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Sarracenia – an exotic hostel for European aquatic invertebrates?

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Abstract
Pitcher plants provide temporal aquatic habitats, known as phytotelmata, which can be colonized by aquatic invertebrates. In this study, we tested, if phytotelma provided by an exotic pitcher plant *Sarracenia purpurea* L. could be colonized by native aquatic organisms. Thus, we exposed three plants to natural conditions for three months from June to August in E Slovakia and sampled the contained water in monthly intervals. As many as 15 taxa of the groups Rotatoria, Ciliophora, Flagellata, Nematoda, Tardigrada, and Diptera colonized the phytotelmata. The Rotifera species belonged to *Lecane bulla* (Gosse 1851), *L. inermis* (Bryce 1892), and *Colurella obtusa* (Gosse 1886). Dipterans were represented by families Ceratopogonidae, Chironomidae, Psychodidae, and Sciomyzidae. The results confirmed that phytotelmata provided by non-native plant species can potentially be colonized by native aquatic organisms, even though some microorganisms could have been remains of a previous colonization.

Key words: phytotelmata, pitcher plants, exotic plant species, cultivation, new environment, colonization, invertebrates, Insecta

Introduction

Small periodic waters are undeniably interesting but often overlooked ecosystems. Kitching (2000) and Williams (2006) developed their detailed classification. An interesting type of small periodic aquatic habitats are phytotelmata i.e., small temporary habitats provided by water-filled cavities of terrestrial plants. In the climate conditions of Europe, compared to the tropics, the variability of these ecosystems is much smaller. In Europe, phytotelmata occur on plants of the genus *Dipsacus* and natural occurrence of tropical plants forming phytotelmata e.g., from Bromeliaceae or Nepenthales is fully excluded. On the other hand, representatives of these groups are often present as ornamental houseplants throughout Europe (e.g., Kitching 2000).

The natural area of distribution of *Sarracenia purpurea* L. is limited to the eastern part of the USA and Canada (Juniper et al. 1989) where it grows on low-nutrient soils in boggy locations, but allochthonous populations have been reported from Britain and Ireland (Walker 2014), Sweden (Almborn 1983), Switzerland (Marabini 1994; Parisod et al. 2005), and Germany (Marabini 1994; Fürsch 2001; Gebühr et al. 2006). The pitchers of this carnivorous plant are formed in tubular leaves that work as passive pitfall traps, even though at least one species produces attractant substances (Miles et al. 1975). A combination of downward-pointing hairs, waxy sections of the inner walls, the low surface tension of the chamber fluid, and the presence of insect-paralyzing compounds allows to retain prey species (Folkerts 1999). The type of pray captured is largely related to leaf morphology and varies among *Sarracenia* species, with spiders being the prevailing prey for *S. purpurea* (Williams 2006). The decomposition of prey residuals occurs mainly by microbial extracellular enzyme activity (Bradshaw & Creelman 1984), although some *Nepenthes* and most *Sarracenia* species also produce digestive enzymes (Juniper et al. 1989). Despite the carnivorous nature of the plant, a number of invertebrate species have become residents in *Sarracenia* pitchers, even though the mechanism of the survival of these organisms is not fully understood. Most of the pitcher colonizers profit from the food resources i.e., the accumulation of the bodies of prey. Typical inhabitants of this habitat are dipterans, such as mosquitos (*Wyeomyia smithii* (Coquillett, 1901)), chironomids (*Metriocnemus knabi* Coquillett, 1904), sciarids and phorids (e.g., Aldrich 1916; Jones 1918; Buffington 1970; Cameron et al. 1977; Rymal & Folkerts 1982; Bradshaw 1983; Milne et al. 2008; Hamilton & Duffield 2002). From microscopic organisms there were recorded mites, microcrustaceans, rotifers, nematodes, and protozoans (e.g., Aldrich 1916; Hegner 1926; Goss et al. 1964; Addicott 1974; Petersen et al. 1997; Hamilton et al. 2000). Top predators, such as Odonata or Megaloptera were recorded from *Sarracenia* pitchers by Mather (1981), Rymal & Folkerts (1982), and Corbet (1983).

Bradshaw (1980) and Cameron et al. (1977) examined the temperature and oxygen regimes within the pitcher liquid of *S. purpurea,* while Fish & Hall (1978) measured pH in such environments. The unique environment of pitcher plants was studied by e.g., Wray & Brimley (1943), Judd (1959), Paterson (1971), Fish & Hall (1978), Kingsolver (1979), Rymal & Folkerts (1982).

The main goal of this work was to find out whether this non-native ecosystem can be colonized by native insect species in European climatic conditions.

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Material and methods

The research was carried out in the vicinity of the village Tulčík, eastern Slovakia (49.0882949 N, 21.3136972 E, 286 m a.s.l.) in 2022. There are no permanent aquatic ecosystems near the site, only seasonal waters, so-called anthropotelmata (rainwater tanks, etc.). Three plants of the genus *Sarracenia* (Figure 1) were used for the experiment.

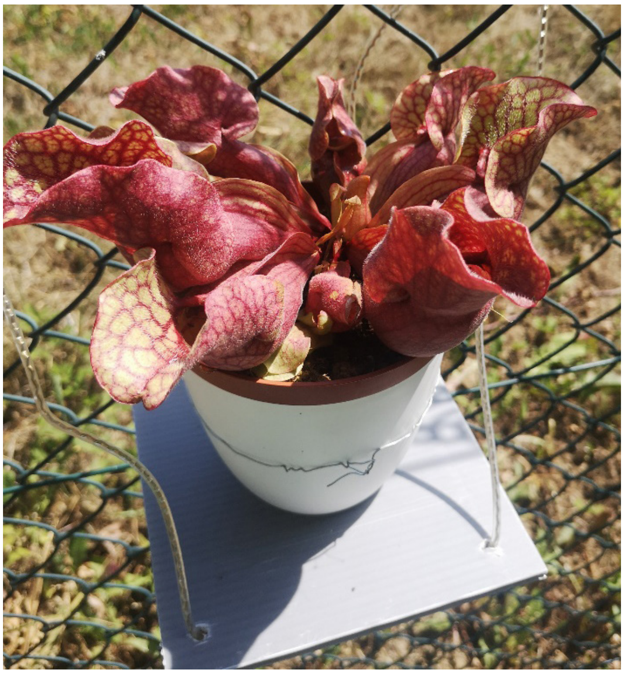

Figure 1. One from the tree experimental plants *Sarracenia purpurea* L.

At the beginning of the experiment (7.5.2022), the plants were completely drained of old water that they contained and filled with rainwater free of organisms after filtering through a plankton net. The plants prepared in this way were then placed outside in the nature and left to self-develop. Subsequently, the plants were checked at monthly intervals during the three-month experiment (7.6., 7.7. and 7.8.). The last date, however, was without water, since owing to the extremely hot summer the phytotelmata naturally dried up. At each inspection, the number of leaves that formed phytotelma was counted, water was removed from each plant and its total volume was measured. Water samples were subsequently fixed with 96% ethanol and transferred to the laboratory for further processing. The amount of pumped water from phytotelmata was always filled up with new filtered water as described above.

In laboratory the water samples were thoroughly examined under a stereomicroscope and the representatives of insects were picked. Subsequently, water samples were examined once again under high magnification for aquatic microorganisms.

Insects were identified according to Rozkošný (1980) and Nilsson (1997), rotifers using keys of Bartoš (1959) and Segers (1995), and for microinvertebrates guide of Sládeček & Sládečková (1997) was used.

Results

The volume of water changed over time. While in June there was about 350 ml of water contained in the pitchers, one month later less than half of this water was present in the pitcher leaves. In August there was no water present. The basic overview of the development (number and volume) of phytotelmata (Figure 2) in the three examined plants in different sampling dates is given in Table 1.

Figure 2. Phytotelmata created in *Sarracenia purpurea* L.

Table 1. Overview of the number of pitcher leaves and contained water volume in different sampling dates.

Sampling date/ experimental plant No.	7.6.2022		7.7.2022	
	No. leaves*	Volume (ml)	No. leaves*	Volume (ml)
1	11	105	13	40
2	9	108	7	50
3	11	143	11	70
Total	31	356	31	160

* Leaves with water

A total of 15 taxa were recorded in the pitcher phytotelmata during the three-month period (Table 2). While seven taxa were collected at the first sampling date, 14 taxa were found one month later. Six taxa overlapped between the two samplings. We primarily focused on the composition and dynamics of the Rotifera and Diptera fauna. From the rotifer fauna, we recorded only bdelloids (mainly juvenile individuals) with a frequency of ~1.3 ind./leaf in June. One month later, in July, we found a significantly larger amount of deposited organic material and, at the same time, an increase in both the number of individuals and the species diversity of rotifers (Bdelloidea 108.5; *Lecane bulla* (Gosse 1851) 147.7 ind/leaf; *L. inermis* (Bryce 1892) 124.5 ind/leaf; *Colurella obtusa* (Gosse 1886) 2.3 ind/leaf. From dipterans, a representative of the family Psychodidae (*Psychoda* sp.) and Chironomidae (*Paratanytarsus* sp.) were recorded in June, while Ceratopogonidae (*Dasyhelea* sp.), Sciomyzidae and Chironomidae (*Paratanytarsus* sp. and *Chironomus* sp.) in July. Representatives of Tardigrada, Nematoda, Ciliophora (e.g., *Colpidium* sp.) and Flagellata (e.g., *Katodinium* sp.) were also recorded.

Table 2. List of collected taxa in different sampling dates.

Taxon	7.6.2022	7.7.2022
Diptera		
Ceratopogonidae		
Dasyhelea sp.	-	3 larvae
Chironomidae		
Chironomus sp.	-	1 larva
Paratanytarsus sp.	1 larva	4 larvae
Psychodidae		
Psychoda sp.	2 larvae	-
Sciomyzidae		
Sciomyzidae indet.	-	2 larvae
Rotatoria		
Bdelloidea	1.3 ind/leaf	108.5 ind/leaf
unidentified bdelloids	(*)	(*)
Habrotrocha sp.	(*)	(*)
Lecanidae		
Lecane bulla (Gosse, 1851)	-	147.7 ind/leaf
Lecane inermis (Bryce, 1892)	-	124.5 ind/leaf
Lepadellidae		
Colurella obtusa (Gosse, 1886)	-	2.3 ind/leaf
Ciliophora		
Colpidium sp.	-	*
Flagellata		
Katodinium sp.	-	*
Nematoda	*	*
Tardigrada	*	*

(*) since most individuals (>90%) were juveniles or morphologically unidentifiable specimens, the numbers could not be relevantly quantified to this level

Discussion

Dipteran larvae are the most frequent inhabitants of pitchers. Fish & Hall (1987) confirmed three dipteran families, Chironomidae, Sarcophagidae and Culicidae. In the present study, larvae of four families were recorded. Chironomidae were represented by genera *Chironomus* and *Paratanytarsus. Chironomus* is one of the most species-rich genera of the family with many opportunistic species that may be early colonizers after a significant environmental change (Brooks 1997). It was also a common inhabitant in fountains of some European cities (Hamerlík & Brodersen 2010; Oboňa et al. 2017), and frequently one of the first colonizers after their fill-up. Moreover, it was the most abundant and frequent chironomid in water-filled garden barrels in eastern Slovakia (unpublished data), so this could be the colonization source of the plants in our case, since natural water bodies did not occur close to the experimental set-up.

Occurrence of *Paratanytarsus* in the pitchers is interesting, since the genus has not been known as an exceptionally good colonizer. *Paratanytarsus grimmii* (Schneider 1885) was, however, recorded in some fountains (Hamerlík & Brodersen 2010). This parthenogenetic species, known as a pest through its ability to breed in water distribution system, was hypothesised to originate from the tap water network, however, in nature it may occupy hyporheic habitats. Unfortunately, in our case the species and its source of colonization remain unknown.

When it comes to the food source of the recorded chironomids, it is likely that similar to the larvae of *Metriocnemus knabi* found previously in pitcher plants, they feed on the food remains and detritus on the bottom of the pitcher.

We are aware that in the case of microorganisms, it is challenging to decide whether the plants were newly colonized, or they are remains of the previous environment. It is likely that draining the old water from the pitchers did not remove the microscopic organisms completely, which may have easily survived in the newly added water. Many of the taxa identified in our study survive unfavourable conditions in various stages and that once suitable conditions are restored, the 'dormant' stages are reactivated. If this is the case, the colonisation of the plants occurred much earlier and not in the new environment, during the experiment. The bdelloid rotifer, *Habrotrocha rosa* Donner 1949 is considered as a common and dominant inhabitant of *Sarracenia purpurea* leaves by many authors (Bateman 1987; Błedzki & Ellison 1998, 2003; Kneitel & Miller 2002; Petersen et al. 1997). *H. rosa* was found also in the pitchers of the allochthonous *S. purpurea* populations in Germany (Gebühr et al. 2006). Petersen et al. (1997) found two other bdelloid species (*Macrotrachela quadricornifera* Milne, 1886, and *Adineta steineri* Bartos, 1951) and two individuals of the genus *Lecane* in *S. purpurea* leaves. Błedzki & Ellison (2003) added three more species to the list of *Sarracenia* dwellers, *Cephalodella anebodica* (Berzins 1976), *Lecane lunaris* (Ehrenberg 1832) and *Notholca acuminata* (Ehrenberg 1832).

Based on the above results, we can conclude that *Sarracenia purpurea* phytotelmata represent an interesting ecosystem, with a potential for a suitable free ecological niche even in a new environment, and which is colonized by similar groups of organisms as in the original ecosystems. However, presence of some microscopic organisms could be the result of a previous colonisation that occurred in the original environment.

Conclusion

Common inhabitants of the water-filled pitchers of *S. purpurea* were rotifers, dominated by bdelloid rotifers, as well as *Lecane bulla* and *L. inermis,* and larvae of dipterans, especially Chironomidae. Our results indicate that the biodiversity of the pitcher-occupying communities increase with retention time of the water and consequently the accumulation of sediment. Longer and more complex survey will be needed to describe the succession of the aquatic communities in pitcher plants.

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