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The onset of invasion of bryozoan *Pectinatella magnifica* in South Bohemia (Czech Republic)

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Abstract: *Pectinatella magnifica* is an invasive freshwater bryozoan with ability to produce large colonies reaching a capacity of up to several tens dm^3. In the Protected Landscape Area and Biosphere reserve Třeboňsko the bryozoan was first found in 2003 in one mesotrophic sandpit. The species gradually spread to many other sites around the Třeboň area and at most of these locations its occurrence has invasion properties. *Pectinatella* expanded to some other sandpits, fishponds without intensive pisciculture. *Pectinatella* colonies are found mainly on submerged branches of willow trees. The differences between biomass in transects with the occurrence of shrub willow and biomass in transects without their presence were statistically significant in the total biomass weight and the number of colonies. The average weight of several colonies did not differ. The most important parameter affecting the occurrence was the low trophy of water. The water temperature is evidently an important factor affecting the seasonal dynamics of occurence. Differences in nitrogen and phosphorous content between the water outside and inside the colonies were statistically significant. The colonies also accumulate other elements, including microelements.

Key words: *Pectinatella magnifica*; sandpits; fishponds; trophy; biomass; invasion

Introduction

Monitoring of invasive alien species is important for obtaining the necessary data on their distribution, biology in the new environment and potential interactions with indigenous organisms. In recent years a massive spread of the bryozoan *Pectinatella magnifica* (Leidy, 1851) has been reported from many countries. Yet, the impact of this invasion is not well known. This paper describes the beginning of the invasion of this organism in the Protected Landscape Area (PLA) and Biosphere Reserve (BR) Třeboňsko.

Pectinatella magnifica was first found in 2003 (Šetlíková et al. 2005) in this area. Although this organism did not appear in Bohemia for the first time, this was the first mass occurrence after a few decades (Opravilová 2005). In spite of the fact that there are many fishponds with intensive pisciculture in South Bohemia, *Pectinatella* was first found in sandpits. Compared to fishponds, the sandpits are oligotroph water bodies (Drbal et al. 1990). In these reservoirs sport fishing is allowed and to a limited extent they are used for recreational activities.

The population dynamics of the species is described by Joo et al. (1992) from Alabama. The authors also mention the influence of the presence of colonies on the composition of phytoplankton. Very interesting and worth mentioning is one of the earlier works that experimentally deals with *Pectinatella* preferences towards various substrates (Hübschman 1970). The relationship between enlargement of five bryozoan species and physico-chemical parameters of the aquatic environment was described by Everitt (1975); its ecological role in ecosystems was elaborated by Ricciardi & Lewis (1991). Probably the most important recent European study is a description of its colonies and population dynamics originating in France (Rodriguez & Vergon 2002).

Relationships between bryozoan and other freshwater species are described in the study of ponds in Alabama (Dendy 1963). The description of bryozoans ability of inner accumulation of particular elements dissolved in water can be found in the study of Schöpf & Manheim (1967). Quite often *Pectinatella* is seen as an intermediate host for fish parasites, especially microsporidia (e.g., Canning et al. 2002). In Central Europe, so far, *P. magnifica* has not been explored in detail; we can mention only a descriptive study from Western Europe (Massard & Geimer 2002) and a study summarizing the history of its spread (Opravilová 2005).

In this paper the basic aspects of invasion origin of bryozoan *P. magnifica* in the South Bohemian area are described (Czech Republic, Central Europe).

Methods

The monitoring of *Pectinatella magnifica* occurence in water reservoirs, including fishponds, was primarily made in the Třeboň area. Monitoring was carried out in 2005–2007.

The methodology of biomass detecting was based on quantitative sampling of all colonies on the ten-meter transect along the coast. Arbitrarily, the transect width was set 5 m from the reservoir shore, thus bringing the total exploration area always to 50 m^2.

All the obtained colonies were weighed (on laboratory scales with an accuracy of $\pm$ 2 g, the weight was then rounded to the tens of grams). Next, number of colonies was counted, making it possible to assess both the total biomass, the number of colonies and the size of the average and at the same time the largest colony present. As well, the water temperature was measured.

Transects were selected randomly in order to cover different types of coastal vegetation. Considering the fact that the *P. magnifica* colonies are abundant on the submerged branches of willow trees, transects were primarily chosen with regard to the occurrence of willow polykormons. Each sampling consisted of a minimum of 6 transects, half of which was always along the coast with prevailing willow shrubs vegetation.

While collecting the colonies, water samples from the reservoir and from the inside of the colonies were taken. The concentration of nitrogen and phosphorus by Flow Injection Analyser was determined. The concentration of other selected elements present in the filtered water was determined by Atomic Absorption Spectrometry (AAS, SpectrAA-640, Varian, Australia) and by Inductively Coupled Plasma Mass Spectrometry (ICP-MS, PQ-ExCell, VG-Thermo Elemental, Winsford, Cheshire, UK).

In July 2005, a single sampling was carried out at six transects. In summer of 2006 there were two samplings, one in July and the other in August, the same sampling system was also used in the season of 2007. Simultaneously, the sampling process was carried out at other (newly discovered) places with bryozoans occurence. Data from the temperature data logger Commet for 2006 can only be used as a guide, since the device was damaged during spring flooding. At the same time the pH and conductivity were measured.

Results

Invasion of P. magnifica in the Třeboň area and findings in other areas

Pectinatella magnifica was first found in South Bohemia in 2003, namely in the Cep sandpit. From here, it gradually spread to the connecting channel reservoir Cep I, where it was found in a small amount in the next year. In 2005, the organism was newly found in the Podřezaný pond, which is located approximately 7 km west of the Cep sandpit. In 2006, the Hejtman fishpond was added to these sites (4 km east of Cep sandpit) and the Hněvkovice dam (alleged unverified occurrence in 2004). At the end of summer 2006, individual colonies were also found in the Orlik dam on the Vltava River.

In 2007, the Nový Kanclíř fishpond in the Třeboň area, 3 kilometres northeast of Cep sandpit, was added to the sites; in addition, colonies of bryozoan were found by Špacek J. (*in verb*) in Mělník directly in the Labe River. Three colonies were found in August 2007, it was in a bay of the Vlkov sandpit in the sandpit system Veselí sandpits, about 30 km north of the Cep sandpit.

All sites, at which the bryozoan has occurred, are still inhabited by this organism. In the Podřezaný pond bryozoans showed very low biomass in 2007; this was due to very low water levels in the pond, which resulted in the substantial loss of suitable substrate (coastal scrubs were out of the water).

Seasonal dynamics of P. magnifica in the Cep sandpit

In 2003, the bryozoan was not found until late July. Late finding, however, does not preclude its earlier development, which evaded our attention. The maximum weight of the colonies was about 2 kg. In early September, the colonies began to disintegrate. In 2004 the bryozoan appeared on 3 July and continued to grow, but the colonies were smaller, the maximum weight (obtained by measuring 138 randomly collected colonies) amounted to only 0.27 kg. The average weight was 0.037 kg. The colonies began to disintergrate again around 6 September, and at the same time there was a massive production of statoblasts.

In 2005, the bryozoan appeared on 11 June. The maximum recorded weight of colonies (29 July) reached 4.3 kg, the average weight was 0.44 kg. Differences between transects with the occurrence of shrub willow and transects without their presence were statistically significant in the total biomass and the number of colonies ($P < 0.01$), where the total average biomass of the colonies at transects with willows was 6.76 kg m^{-1}, whereas for transects without willows it was only 0.22 kg m^{-1}. By contrast, the average weight of the colonies did not differ – in transects with willows 0.43 kg, in transects without willows 0.5 kg. The bryozoan colonies disintegrated around 9 September, again with a massive production of statoblasts.

In 2006 the bryozoan appeared on 27 June. The first sampling was carried out on 13 July, the maximum colony weight reached 1.87 kg, the average weight was 0.25 kg. Differences between transects with willows and without willows were significant in the total biomass and average weight of colonies (both $P < 0.05$), but not in the number of colonies. The average total biomass of the colonies was 1.14 kg m^{-1} in transects with willows and only 0.57 kg m^{-1} in transects without willows. The average weight of the colonies in transects with willows was 0.32 kg, in transects without willows only 0.18 kg.

The other sampling was carried out on 20 August 2006, the maximum weight of the colonies reached 9.4 kg, the average was 0.65 kg. The colonies were significantly larger than in 2005 and 2004 ($P < 0.01$ in both cases). The average total biomass and weight of the colonies in August 2006 significantly differed from those in July; in addition, in transects without willows the increase of biomass was much greater than in transects with willows. This means the total biomass of 6.2 kg m^{-1} (approximately the same as the value in 2005) and the average colony weight of 0.75 kg for transects with willows, whereas for the transects without willows only 0.84 kg m^{-1} (significantly higher than in 2005) and 0.55 kg. Colonies gradually disintegrated in the first half

Table 1. *Pectinatella magnifica* biomass (sandpit Cep, 2005–2007).

Year	Maximum weight of colony [kg]	Total average weight of colony [kg]	Average weight of colony in transect with shrub willow [kg]	Average weight of colony in transect without shrub willow [kg]	Biomass in transect with shrub willow [kg m^{-2}]	Biomass in transect without shrub willow [kg m^{-2}]
2005	4.30	0.44	0.43	0.50	6.76	0.22
2006 – 1st sampling	1.87	0.25	0.32	0.18	1.14	0.57
2006 – 2nd sampling	9.40	0.65	0.75	0.84	total 6.2	
2007 – 1st sampling	4.36	0.32			1.51	0.019
2007 – 2nd sampling	0.82	0.14	0.05	0.19	0.18	0.18

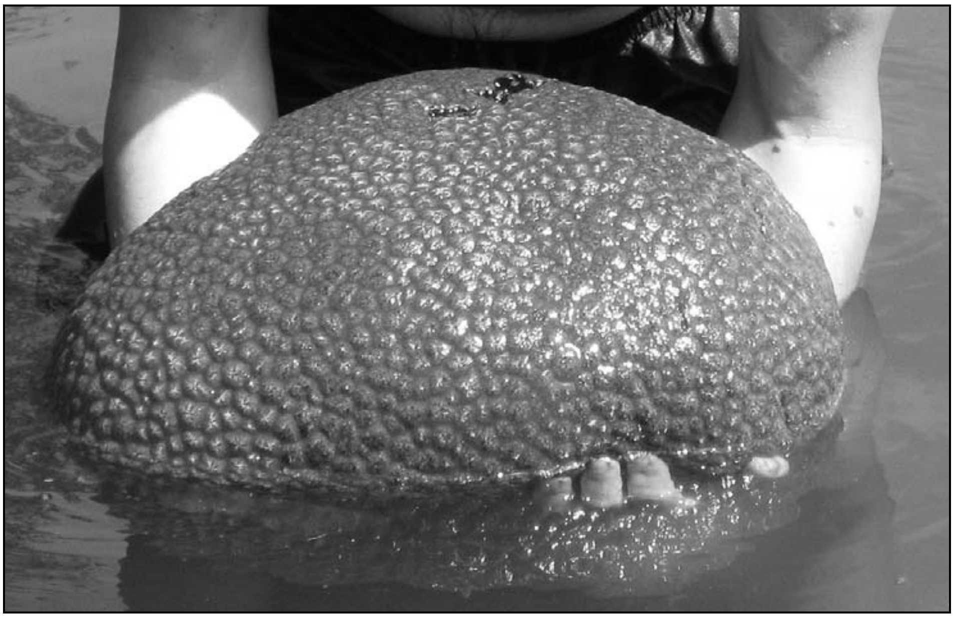

Fig. 1. Colony of *Pectinatella magnifica.*

of September, but still in early October the sandpit was occupied by smaller colonies.

In 2007 the bryozoan appeared on 21 June, its increase was, however, slowed down in the first July week. The first sampling was therefore carried out on 27 July. The maximum weight of the colony was 4.36 kg, the average weight of the colony reached only 0.32 kg. The average total biomass of the willow transects was 1.51 kg m^{-1}, the transect without willows only 0.019 kg m^{-1} (only three colonies were found on 50 m length of coastline).

The other sampling was carried out on 28 August. The maximum weight of the colony was only 0.82 kg, the average weight 0.14 kg. Interestingly, there was a settlement of biomass for transects with and without willow scrubs – on average 0.18 kg m^{-1}. The average weight of colonies was significantly greater at transects without willows (0.19 kg) than at willow transects (0.05 kg). In late August, it came to a rapid cooling and to a complete disintegration of the colonies of *P. magnifica*. Owing to this fact, colonies in both samplings were significantly greater than in 2004, but smaller than by sampling in 2005 and 2006. Basic data on biomass shows Table 1.

In general, the colonies (in all localities) had yellow-brown colour and structure of solid jelly, sometimes occupied with algae and cyanobacteria, spherical or oblong, sometimes taking the shape of the ground surface (Fig. 1). This species can act as a kind of filter; in reservoirs, where it appeared, the occurence and further spread of algae and cyanobacteria was limited, which is usually delayed until the disintegration of colonies (mostly during September).

Abiotic factors observed during the summer season

The water temperature in the reservoir turns out to be an important factor affecting the seasonal dynamics of the colonies. The first colonies begin to appear after the water temperature rises above 20 ℃ at least on three consecutive days. Even short-term drop in temperatures below 20 ℃ during the summer season results in halting the colonies growth and continuing drop in temperature leads to disintegration of colonies and release of statoblasts.

As an example we can use the influence of temperature in 2005. Short temperature drop on 24 July led to the production of statoblasts, which did not massively transfer in this case. On the contrary, a sharp

Table 2. Average values of the basic parameters in water localities (2005–2007).

Locality	Month/year	Temperature [℃]	Water transparency [cm]	pH	Conductivity [µS cm^{-1}]
Cep + Cep I.	7/2005	22.1	150	7.76	137
Cep + Cep I.	7/2006	25.2			128
Hejtman	7/2006	23.4	110	7.07	81
Podřezaný	7/2006	27.6	70	8.11	93
Cep + Cep I.	7/2007	21.7	110	7.64	176
Hejtman	7/2007	21.4	60	7.38	127
Podřezaný	7/2007	26.5	30	9.5	175
Nový Kanclíř	7/2007	24.8	90	9.04	162
Hněvkovice	7/2007	22.3	80	8.26	160
Cep + Cep I.	8/2007	22.4	170	8.38	182
Hejtman	8/2007	20.1	80	8.24	125
Nový Kanclíř	8/2007	19.0	40	8.47	160

and prolonged drop in temperatures after 10 August led to the colonies disintegration. Certain biomass increase occurred again at the end of August, but after 9 September the colonies finally disintegrated.

The beginning of summer in 2006 was cooler, which corresponds to the later beginning of the colonies formation. However, July was about 5 ℃ warmer than the long-term average (Anonymus 2007), which suggests the rapid increase in the weight of the colonies and their much larger weight. Water temperature reached more than 28 ℃ in the second half of July. High temperatures continuing until the autumn months (at the end of August the water temperature was of 21 ℃, in late September still around 19 ℃) enabled the existence of colonies until the beginning of October and resulted in a very slow disintegration. In the late August 2007 the cooling-down was very rapid (30 August, the water temperature was 20 ℃, while the maximum air temperature exceeded 13 ℃) and precipitated the disintegration of the colonies. Other important measuring values are the physical and chemical characteristics of the aquatic environment. Average values of measured characteristics are shown in Table 2.

Comparison of hydrochemical parameters in the external water and internal water in colonies of bryozoans

Concentration differences of different forms of nitrogen and phosphorus between the water inside the colonies and in the external water are in all forms statistically significant, thus, the colonies greatly accumulate the mentioned nutrients. Furthermore, they tend to accumulate other elements; the difference was statistically significant at concentrations of Al, Cr, Mn, Co, Ni, Cu, Zn, Se, Cd and As. Concentration of these elements shown in Table 3.

Table 3. Concentration of selected elements in external water and in *Pectinatella magnifica* biomass (sandpit Cep, 2005).

Element	Concentration in external water	Concentration in biomass
N [mg L^{-1}]	0.582	109.45
P [µg L^{-1}]	85.27	19074.76
Al [ppb]	8.98	12.16
Cr [ppb]	0.78	2.44
Mn [ppb]	0.52	85.40
Co [ppb]	0.13	0.45
Ni [ppb]	1.90	4.71
Cu [ppb]	0.39	1.41
Zn [ppb]	5.93	45.60
Se [ppb]	0.36	1.71
Cd [ppb]	0.018	0.331
As [ppb]	0.054	2.28

Comparison of occurence to other reservoirs

The dynamics in other localities with the presence of *Pectinatella magnifica* is similar in some indicators. The year 2006 was the year with a record size of colonies and biomass in the Podřezaný and Hejtman ponds; in the Hejtman fishpond a colony weighing 19.2 kg (the diameter was 55 cm) was found and the average biomass in the transect without willows (along the pond shores there are no willow shrubs) was 7.33 kg m^{-1} and was distributed very evenly. Values of transparency and conductivity in other localities are slightly lower. Very different, however, is the substrate that was settled by bryozoan. At both the above mentioned ponds the bryozoan was in 2006 most frequently found directly on the rocks, whereas in 2007, in the Hejtman pond, it was mainly concentrated on a single birch, fallen into water, but in enormous biomass, continuously enwrapping the whole tree trunk. In other parts of this pond there was a small number of relatively tiny colonies reaching the maximum weight of 1 kg. At Nový Kanclíř pond, in 2007, the bryozoan was primarily located on submerged tree trunks and branches.

Specific was also the occurence in the Hněvkovice dam. Colonies grew very unequally, they ranged from a record number of biomass (more than 12 kg m^{-1}) to long stretches of coast without any incidence. The presence on rocks was dominative, found also at a depth of over 3 m. And at one of the sampling sites a contiguous group of colonies weighing over 70 kg were found.

Discussion

Since the mid-20th century until recently *Pectinatella magnifica* occurred in the CR only sparsely (Opravilová

2005) and the last known appearance of its colonies in the CR before 2003 is from the year 1995 (Polaufová 2006, *in verb.*) from a pond located about 11 km from Tábor. Since 2003 *P. magnifica* has been spreading, which may have a character of invasion in some localities. One of the factors contributing to its spread can be the global climate change (a gradual increase in summer air temperatures can be seen from the orientation data of monthly averages Publisher by the Czech Hydrometeorological Institute – Anonymus (2007). The mechanisms of statoblasts transport to the sandpit are not known, one possible explanation is due to transport mining techniques – ships such as transport vessels are referred to from Alabama (Joo et al. 1992). As the main migratory path, however, are generally considered river flows (Rodriguez & Vergon 2002; Opravilová 2005), spreading along the river was also supported by our finding of colonies in Hněvkovice, then the Orlik dam and this year even from the confluence of the Labe and Vltava rivers (Špaček J. 2007, *in verb*). Statoblasts have hooks on them, enabling zoochorical transfer (Davenport 1900); interestingly, whrereas the Hejtman pond was high in occurence of large number of colonies of *P. magnifica*, in a nearby hydrochemically similar Stankovsky fishpond this organism was not found, which does not support the hypothesis of transmission by water birds, eventually, holidaymakers.

Pectinatella magnifica obviously preferred oligotrophic and mesotrophic reservoirs, with the conductivity significantly below 200 μS cm^{-1}, whereas in nearby fishponds (with a conductivity of about 500 μS cm^{-1}) did not occur. In 2007, when the conductivity values in Hejtman and Podřezaný ponds were higher (probably because of lower water levels in hot and dry summer), also the total biomass and number of colonies were significantly lower (up to thousandfold). But potential counteraction is also possible in this case – the higher incidence of colonies decreases the conductivity – due to influence of accumulation of nutrients in the water inside the colonies. Due to an intensive metabolism of the colony the composition of phytoplankton in the reservoirs is also affected (Ricciardi & Lewis 1991).

Very interesting are significantly different preferences in the type of substrate, not only in individual localities, but also between different summer seasons. It turns out that the smaller the biomass of this species in a given year is, the higher the preference of submerged willow branches is. Very different substrates (coarse sand, rocks, bedrock, branches), were also described by Hübschman (1969), but he did not find out a similar mutual relation, and does not even indicate a distinct preference for submerged willow branches, probably they were completely missing in those sites he had been exploring. *P. magnifica* accumulates in its biomass some kinds of heavy metals, which is also consistent with the data from the literature (Schöpf & Manheim 1967), however, the concentration of heavy metals in the sandpits is generally very low (Drbal et al. 1990), thus there is no threat of any potential health risks for consumers. However, there is no known evidence that any wild animal species would under common circumstances feed on *P. magnifica* biomass. The only case recorded by our author team were young individuals of domesticated muscovy duck (*Cairina moschata* f. *domestica*) feeding on this bryozoan, not in situ, but by the experimental use of biomass.

Conclusions

Pectinatella magnifica is an allochtonous species of bryozoa, with a massive occurence in many localities in Třeboň area and in other areas in the Czech Republic. Its occurence and dispersion have properties of massive invasion. *P. magnifica* was first found in southern Bohemia in 2003 in the Cep sandpit. And then, during next four years in five other sites in the same area the massive occurence was also found in two dams on the Vltava and Labe rivers. At all sites at which this bryozoan was found, its occurence in following years was confirmed. Cases of presence of *P. magnifica* were reported from other localities.

The seasonal start of occurence arised during June. Most of the colonies were found in the willow shrubs. Differences between transects with the occurrence of shrub willow and transects without their presence were statistically significant in the total biomass and the number of colonies. On the other hand, the average weight of the colonies did not differ. The water temperature in the reservoir appears as an important factor affecting the seasonal dynamics of the colonies. Differences in all forms of nitrogen and phosphorus content between external and internal colonies water were statistically significant. The colonies also accumulate other elements including microelements.

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