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Diel and seasonal patterns of microcrustacean communities in relation to environmental factors in peatland ponds (Turjánvidék, Ócsa, Hungary)

– *Abstract of the PhD thesis* –

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1. Introduction and aims

Ponds and pools have long been poorly studied objects of limnological investigations compared to larger lakes or rivers (De Meester *et al*. 2005, Céréghino *et al*. 2008, Oertli *et al*. 2009), but there is a growing interest in their research since the 90s (Oertli *et al*. 2009), due to their high frequency of occurrence (and therefore, their possible role as model systems on landscape level; De Meester *et al*. 2005), conservation importance (Oertli *et al*. 2009) and the ecosystem services and several other important ecological roles they provide (Oertli *et al*. 2005). Based on data resulting from the last decades, ponds can be considered quite different systems from larger lakes according to their ecology and functions (Oertli *et al*. 2002, Søndergaard *et al*. 2005), but much of their biota and ecological processes are still undiscovered. Peatland ponds are a special, even lesser known subgroup of these habitats. Peatlands have a special role in conserving biodiversity worldwide, including Hungary (Mahunka 1991, Borhidi 2003, Borics *et al*. 2003), where they are protected by law. Apart from their unique flora and fauna, they have an important global role in climatic regulation, carbon storage and basic ecosystem services (Joosten and Clarke 2002). My thesis aims to study microcrustacean communities of permanent (cutaway ponds at Öreg-turján) and temporary (astatic swamp) peatland ponds in the internationally protected Turjánvidék of Ócsa (Central Hungary). Given their essential trophic role, revealing the functioning, dynamics and distribution patterns of zooplankton communities and the underlying factors is essential in any lentic ecosystem.

Our main questions were:

1. Which Harpacticoida (Copepoda) species inhabit the permanent peatland ponds of Öreg-turján, and which Cladocera and Copepoda species are found in the astatic alder swamps of Nagyerdő? What are the possible differences between the fauna of these two areas?
2. How can seasonal patterns in the microcrustacean zooplankton be described and how similar are these to the general patterns described in the PEG model? How can it be related to environmental factors?
3. Are zooplankton species richness and abundance related to vegetation cover in a shallow astatic habitat?
4. What could be an optimal strategy for monitoring such habitats according to the seasonality of the different species? When and how many samplings are advisable for collecting most of the species in an effort-saving way?

5. Are there any differences in the species richness and abundance of zooplankton communities of an astatic alder swamp between two years of contrasting rainfall?
6. What vertical patterns are observable in zooplankton distribution in a shallow peatland pond? Can it be related to environmental drivers, particularly to dissolved oxygen? Are there any diel changes?

2. Materials and methods

2.1. The peatland of Ócsa (Turjánvidék)

The peatland area near to Ócsa and Dabas villages (named Turjánvidék of Ócsa) is one of the last remains of the formerly extended wetlands of Central Hungary (Turjánvidék).

Öreg-turján is the northern part of the Ócsa Landscape Protection Area. It is a strictly protected area, part of the Natura 2000 network and also listed among the Ramsar Convention Sites. Its present features are largely resulted by human activities in the 20th century. Drainage and peat mining mostly eliminated the original vegetation, and peat excavation pits were formed with open waters, which are nowadays mostly covered by reed. During our studies (2008-2011), habitats of Öreg-turján could be described by very abundant reed vegetation, with shallow inner ponds (max. depth: 1 to 1.5 m) with thick muddy sediment (min. 0.5 m).

Nagyerdő (which is similarly listed in the Ramsar Convention on Wetlands) is a representative of the formerly widely distributed swamps and alluvial forests formed in sand dune depressions of the Danube–Tisza Interfluve. Compared to Öreg-turján, it suffered from less human modifications, but due to several drainage channels, its formerly permanent waters are nowadays temporary (astatic): in spring, they hold water which mostly disappears by the middle of summer, with some remaining pools in the deepest spots.

2.2. Sampling

We sampled five ponds of Öreg-turján in three-week intervals from January until December in 2008. We collected qualitative and quantitative zooplankton samples. In the ash-alder swamp, we collected faunistic data in spring (29th April) and summer (11st August) of 2009. Our seasonal study in the ash-alder swamp was carried out in four-week intervals between 4th March 2010 and 12th July 2011 (from filling up after the winter of 2010 till drying out during summer in 2011).

Diel patterns were investigated in a peatland pond of Öreg-turján. Sampling was performed during three 24-h periods in summer and early autumn 2011 (19–20th July, 17–18th August and 11–12th September). Samples were taken four times in each diel period: at sunrise (between 05:00 and 07:00), at mid-day (12:00 and 14:00), at sunset (18:00 and 20:00) and during night (01:00 and 03:00). In order to study the vertical distribution of zooplankton, samples were taken from three different depths (0–20, 20–40 and 40–60 cm below the surface) with a transparent plastic Van Dorn bottle, which was used vertically.

Individuals of Cladocera and Copepoda (Calanoida, Cyclopoida, Harpacticoida) were identified to species level. We used subsampling to estimate abundance. In the case of the long-term study of the ash-alder swamp and the diel patterns, the planktonic predatory *Chaoborus* larvae were also counted in the samples. Temperature, pH, conductivity, dissolved oxygen and turbidity were measured with field equipment, along with recording vegetation cover and water depth. The concentration of chlorophyll-*a* and – in the ash-alder swamp – nitrate, ammonium and reactive phosphorus was determined in the laboratory. In our diel study, we also investigated phytoplankton composition.

3. Results and discussion

3.1. Species composition

We found 5 Harpacticoida species in five peatland ponds of Öreg-turján, by which the total microcrustacean species set of the area increased to 33. During the faunistic and seasonal study of the astatic swamp, we found 21 Cladocera and 15 Copepoda (12 Cyclopoida, 2 Harpacticoida, 1 Calanoida) species, of which 13 has not been observed in Öreg-turján. Altogether, we found 46 species in the whole territory of the Ócsa Landscape Protection Area between 2008 and 2011. The overlap between the species sets of the two areas was only 53%, which can be partly explained by the astatic nature of the swamp. Microcrustaceans were mainly frequent and widely distributed taxa, with some rare species, including *Scapholeberis erinaceus*, a cladoceran rare worldwide, *Cyclops insignis* (Copepoda), that occurs in Hungary and Central Europe only sporadically and the similarly rare *Paracyclops poppei* (Copepoda).

3.2. Seasonal dynamics of zooplankton communities

We found apparent seasonal patterns in both cladoceran and copepod communities. In spring and early summer, cold-stenothermic species occurred, i.a. *Cyclops insignis*. In the warmer seasons, cladocerans dominated, of which *Daphnia curvirostris* was the most abundant in Öreg-turján from late spring till midsummer. Later on, smaller-sized *Ceriodaphnia* species and thermophilic copepods (e.g. *Thermocyclops dybowskii*) became dominant. In Öreg-turján, autumn communities were dominated by large-sized Cladocera (*Simocephalus exspinosus* and *D. curvirostris*), while in the astatic swamp, *D. curvirostris* was the most abundant. Density peaks were observed during summer or early autumn, primarily due to cladocerans.

Seasonal patterns were very similar to the general patterns described in the PEG model (Sommer *et al*. 1986). Two ponds in Öreg-turján were markedly different from all the other habitats, most likely related to their high duckweed cover and the scarceness of submerged macrophytes. After their general cyclopoid copepod dominance in winter, succession in these ponds led to less diverse autumn assemblages with fewer species, dominated by *Simocephalus exspinosus*. Ponds with higher proportion of submerged macrophytes had more diverse autumnal communities, composed mainly of littoral species. In the open water of the astatic swamp, we observed a constant dominance of *Daphnia* from spring till winter.

Revealing seasonal patterns in different types of ponds is essential for designing further plans of monitoring and their schedule (Céréghino *et al*. 2008). In the Öreg-turján peatland, we found two main types of succession in the case of five ponds, mainly related to habitat complexity. In the open water of the astatic swamp, pelagic species dominated; additionally, we found remarkable within-year differences during our investigations (see chapter 3.5.)

3.3. The role of submerged macrophytes

In the case of Öreg-turján, the largest species sets belonged to ponds with higher submerged and emerged macrophyte cover. The most likely explanation of this difference is habitat complexity.

In the astatic swamp, both density and species richness were higher in the submerged macrophyte bed compared to the open water. While the majority of species showed a preference for the *Hottonia palustris* beds (based on density data), species richness was only slightly higher (marginally significant relationship) here. Community dissimilarity shoved a positive relationship with the extent of vegetation.

Daphnia longispina was the only species which showed a clear preference for open water. This is in accordance with previous studies, which proved that *Daphnia* are negatively affected by the extreme high densities of macrophytes, and they show a unimodal relationship with macrophyte density (Wetzel 2001).

We can conclude that in this shallow littoral habitat, dominance-patterns (rather than the presence or absence of particular species) caused the main differences in species composition between the macrophyte bed and open water. Phytophilous species, although in small numbers, occur also in the open water, while surface-associated species can dwell also in mud-surface and can easily be mixed up, hence occur in the open water.

3.4. The role of sampling frequency in diversity assessment

In the case of the five ponds of Öreg-turján, three exhibited late summer or early autumn richness peaks, while late spring or early autumn peaks could be observed in two. In the astatic swamp, the highest richness occurred in the late spring-early summer period, a few months after refilling. Temporal beta diversity proved to be higher in the swamp compared to the permanent ponds of Öreg-turján. According to our results, 80% of the total species number per site could be reached by half of the collected samples in all the investigated ponds. Additionally, we found that even a single well-timed sample can contain 70% of the total species set.

Based on our results, we emphasise the importance of sampling campaigns covering the late spring-early summer or late summer-early autumn periods, when both thermophilic and cold-stenothermic species occur. The development of aquatic macrophytes also influences positively the diversity of species by creating new microhabitats and niches. In our case, richness peaks always coincided with the highest extent of submerged macrophytes, both in the ponds rich in submerged aquatic vegetation and in the swamp.

We found that a few well-timed sampling events can contribute to an effort-saving, but still sufficient understanding of crustacean zooplankton species diversity. The choice of these dates requires preliminary knowledge of the area. It is also worth to mention, that some species could be found only in winter, by the time of the lowest richness. This highlights the importance of winter sampling for the better understanding of species richness in similar areas, which otherwise is often ignored.

3.5. Inter-annual differences in the astatic swamp

Both species richness and Shannon diversity were significantly lower in the second year, before which no desiccation occurred. Of the 23 species present in the first year, 11 disappeared. Densities of total microcrustaceans were similar, but differed significantly when we subtracted *Daphnia* densities, with significantly lower values in the second year.

The dominance patterns of the resting egg bank highly influence the assembly of active communities (Havel *et al*. 2000, Cáceres and Schwalbach 2001). In the second part of the first year, *Daphnia curvirostris* became dominant exhibiting high densities and their ephippia, which remained in the sediment due to the lack of desiccation (and therefore, were not exposed to wind), provided a high potential to build up large populations already in spring. Its dominance was presumably enhanced by the spring algal bloom, as *Daphnia* are superior competitors compared to smaller-sized species under food-saturated conditions (Vanni 1986). Besides, the disappearence of some resting egg forming species, like the temporary water species *Mixodiaptomus kupelwieseri* and some cladocerans, can also be related to the lack of previous desiccation.

Densities of macroinvertebrate predators can show high within-year variations in relation to hydroperiod length, having a tremendous effect on zooplankton community composition (Brooks 2000, Florencio *et al*. 2009, Caramujo and Boavida 2010). In our case, the planktonic predator *Chaoborus* larvae occurred only in summer in the first year, but their population lasted until desiccation, exhibiting the highest densities in the second spring. Selective predation of this species drives to the dominance of large-bodied Cladocera in the zooplankton communities (Lynch 1979).

Our results supported the previously suggested phenomenon that instead of the abiotic environment, biotic factors (e.g. phytoplankton peaks, predation, competition) drive the seasonal succession of zooplankton (Sommer *et al*. 1986, Lampert 1997, Lampert and Sommer 2007).

3.6. Diel vertical patterns

We found strikingly clear vertical gradients in both the environmental variables and zooplankton distribution in the only 60-cm-deep pond. The highest proportion of zooplankters was usually present in the surface layer, which could be related to the increasing hypoxia towards the sediment. Chlorophyll-*a* concentration and phytoplankton biomass were inversely distributed compared to zooplankton. These patterns were highly similar for the three distinct 24-h periods covering the late summer season.

Dissolved oxygen clearly had a predominant effect on the vertical distribution of zooplankton by maintaining its aggregation in the surface layers. No or very few animals occurred in the bottom layer even in August, when we found vertical migration performed by *D. curvirostris*, likely because of food depletion in the surface layer. Regarding the strong gradient of oxygen, the whole waterbody was similar to the metalimnetic oxycline of a thermally stratified lake. The vertical distributions of zooplankton and phytoplankton also support this similarity, as they correspond to lakes with metalimnetic algal maximum. Our results show that strong vertical gradients of abiotic and biotic factors occur even in such shallow waterbodies.

There is a growing interest in the ecology of ponds (Oertli *et al.* 2009, Boix *et al.* 2012), but plankton communities of peatland ponds are still poorly investigated. However, as these systems are generally oxygen-limited, the strong vertical stratification of plankton may be widespread in this habitat type and even in other ponds and pools with similarly high productivity. Therefore, investigations regarding micro-scale patterns could be an important part of monitoring such habitats and could significantly contribute to our knowledge on pond ecology.

4. References

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5. Publications

5.1.1. Publications that served as a basis for the thesis

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5.1.2. Presentations that served as a basis for the thesis

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