native range through canals, ballast water, intentional introductions, and releases from gardens, aquaria, bait buckets, etc. As a result, numerous freshwater bodies around the world contain dozens of alien species (Strayer 2009). Native unionid bivalves compete with invasive bivalve species for space and hosts for glochidia incubation (Douda et al. 2012) and food (Hörmann & Maier 2006; Douda et al. 2012). Thus, the presence of these alien species can cause changes in the ecosystem.

In waters around the world, one of the most successful invertebrate colonizers is a Ponto-Caspian species – *Dreissena polymorpha* (Pallas, 1771). It is well known that bivalve shells are a suitable substrate for this invasive clam species (Lewandowski 1976; Schloesser et al. 1998; Burlakova et al. 2014). The zebra mussels significantly affect the physiology and biology of the hosts (Grizzle & Brunner 2009; Bódis et al. 2014). These invasive mussels benefit from a relationship with native European unionid species, reaching a higher standardized body mass and glycogen content (Pilotto et al. 2016). As a result, *D. polymorpha* can dramatically affect their mollusk hosts (Schloesser & Nalepa 1994; Burlakova et al. 2000; Grizzle & Brunner 2009).

The alarming situation of Unionidae populations, native to Poland, prompted us to undertake the presented research. The main objective of the research was to check whether *D. polymorpha* can prevent the establishment, population growth and spread of other invasive species of bivalves in thermally polluted lakes. This was achieved by checking *D. polymorpha* overgrowths on shells of both alien and native bivalve species inhabiting the study area.

Samples were collected from three lakes in central Poland: Lake Licheńskie (52°18'59"N, 18°21'7"E), Lake Mikorzyńskie (52°20'47"N, 18°18'9"E) and Lake Ślesińskie (52°22'33"N, 18°18'52"E) (Fig. 1). The sampling area belongs to the cooling system of the power plants: Konin (launched in 1958; electric power of 198 MW) and Pątnów (launched in 1967; electric power of 200 MW). The heated water from the Konin power plant is discharged into Lake Mikorzyńskie, while the heated water from the Pątnów power plant is discharged into Lake Licheńskie. Thermally polluted water from Lake Licheńske flows into Lake Ślesińskie (large loop). The temperature difference in water discharged from the power plant and water collected from the lakes is on average between 6.0°C and 9.0°C (Żbikowska et al. 2014). There is great interest in research on thermally polluted lakes, because they can be used as model ecosystems in microscale research on global warming.

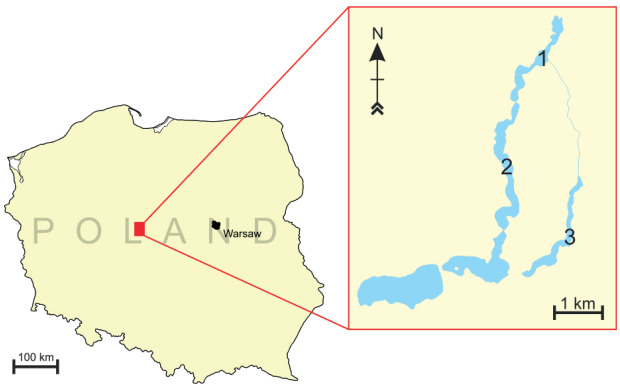

Figure 1
Study area (1 – Lake Ślesińskie, 2 – Lake Mikorzyńskie, 3 – Lake Licheńskie)

Live representatives of native Unionidae – *Anodonta anatina* (Linnaeus, 1758), *Unio pictorum* (Linnaeus, 1758) and *Unio tumidus* Philipsson, 1788, as well as alien species – *Corbicula fluminea* (O. F. Müller, 1774) and *Sinanodonta woodiana* (Lea, 1834) were collected in the littoral zone of lakes (up to a depth of 1.5 m) once a month from May to August 2016. Bivalves were collected from the study sites (ca. 0.5 ha each) by wading and tactile techniques, spending one person-hour of search time, similarly to Burlakova et al. (2014). The water temperature in the shore zone of lakes was also measured.

Morphological identification of bivalve species was carried out on the basis of characteristics described by Piechocki & Wawrzyniak-Wydrowska (2016). *D. polymorpha* individuals attached to the shells of other mussels were gently detached and counted. Next, the wet weight (in grams) of all zebra mussels and other collected mollusks was determined.

The Chi-square test of a contingency table was used to compare the number of bivalve specimens overgrown and not-overgrown by *D. polymorpha* in terms of mollusk species and study sites. The post-hoc test based on a standardized residual was used. A standardized residual (SR) of plus or minus 1.96 presented a significant deviation from 0 at $p = 0.05$ (Sidanius et al. 2008). Temperatures of the lake water were analyzed by one-way ANOVA, followed by the post-hoc Tukey test.

A total of 458 individuals of native Unionidae (108 – *A. anatina*, 329 – *U. tumidus*, 21 – *U. pictorum*), 164 individuals of *S. woodiana*, 347 individuals of *C. fluminea* and 1468 individuals of *D. polymorpha* were collected from the shells of sampled bivalves. *S. woodiana* was found only in Lake Licheńskie, *C. fluminea* occurred mainly in Lake Mikorzyńskie, while native Unionidae were more frequently observed in Lake Ślesińskie than in other lakes (Fig. 2).

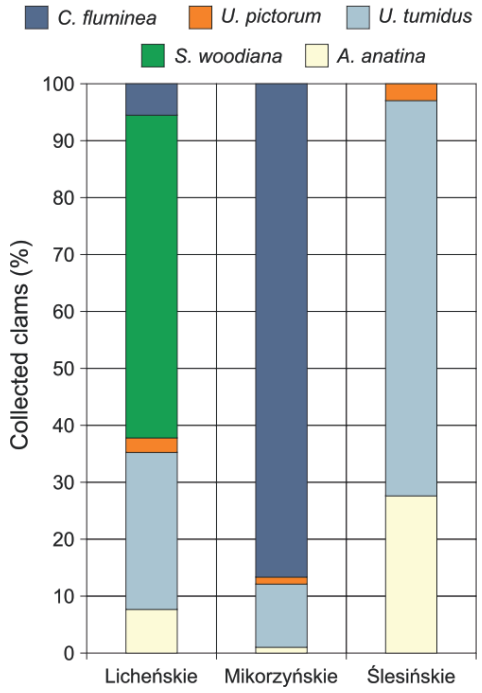

Figure 2

Species diversity of host bivalves from the thermally polluted lakes

D. polymorpha was found on the surface of 16.9% of all collected clams. The number of bivalves overgrown by *D. polymorpha* significantly differed depending on the species ($\chi^2 = 239.85$; df = 4; $p < 0.001$). The post-hoc test indicated that *A. anatina* and *U. tumidus* were more often colonized by zebra mussels than *S. woodiana* and *C. fluminea* (Fig. 3). Similarly, a greater number of *D. polymorpha* and greater weight of their colonies

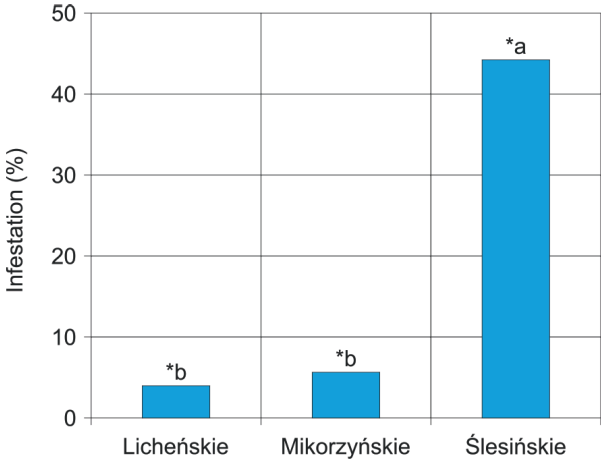

Figure 3

Infestation of various Bivalvia species by *Dreissena polymorpha* [* – statistical significant differences (Chi², $p < 0.05$), a,b – "a" was significantly more often colonized by zebra mussels than "b" (SR)]

on the surface of shells of native bivalves were noted (Table 1). The largest colonies, in relation to the wet weight of inhabited mollusks, were noted on the surface of *A. anatina* shells (Table 1).

A significant difference in the number of Bivalvia individuals inhabited by *D. polymorpha* was determined in the studied lakes (Fig. 4; $\chi^2 = 229.63$; df = 2; $p < 0.001$). The post-hoc test indicated that Lake Ślesińskie was more often colonized by *D. polymorpha* than Lake Licheńskie and Lake Mikorzyńskie (Fig. 4).

Average water temperatures at sampling sites were 25.2°C (SD ± 1.8) (Licheńskie), 21.4°C (SD ± 1.8) (Mikorzyńskie) and 20.7°C (SD ± 1.7) (Ślesińskie), and the differences were statistically significant (one-way ANOVA $F_{2,9} = 7.453$; $p = 0.01$). Post-hoc tests indicated that Lake Licheńskie is warmer than both Lake Mikorzyńskie ($p = 0.03$) and Lake Ślesińskie ($p = 0.01$).

It appears that the differences in the infestation of clams by zebra mussels at the study sites are the result of mussel species diversity (Fig. 3). The lakes inhabited in large part by alien species of mollusks were characterized by smaller infestation (Fig. 4). The phenomenon of clam species diversity results from the fact that higher temperature in a lake provides favorable residence conditions for alien species (Fig. 2), because they are characterized by higher tolerance to thermal stress (Bielen et al. 2016). More frequent (Fig. 3) and stronger (Table 1) infestation of native Unionidae by zebra mussels rather than alien clams is also confirmed by Bódis et al. (2014), despite the fact that physiological, morphological and behavioral features of these alien species provided seemingly good conditions (Bódis et al. 2014; Piechocki &

Table 1

Quantitative data on native and alien Bivalvia species and *Dreissena polymorpha* individuals covering their shells

	A. anatina	*U. tumidus*	*U. pictorum*	*S. woodiana*	*C. fluminea*
Number of *D. polymorpha* individuals ± SD	13.6 ± 13	6.2 ± 6.2	9.6 ± 7.5	3.2 ± 2.1	2.0 ± 0.0
Wet weight of *D. polymorpha* colonies (g) ± SD	4.8 ± 5.8	1.8 ± 2.2	2.5 ± 0.7	1.7 ± 1.3	1.2 ± 0.8
Wet weight of inhabited mussels (g) ± SD	38.2 ± 16.2	32.6 ± 13.7	23.3 ± 8.8	183.1 ± 80.2	11.3 ± 0.1

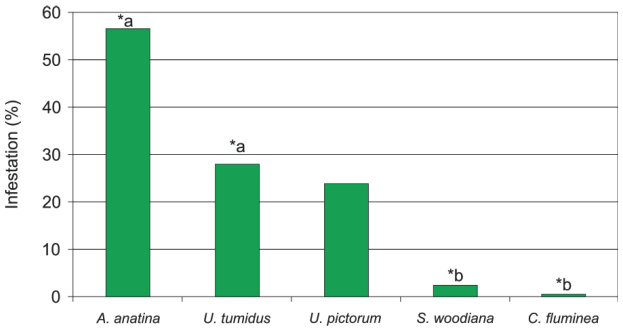

Figure 4

Infestation by *Dreissena polymorpha* in the thermally polluted lakes [* – statistical significant differences (Chi^2, $p < 0.05$), ^{a,b} – "a" was significantly more often colonized by zebra mussels than "b" (SR)]

Wawrzyniak-Wydrowska 2016). However, according to the above-mentioned authors some specimens of both studied alien species were heavily fouled by *D. polymorpha*, which is inconsistent with our results (Table 1). The latest research presented by Dzierżyńska-Białończyk et al. (2018) also indicates extensive overgrowths of *D. polymorha* on *S. woodiana*. Furthermore, Lewandowski (1976) indicates the formation of larger *D. polymorpha* colonies on the surface of shells of native Unionidae species compared to those recorded in our study (Table 1). In addition, we found that the infestation of *D. polymorpha* observed in thermally polluted lakes (Fig. 4) was generally low compared to lakes with natural thermal conditions (Marszewska & Cichy 2015). As a result, we observed that warmer, thermally polluted lakes were characterized by lesser infestation of clams by *D. polymorpha*. White et al. (2015) showed that the "upper incipient lethal temperature" for zebra mussels is considerably lower than 30°C in the natural environment. For example, Lake Licheńskie, used in the cooling system of the power plant, is the warmest one and its water temperature can fluctuate even above 30°C (Záhorská et al. 2014). This may account for low infestation by *D. polymorpha*.

The majority of alien species in new areas do not have natural enemies such as parasites, predators, competitors. Our report indicates that *D. polymorpha* does not pose a significant natural threat to alien mussels in the studied thermally polluted lakes.

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