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Spatial distribution of rotifers (Rotifera) in monospecies beds of invasive *Vallisneria spiralis* L. in heated lakes

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Abstract

Species abundance and richness of rotifer communities occupying monospecies beds of *Vallisneria* was studied in Lake Licheńskie included in the open cooling system of heat and power stations. Differences were found in rotifer numbers, species composition and diversity between sampling points within the same location and between the locations. Factors that seem to be responsible for the high diversity of rotifer communities inhabiting *Vallisneria* beds are: large-scale horizontal diversity (between macrophyte patches), small-scale horizontal diversity (within patches) and the high vulnerability of *Vallisneria* epiphyton to disturbances caused by wave action.

INTRODUCTION

Among the most discussed recent questions is to what extent the key-stone invasive species modify the biodiversity of native communities. The morphological and spatial structure of phytocoenoses are among the main factors determining the distribution and diversity of littoral communities of Rotifera (Kuczyńska-Kippen, Nagengast 2002). However, the comparison of species composition between central and peripheral parts of the *Myriophyllum verticillatum* bed did not reveal statistically significant differences (Kuczyńska-Kippen 2003).

Many authors (i.e. Havens 1991; Duggan et al. 1998, 2001) have noticed a great richness of rotifer communities occupying the littoral zone. They have explained the richness by more heterogeneous nature of the environment and greater niche diversity compared with the pelagic zone. Pontin and Shiel (1995), and Duggan et al. (2001) suggest that the species of macrophytes, their community composition, and distribution in the littoral is the most important factor structuring the rotifer communities in the littoral zone of lakes. However, analysis of the taxonomic structure of rotifer communities, from monospecies *Vallisneria* beds and multispecies macrophyte beds, showed that both types of the communities were relatively rich in species (Ejsmont-Karabin, Hutorowicz 2011). High species richness of the littoral communities of Rotifera on Lake Licheńskie has been also pointed out by Paturej et al. (2007). The richness occurs despite the fact that *Vallisneria* has a rather simple morphology and therefore it is not expected to offer very differentiated substrates for littoral rotifers. Yet, *Vallisneria* assemblages occupying large areas of the littoral zone may be spatially variable in terms of: macrophyte condition, shading, and exposure to

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wave stress. These factors could then affect the spatial distribution of rotifers within the zone.

The purpose of the study was to search for factors explaining this relatively high species richness of rotifer communities occupying monospecies beds of the invasive macrophyte.

Material And Methods

Littoral communities of Rotifera were studied in Lake Licheńskie. This lake is included in the open cooling system of heat and power stations in the vicinity of the town of Konin (Kujawskie Lake District). The long-term studies carried out in the aforementioned lake and the remaining four lakes of the system focused on the following aspects: environmental conditions and biota, the effect of water heating on physicochemical properties of the water, primary and secondary production, species composition and density of plankton (Hillbricht-Ilkowska et al. 1988, Simm 1988, Zdanowski 1994, Zdanowski et al. 2002). *Vallisneria spiralis* (Hydrocharitaceae), an exotic, tropical hydrophyte, was introduced into the lakes probably at the beginning of the 1990s and colonized three lakes (Hutorowicz et al. 2006). The high temperatures of water in the lake were one of the most important reasons for the rapid invasion of *Vallisneria spiralis* in the lakes' littoral (Hutorowicz 2006). In Lake Licheńskie *Vallisneria* formed very dense monospecies phytocoenoses and almost entirely displaced native submerged macrophytes.

The study was carried out on one occasion, i.e. on 1 August 2006. Small-scale patchiness was studied in *Vallisneria* beds at two locations physically separated by open water and seven sampling points at each location (Fig. 1). The distance of the sampling points from the shore and from the vegetation-free water was ca. 10 m and between the sampling points – 20 m. Water temperature and oxygen concentrations were measured at several points with a YSI model 58 oxygen meter (Table 1).

Plankton and epiphyton were sampled and prepared separately. Samples of macrophytes and their epiphyton were taken with a 10-liter vessel, then five macrophyte leaves were cut and very gently pulled out. Epiphytic rotifers were removed from live macrophytes using a soft bristle brush. Epiphytic rotifers were condensed on a plankton net which had a mesh size of 30-μm, transferred into bottles and fixed with Lugol's solution and then with 4% formalin. The plant material devoid of epiphyton was

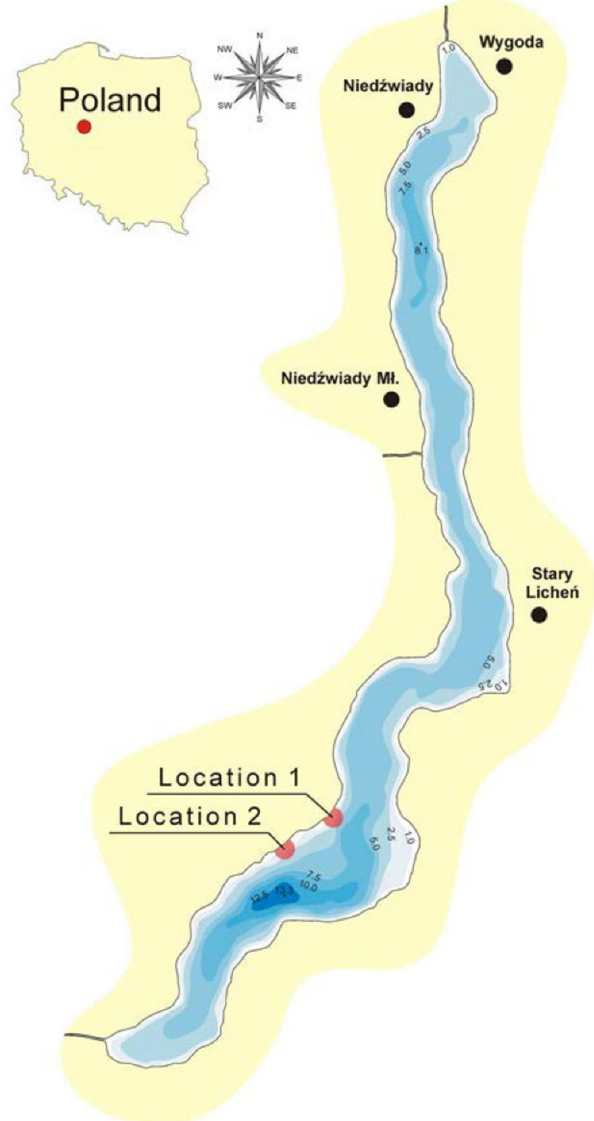

Fig. 1. Lake Licheńskie – distribution of locations.

Table 1

Range of physico-chemical parameters at the studied locations.

		Temperature (°C)	Oxygen (mg l^{-1})
LOCATION1		23.1 – 23.9	4.88 – 9.14
LOCATION 2	surface	25.0 – 25.5	8.15 – 10.31
	bottom	25.0 – 25.3	7.34 – 8.48

dried overnight at 60°C and weighed. Five-liter samples of plankton material were collected separately in a center of a macrophyte patch, condensed on a plankton net which had a mesh-size of 30-μm and fixed with Lugol's solution and then with 4% formalin. All rotifers were counted and identified, in three subsamples, each equal to 10% of the sample, under the light microscope Nikon Eclipse E600, at ×400 and ×100 magnification.

The index of percentage similarity of community (PSC) (Whittaker, Fairbanks 1958) was used:

$$PSC = 100 - 0.5\sum(a-b) = \sum_{min.}(a,b) \qquad (1)$$

where *a* and *b* are percentages of individuals of each species in total numbers of the communities at study sites A and B, compared in pairs.

Statistical analyses were run with STATISTICA (Statsoft. Inc.) software. Data were analyzed by t-tests. Probability levels of ≤0.05 were considered significant. All proportion data were arcsin-square-root transformed prior to statistical analyses.

RESULTS

The two studied locations, with monospecies *Vallisneria* beds, differed in their sets of dominant rotifers. Plankton community at location 1 consisted of 48 species. The dominant species were *Testudinella patina* (Hermann) and *Lecane hamata* (Stokes). These free-living species of littoral waters were also accompanied by the abundant sessile species *Limnias ceratophylli* Schrank (Fig. 2). Plankton communities from location 2 differed from the previous one, and they were dominated by free-living *Plationus patulus* (Muller), *Lepadella patella* (Muller) and numerous species of the genus *Lecane* (*L. hamata* (Stokes), *L. aculeata* (Jakubski), *L. bulla* (Gosse), *L. nana* (Murray), *L. furcata* (Murray). Pelagic species *Keratella cochlearis* (Gosse) and sessile *Limnias ceratophylli* played a significant role at the sampling points close to open waters (Fig. 2).

Epiphytic communities of Rotifera at location 1 were dominated by two sessile species, *L. ceratophylli* and *Sinantherina socialis* (L.) as well as free-living *Testudinella patina* and *Lecane hamata*. The communities at location 2 were dominated by predatory *Cupelopagis vorax* (Leidy), sessile *Limnias ceratophylli* and free-swimming species of the *Lecane* genus, with *Lecane hamata* as the most abundant one (Fig. 3). The percentage similarity for plankton and epiphyton communities of Rotifera compared for the same sampling point was relatively high and similar at both locations, i.e. from 42% to 69% at location 1 and from 42% to 76% at location 2. The comparison of communities for pairs of the same sampling points at two studied locations (for example, sampling point 1A from location 1 versus 1A from location 2) revealed that the differences in rotifer structure in the

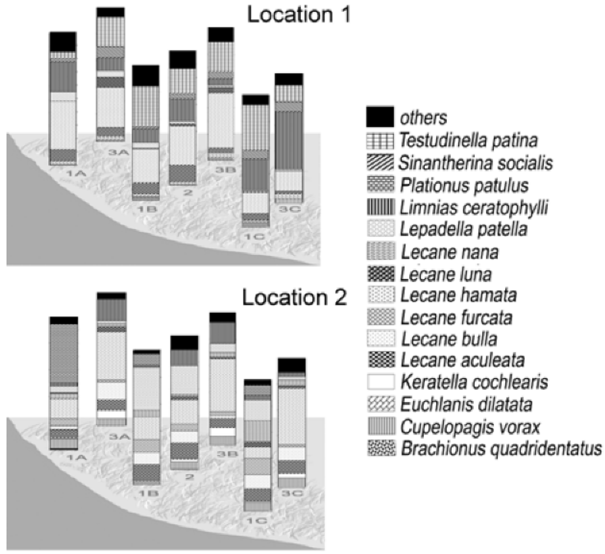

Fig. 2. Percentage contribution of dominant rotifer species in the total density of plankton communities on particular sampling points at two locations in Lake Licheńskie.

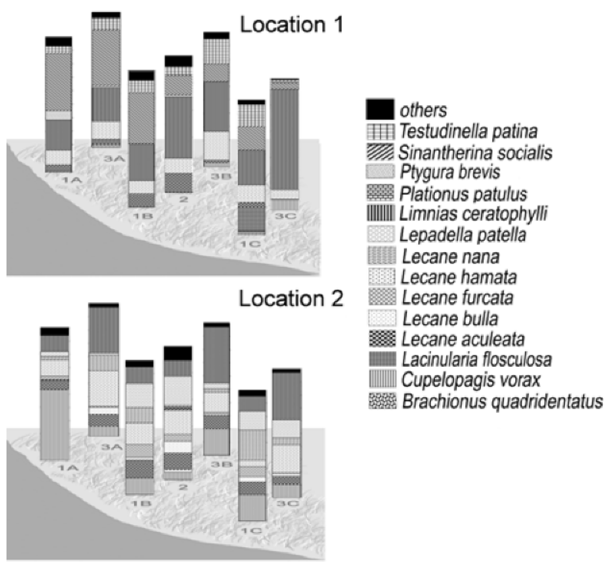

Fig. 3. Percentage contribution of dominant rotifer species in the total density of epiphyton communities on particular sampling points at two locations in Lake Licheńskie.

part of *Vallisneria* patches near the lake shore (sampling points 1A, 1B, 1C) were markedly higher than in the part under the influence of open water (s.p. 3A, 3B and 3C). PSC values were 27.3 ±7.0% for plankton and 29.3 ±6.1% for epiphyton at points 1A-1C and nearly twice that, i.e. 54.9 ±3.5% and 53.4 ±6.2%, respectively, for points 3A-3C (Fig. 4). The

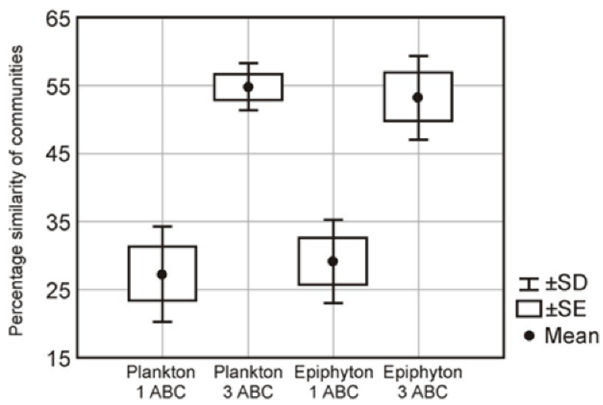

Fig. 4. Comparison of the percentage similarity for plankton and epiphyton communities of Rotifera for the same sampling points at both locations in Lake Licheńskie. 1ABC – sampling points located close to the lake shore; 3ABC – sampling points located close to open waters.

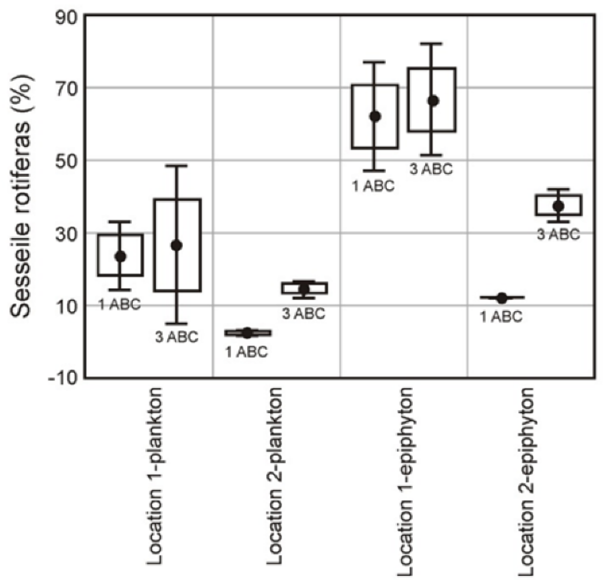

Fig. 5. Comparison of the percentage contribution of the sessile species in the numbers of the rotifer community at both study locations in Lake Licheńskie. 1ABC – sampling points located close to the lake shore; 3ABC – sampling points located close to open waters.

differences between points 1ABC and 3ABC for both plankton and epiphyton communities, were significant at p = 0.004 and p = 0.009, respectively (*t*-test).

The sessile rotifers constituted a relatively large part of the rotifer community, both in epiphyton and plankton (Fig. 5). At location 1 their contribution in the total community was markedly lower in plankton and accounted for 23.9 ±9.6% at sampling points 1ABC and 26.9 ±22.0% for sampling points 3ABC. They constituted a larger part in epiphyton, 62.7 ±15.0% (s.p. 1ABC) and 67.1 ±15.3% (s.p. 3ABC). The differences between percentage of sessile rotifers in the two lines of sampling points were higher at location 2. The plankton communities involved 2.6 ±0.9% of sessile individuals at sampling points 1ABC and 18.2 ±3.7% at sampling points 3ABC. Their contribution in the epiphytic community was markedly higher – 12.4 ±0.5% (s.p. 1ABC) and 37.7 ±4.3% (s.p. 3ABC). Thus, the differences between the share of sessile forms in plankton and epiphyton were insignificant for location 1 and highly significant for location 2 (p = 0.001 and p = 0.0005, respectively). It seems, however, that at both locations, the relation between plankton and epiphyton as regards the percentage contribution of sessile rotifers, is lower at sampling points 1ABC than at 3ABC.

DISCUSSION

Strong changes in the ecosystem of Lake Licheńskie, i.e. the increase in temperature of its waters, as well as the invasion of *Vallisneria spiralis*, which completely displaced native macrophytes, were expected to lead to significant changes in littoral communities of rotifers. Some examples of alterations of epiphytic invertebrate communities, through the replacement of native macrophytes by invasive ones, may be found in literature. Invasion of the littoral zone of Lake Wanaka (New Zealand) by macrophytes *Lagarosiphon major* and *Elodea canadensis* facilitated significant changes in the ecology of the lake (Kelly, Hawes 2005). Invertebrate communities in exotic beds were more dense and more diverse. Similarly, invasive *Phragmites australis* modified epifaunal communities of gastropods from the eastern seaboard of the USA (Talley, Levin 2001). However, the indirect effect of replacement of native macrophytes by exotic species may vary across sites and sampling dates as it was shown for *Myriophyllum* and epiphytic macroinvertebrates (Wilson, Ricciardi 2009). Invasion of the habitat-forming *Fucus evanescens* (a brown alga of Arctic origin) in southern Sweden, affected the environmental conditions for different epiphytic species, but it had a rather low direct effect on their biodiversity (Wikstrom, Kautsky 2004). Additionally, Shurin's (2000) experimental studies have shown that the introduction of potential invaders has no effect on the total zooplankton diversity.

Strong changes in abiotic and biotic factors in Lake Licheńskie had a strong impact on rotifer fauna connected with the invasive macrophyte. New species appeared, but they did not achieve high density (Ejsmont-Karabin 2011). Another phenomenon observed in the lake was the change in the dominant species, like *Cupelopagis vorax* (which is rather rare in the Polish fauna) and *Limnias ceratophylli*, which is more common, but its density is usually relatively low. The changes, however, did not lead to a decrease in species richness of rotifer fauna.

Factors that may be responsible for high diversity of rotifer communities inhabiting *Vallisneria* beds are:

1) large-scale horizontal diversity (i.e. between macrophyte patches);
2) small-scale horizontal diversity (within patches)
3) high vulnerability of *Vallisneria* epiphyton to disturbances caused by wave action.

The comparison of rotifer communities in two different locations revealed relatively high differences in their sets of dominants, especially at sampling points close to the lake shore. It supports the hypothesis of large-scale horizontal diversity.

It has been shown that the similarity of rotifer communities depends on the position of a particular macrophyte stand in relation to the open water zone (Kuczyńska-Kippen, Nagengast 2003). *Vallisneria* leaves may reach the water surface already by the end of July. This growth then limits the mixing of lake water with heated waters from the open zone. Thus, considerable temperature differences were recorded in the patches examined by Hutorowicz (2006) in Lake Licheńskie. This may also explain the significant variation of the species structure of rotifer communities within the patches. The temperature decreased by over 4°C within a 60 m stretch along location 1, which was studied in 2004 by Hutorowicz (2006). Differences in this range were observed in September and October. In this study, the differences were not so big (Table 1). On the contrary, the temperatures were nearly the same at all sampling points, both at the surface and close to the bottom at location 2. Some differences, however, may be observed as regards the concentration of oxygen (Table 1), especially at location 1.

Grazing by snails had a significant influence on the algal community because it reduced the competition (Jones et al. 2000). Wave action could have a similar influence on the cleaning of plant surfaces from periphyton. Kairesalo (1980) suggested that wind-induced water movements between pelagial and littoral zones might be of considerable importance and they may rapidly change the algal composition. It is possible that similar phenomena could be expected as far as small invertebrates are concerned. A relatively high similarity between plankton and epiphyton communities may indicate strong impact of epiphyton on the structure of littoral plankton. This presumption was confirmed in our study. We found a high contribution of sessile rotifers to the plankton density. This group of rotifers is usually attached to their substrate and if they are found in plankton, they are probably detached from their natural substrate. The occurrence of high density of sessile species in plankton communities and markedly higher density at sampling points adjacent to open waters, may support this hypothesis.

CONCLUSIONS

The high temperature of water in Lake Licheńskie was one of the most important reasons for the rapid invasion of the littoral zone by *Vallisneria spiralis*. This species formed a very dense monospecies phytocoenosisand almost entirely displaced native submerged macrophytes (Hutorowicz 2006). This simplification of littoral vegetation did not lead, however, to lower richness of rotifer communities occupying this habitat. The factors which are probably responsible for the high diversity of rotifer communities inhabiting *Vallisneria* beds are as follows:

1) Large-scale horizontal diversity (i.e. between macrophyte patches), which was reflected in differences between the rotifer species that dominated in the two studied localities;
2) Small-scale horizontal diversity (within patches), reflected in the differences found between the sampling points close to the lake shore and those close to open waters;
3) High vulnerability of *Vallisneria* epiphyton to disturbances induced by wave action, which is supported by high contribution of sessile species in the plankton community;

Thus, even monospecies assemblages of an invasive macrophyte with a very simple structure may create different habitats for littoral fauna of Rotifera.

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