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MACROPHYTE MONITORING IN THE REHABILITATED AREAS OF LAKE KOLON, HUNGARY

Saláta-Falusi Eszter, PhD

Supervisor: Veresné Valentinyi Klára, PhD
External supervisor: Tölgyesi Csaba, PhD

2023

I, Saláta-Falusi Eszter voluntarily agree that my dissertation can be used for research purposes.

Gödöllő, May 9, 2023

signature

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Abstract

In Lake Kolon open water habitats were created to increase habitat diversity. Monitoring of aquatic macrophytes in these areas was conducted by Kohler-method. Deposition sites and edges were surveyed by cover estimation and evaluated by hierarchical clustering and principal component analysis. Our results confirm that the dis-, meso- and eutrophic macrophyte vegetation has good regeneration potential in presence of propagules. The long-term study of the deposition sites in the edges found that 7 years after the reconstruction their vegetation was similar to undisturbed conditions.

Keywords: aquatic plant, wetland, reconstruction, colonization, Kohler method, reed

1. Introduction

Wetlands are globally endangered habitats due to irrigation and eutrophication (Tardy 2007). This degradation process and habitat loss can be globally observed on a large scale although they maintain a wide set of ecosystem services. The same process could be observed in our research site, Lake Kolon, a priority wetland in Hungary under nature conservation protection as a core area of Kiskunság National Park. The unfavourable successional changes required active conservation management interventions (Kelemen et al. 1998), and creation of open water areas with different water depths became essential. In accordance with the nature conservation management plan (Vidéki 2008) and Natura 2000 conservation objectives (Pallag et al. 2009) the projects aimed at partial rehabilitation of the once extensive matrix of open water, marsh and fen habitats, that had almost disappeared in the last century. These new habitats increase the conservation value of Lake Kolon, and several benefits in terms of biodiversity were prognosticated as habitat creation through bed dredging provide optimal conditions for songbirds, shorebirds and other animal and plant species preferring open and edge habitats. Although the main focus of the habitat reconstruction was to increase nesting potential for endangered bird species, at the same time an additional research was set up to assess the colonization of macrophytes in the newly designed sites.

Our monitoring was based on the following research questions:

1. How fast is the colonization process of plant species considering verified presence in literature and preliminary survey data?
2. Is there any difference in colonization steps and in the share of social behaviour types in the case of the two different reconstruction sites?
3. What are the colonization steps on deposited material left on the shoreline? And how long is a difference observable?

2. Literature review of Lake Kolon

Lake Kolon lies near the settlement Izsák in N–S direction on the Danube–Tisza interfluve, its full-length is 7 kilometres. The shoreline reaches 96 m above sea level (Iványosi 1984). In terms of its origin Lake Kolon is a former Danube branch and was carved out by the Danube around the turn of the Pleistocene and Holocene period (Kelemen et al. 1998). Its geology was described by Pécsi (1967), Molnár et al. (1979), Tóth (1985) and Keveiné et al. (2004).

At the beginning of the last century it had no natural in- and outflow, and was a lake with fluctuant water level (Szebellédi 2002). At present, a significant part of the surface water entering the Lake is discharged through a belt canal collecting water from the Orgoványi-meadows and through a series of smaller canals from agricultural land. This inflow is essential, however, carries a risk of fertilizer input, which could lead to eutrophication (Velez 2004). In addition to the surface water inflow, outflow zone of the “Turjánvidék” also provides a significant groundwater inflow to the Lake.

The water quality is slightly alkaline, the transparency is good and the colour is yellowish brown characteristic for freshwater marshes. The water is slightly alkaline (pH 7.7–8.2), the chemical composition is dominated by Na-Mg-HCO_3-Cl and the total dissolved mineral content (salinity) is highly variable depending on water conditions (Velez 2004).

In terms of its phytogeographical classification Lake Kolon is located at the border between the *Colocense* and *Praematricum* floristic districts within the floristic sector of the Pannonian Plains, *Eupannonicum* (Hortobágyi and Simon 2000). Tölgyesi (1981), considering the geological history of the Lake and its recent vegetation cover, classifies it more to the floristic district *Colocense*. The diverse vegetation of the Lake was studied specially by Tölgyesi (1981), Bodrogközy and Bagi (1989), Szujkó-Lacza (1993), Sipos (2004) and prior to the reconstruction Pencz (2009) and Sztakó (2010).

3. Material and methods

3.1. Sample areas and methods of field botanical survey

The macrophyte monitoring was carried out continuously on yearly basis after the interventions at the following two reconstruction sites of Lake Kolon:

1. **"Spotty ponds"**[1] KEOP–3.1.2/2F/09–2009–0014 "Establishment of marginal and open water habitats in Lake Kolon" Project. Several, scattered, small open water areas connected with canal system. Excavated material was deposited on site.
2. **"Great Water"**[2] KEOP–7.3.1.2/09–2009–0009 "Habitat reconstruction on Lake Kolon in Izsák" Project. One, big, contiguous water surface. Excavated material was deposited outside the area.

In the area of Spotty Ponds the monitoring was conducted between 2011–2017, and on Great Water between 2014–2018. The field sampling was scheduled between Mid July and Mid August at the highest point of biomass.

The sampling units were canal and shoreline sections. These being linear elements, the application of the Kohler (1978) section mapping method according to the European standard for rivers (MSZ EN 14184:2014) was

[1]Translated by the Author based on the Hungarian nickname of the site: Tókás
[2] Translated by the Author based on the Hungarian nickname of the site: Nagy víz

suitable. This method does not apply random, representative sub-areas to model the quantitative relationships of macrophytes in a watercourse, but divides the entire length of the water body into sections with homogeneous ecological parameters (Kohler 1978). The designation of the study sections (Figures 1–2.) was carried out during the first survey of each area and was applied unchanged afterward.

Figure 1. Section numbers in the Spotty Ponds area

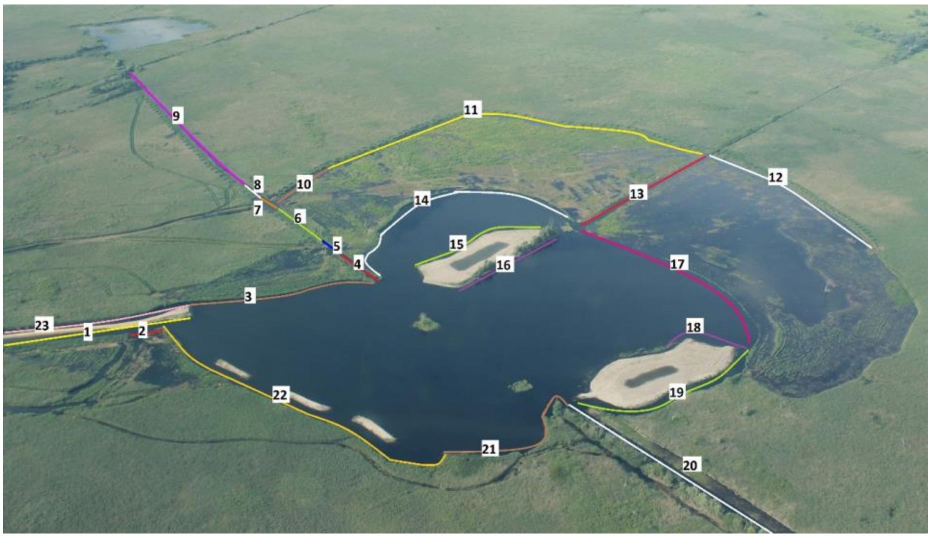

Figure 2. Section numbers of the Great Water area

The plant mass of species recorded per section was estimated after each section had been surveyed. Plant names used in this research report follow the nomenclature of Simon (2000). The estimated value (Table 1.) indicates how widespread/abundant (no cover) a plant is in a given section. This semi-quantitative survey technique for macrophytes is the most efficient use of resources.

5	very abundant
4	abundant
3	frequent
2	occasional
1	rare

Table 1. The meaning of estimated values (Kohler 1978)

Furthermore, in Spotty Ponds in addition to the monitoring of canals, we also focused on the vegetation of edges because riparian plant communities have importance in shaping the habitat conditions (Mjazovszky et al. 2003). Consequently the change of vegetation cover of deposition sites formed during the excavation on one of the shoreline of the ponds were investigated (Figure 3.). Plant species cover was estimated in sampling units of 0.5 m width and entire straight side length on each side. The side divided into two parts by the inlet canal was treated as two separate units, so typically 5 units were established per pond (Figure 4.).

Figure 3. A deposition site in 2011 (Photo: Aranka Hollósi)

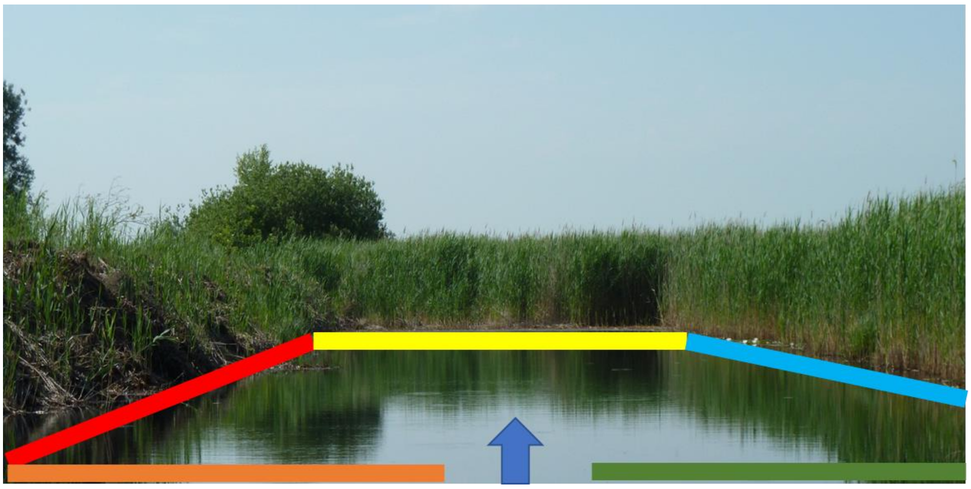

Figure 4. Example for marking the edges of a pond

3.2. Evaluation methods of field data

In the course of the analyses recorded species were classified into three life form categories according to Kohler (1978):

- Hydrophyte: obligatory aquatic plant
- Amphiphyte: plant able to survive for long periods underwater and also without water cover
- Helophyte: marsh plant rooted in the water or water lodged soil

During calculations of distribution indices Kohler (1978) considers only hydrophytes and amphiphytes. Helophytes, typical of riparian vegetation, are unreliable indicators in connection with water quality as other ecological influencing factors has more significant effect on their distribution (Kohler 1978, Kohler and Janauer 1995).

During the evaluation process all calculations with estimated plant mass were based on the assumption of Melzer (1988) that the relationship between estimated plant mass and actual plant volume/spatial extent is not linear but could be described by the function $F = x_{(y)}^3$ ($1^3 = 1$; $2^3 = 8$; $3^3 = 27$; $4^3 = 64$; $5^3 = 125$). Furthermore, due to the non-constant extent of sampling units, i.e. different section lengths, this value had to be corrected by the length of the sections surveyed.

Out of the derived indices the relative distribution length (Lr) shows the percentage of sections in which the species is present (Kohler 1978). The relative plant mass (RPM) shows the percentage share of a given plant species from the total plant mass in a study year (Kohler and Janauer 1995).

To assess ecological condition and evaluate the colonization process Borhidi's (1995) social behaviour types (based on Grime's C-S-R–strategy model, which is dependent on disturbance and plant stress (Table 2.)) were used.

Multivariate analysis of the edge sampling unit results was performed using the PAST (PAleontological STatistics) 3.13 software package (Hammer 1999–2006, Hammer et al. 2001), using hierarchical cluster analysis (UPGMA) and principal component analysis (PCA).

<table>
<tr><td>C</td><td>Competitors (C)</td><td colspan="3">Dominant species of natural communities</td></tr>
<tr><td>S</td><td rowspan="2">Stress tolerants (ST)</td><td colspan="3">Stress tolerants of narrow ecology: specialists (S) – rare specialists (Sr) – unique specialists (Su)</td></tr>
<tr><td>G</td><td colspan="3">Stress tolerants with wide ecology: generalists (G) – rare generalists (Gr) – unique generalists (Gu)</td></tr>
<tr><td>NP</td><td rowspan="7">Ruderals (R)</td><td colspan="3">Plants of habitats disturbed by natural factors: natural pioneers</td></tr>
<tr><td>DT</td><td rowspan="6">Plants of habitats disturbed by human factors</td><td colspan="2">Disturbance tolerant plants of natural habitats</td></tr>
<tr><td>W</td><td colspan="2">Anthropophilic elements of the native flora</td></tr>
<tr><td>I</td><td rowspan="2">Anthropogenic non-indigenous elements</td><td>Introduced crops running wild</td></tr>
<tr><td>A</td><td>Adventitious weeds</td></tr>
<tr><td>RC</td><td rowspan="2">Competitors of secondary habitats</td><td>Ruderal competitors of the native flora</td></tr>
<tr><td>AC</td><td>Alien competitors, aggressive invaders</td></tr>
</table>

Table 2. Categories of Borhidi's social behaviour types (SBT)

4. Results

4.1. Floristic results

The dominant plant species in open waters of the study areas were: *Utricularia vulgaris*, *Nymphaea alba*, *Stratiotes aloides*, *Potamogeton natans*, *Ceratophyllum demersum*, *C. submersum*, *Myriophyllum spicatum*, *Lemna trisulca*, *Hydrocharis morsus-ranae*. The most characteristic amphiphytes in the shoreline zone were *Alisma plantago-aquatica*, *Mentha aquatica* and *Sparganium erectum*. In addition to dominant *Phragmites australis Typha angustifolia*, *Schoenoplectus lacustris* and *Typha latifolia* were common. Other occasional helophytic species include *Iris pseudacorus*, *Carex pseudocyperus* and *Cladium mariscus*.

Compared to the first survey in 2011 there has been an increase in the total number of species in the canal system of Spotty Ponds. The trio of *Utricularia vulgaris*, *Nymphaea alba*, *Lemna trisulca* could be considered permanent in the area since the first year after the reconstruction. *Ceratophyllum submersum* and *Hydrocharis morsus-ranae* appeared in the reconstruction area first only in 2017, although their presence in the northern part of the Lake was previously confirmed by the establishing botanical survey (Sztakó 2010). In the canal system the number and presence of amphiphytic species of marginal habitats were stable during the monitoring.

The first sampling year (2014) of the Great Water had the highest total number of species of all the years surveyed, which phenomenon could typically be observed in disturbed habitats due to both natural pioneer and riparian weed species, which were absent in later records, such as *Persicaria amphibia* and *Ranunculus scleratus*. Considering only hydrophytes the number of species increased from the first year on. It started first with the appearance of *Trapa natans* and *Ceratophyllum submersum* in 2015, and followed by *Myriophyllum spicatum* in 2017. In parallel, a decline in the number of amphiphytes could be observed due to the closure of shallow shorelines with tall helophytes without emergent amphiphytic shoreline vegetation.

If we compare plant species reported by Tölgyesi (1981) and Szujkó-Lacza (1993) *Potamogeton natans Hydrocharis morsus-ranae*, *Ceratophyllum submersum* and *Myriophyllum spicatum* was new in the species list of Vidéki's (2008) management plan, while *Trapa natans* appears for the first time in present survey series in the flora of Lake Kolon. No occurrence of *Wolffia arrhizal* reported by Vidéki (2008) was observed during present monitoring. *Trapa natans*, *Potamogeton crispus* and *Myriophyllum spicatum* were species only occurring in the Great Water. The only record of *Typha laxmannii*, the only invasive species to be mentioned from the Lake, is related also to Great Water. Looking in detail the *Typhya laxmannii* was first reported from Hungary by Boros (1960) and Priszter (1962). In general its distribution area is limited to lowland areas in Hungary and its range is concentrated in the Tiszántúl region, with only scattered populations in the Danube–Tisza area (Bartha et al 2015), Kish and Oleksyk (2000) identified the Danube as the dispersal route of the species from south-eastern Europe. Falusi (2011) reports it from the canal system between the Danube and the

Tisza. Sipos (2004) classifies it as a species of no major conservation concern in the KNPI area of operation, which is supported by the behaviour of non-spreading populations found during present survey.

According to the General National Habitat Classification System (Bölöni et al. 2011) two types of aquatic habitat were determined in the reconstructed sites. The distribution of “Euhydrophyte vegetation of naturally euthrophic and mesotrophic still waters” (Ac) category is limited to the former and present floodplain of the Danube plain, and is often secondary in terms of origin (Bölöni et al. 2011) as in the case of the rehabilitated area of the Great Water. The structure of the habitat consists 2 levels usually with one and rarely 2–3 dominant species per level. Typical species of this habitat occurring in the surveyed sites were *Nymphaea alba, Myriophyllum spicatum, Ceratophyllum demersum, Potamogeton natans.*

The other habitat type was “Euhydrophyte vegetation of oligothrophic lakes and ponds” (A24). The distribution of this type has declined significantly in Hungary, and in many places it has been survived only in the deeper marsh basins (Bölöni et al. 2011). *Stratiotes aloides, Ceratophyllum submersum, Utricularia vulgaris* were the species suitable for habitat classification.

In the canal-like habitats (sections 10–13) of the Great Water this habitat has three levels. In the first emerged and floating level *Stratiotes aloides* was dominant and in the lemnoid level *Hydrocharis morsus-ranae* spread on the water surface, while the submerged level was formed dominantly by *Ceratophyllum submersum* with *Utricularia vulgaris* and *Lemna trisulca* in a subordinate role.

4.2. Detailed results of Great Water

The percentage of total plant mass (RPM) of species in Great Water (Figure 5.) showed more even picture in the first surveyed year as an initial stage of colonization, but already then the dominance of *Stratiotes aloides* (24.15%) could be observed. As *Stratiotes aloides* prefers higher temperature and wind-protected areas of oligo- or mesotrophic standing waters, it has found optimal habitat conditions. This dominance was observed in all survey years, increasing it to 36.03% in 2018. Similarly, in the case of *Hydrocharis morsus-ranae* the same trend could be seen, only with lower values.

Nymphaea alba was the second dominant species with RPM values ranging from 12.06–35.81%. *Ceratophyllum submersum* reached 32, 37% in 2015 but from 2017 declining populations were observed in the submerged level below the dense floating level of *Stratiotes aloides*. Small populations of *Potamogeton natans* were stable as accompanying species in almost all sections of the Great Water. The stands of *Myriophyllum spicatum*, which appeared in 2017 stayed subordinate (2017: 6.39% and 2018: 4.94%) and formed a submerged level under *Nymphaea alba* stands in the central open water sections.

The share of *Trapa natans* was negligible (0.02%) with the only occurrence in section 18 of Great Water. Each year the number of rosettes increased till 2017, but in 2018 only 4–5 leaf rosettes were visible. The RPM value for *Ceratophyllum demersum* showed a slight, not yet significant increase, with larger populations typically observed in the southern outflow canal in section 20.

Amphiphytes typically occurred and reached higher values in the marginal zone of canal-like habitats of Great Water. Their role was subordinate due to the higher water level and 'bed morphology', and also because the recovering helophytes started to form closed stands. Independent, sometimes contiguous stands were formed locally by *Sparganium erectum*. The other two typical amphiphytes but with more solitary pattern were *Mentha aquatica* and *Alisma plantago-aquatica*.

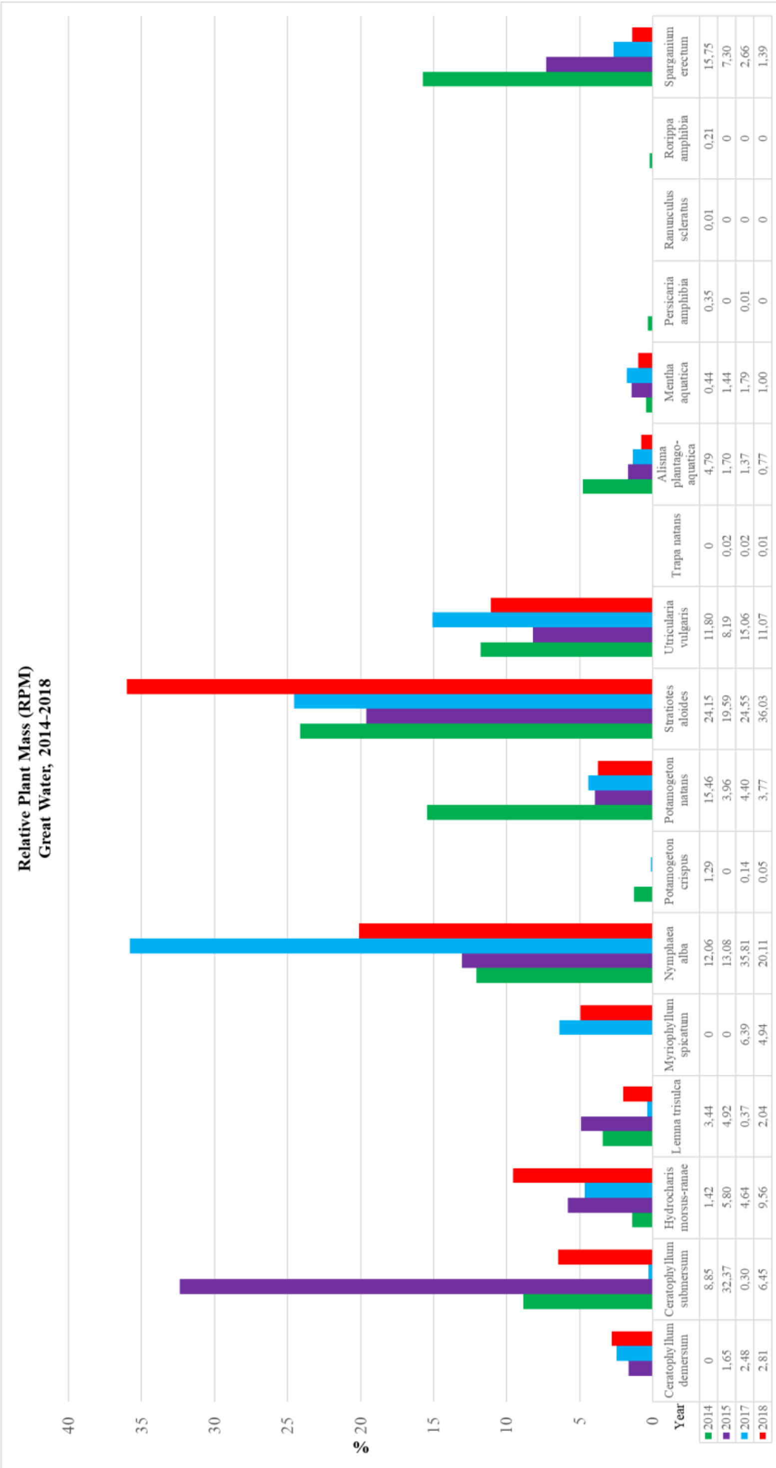

Figure 5. RPM values for species in Great Water between 2014–2018

Assessing the share of plant mass according to Borhidi's social behaviour types (Figure 6.) the changes between 2014 and 2018 were insignificant. In such aquatic habitats, the presence of natural pioneers (NP) as *Utricularia vulgaris* and *Hydrocharis morsus-ranae*, which appear in subordinate role, is typical, along with the dominance of competitors (C).

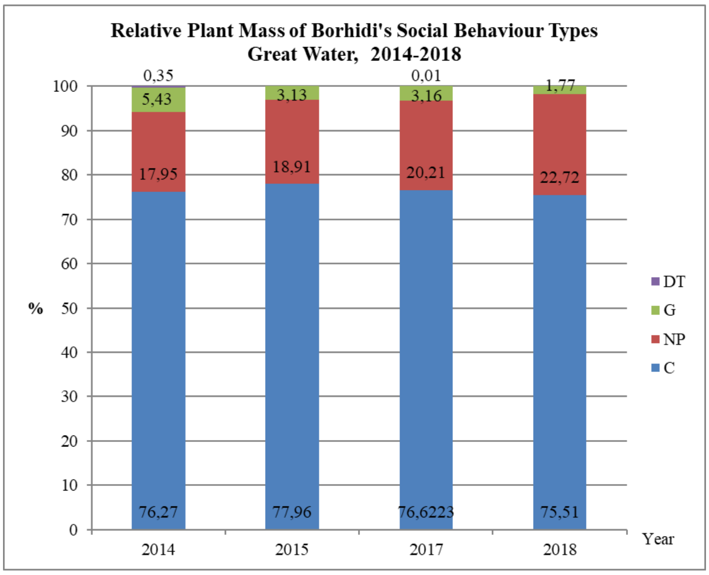

Figure 6. RPM values aggregated by Borhidi’s social behaviour types in Great Water between 2014–2018

The appearance of natural disturbance tolerants (DT) in 2014 and 2017 was due to a single species of *Persicaria amphibia*, which was not considered as a sign of degradation in this case. The decrease in generalists from 5.43% to 1.77% was due to the declining proportion of amphiphytic *Alisma plantago-aquatica* and *Mentha aquatica*, also not assessed as a result of deterioration of water quality, but rather as a result of the aforementioned closure process of marginal habitats. The rapid regeneration potential of the habitat type is illustrated by the fact that a balanced distribution of social behaviour types was established by 2014. Typically, where both stress and disturbance levels are low, competitive behaviour is favoured. Rapid recovery was greatly facilitated by the readily available source of propagule from a former reconstruction site excavated in 1989 (see Figure 2. left corner on the top).

4.3. Detailed results of the canal system in Spotty Ponds

Following the establishment in 2011 the percentage of total plant mass (RPM) (Figure 7.) showed the initial stage of colonization. Already from this first year the predominance of the *Utricularia vulgaris* was observed with 52.11%. This peaked in 2012 and 2013and reached 89,13%, but started to decline afterward. In the case of the canals connecting the ponds as a continuous system, the combined evaluation of relative dispersal lengths became important. *Utricularia vulgaris*, which prefers distrophic waters, occurred in 25% of the total channel length after the intervention and was present on the western side of Spotty Ponds area (section 12, 14, 19, 20). In comparison, it reached 89% in the following year and was present in 100% of the sections by 2013 and remained the following years. Similar rapid regeneration and high relative spreading lengths were observed for *Nymphaea alba*, only the estimated plant mass will be much lower in each stage. *Nymphaea alba* stands were typically stable, restricted to the channel margins. The share of *Potamogeton natans* showed a large variation from year to year, also due to their pioneer nature, and both their scattered and non-stable distribution in the canals. The presence and increasing estimated plant mass of *Ceratophyllum demersum* in 2015 in the inlet reaches towards the settlement of Izsák (Sections 1a–3) deserves further attention as a species that also indicates eutrophication. *Ceratophyllum submersum* appeared in 2017 in the reconstructed area in section 3 and the same year the *Hydrocharis morsus-ranae* in sections 11–13, 15, 17, 21. As Sztakó (2010) reported both species from the vicinity of the reconstruction area, slower regeneration and colonization process was confirmed.

Among the amphiphytes, the floating form of *Persicaria amphibia* was recorded in several years. The other three species (*Sparganium erectum, Mentha aquatica, Alisma plantago-aquatica*) had typically terrestrial forms scattered in the edge zone. Looking at the relative distribution lengths of these species, there were only insignificant changes. Presumably, there was a seasonal effect related to the height of the water level. Overall, the populations were stable over the long-term study period.

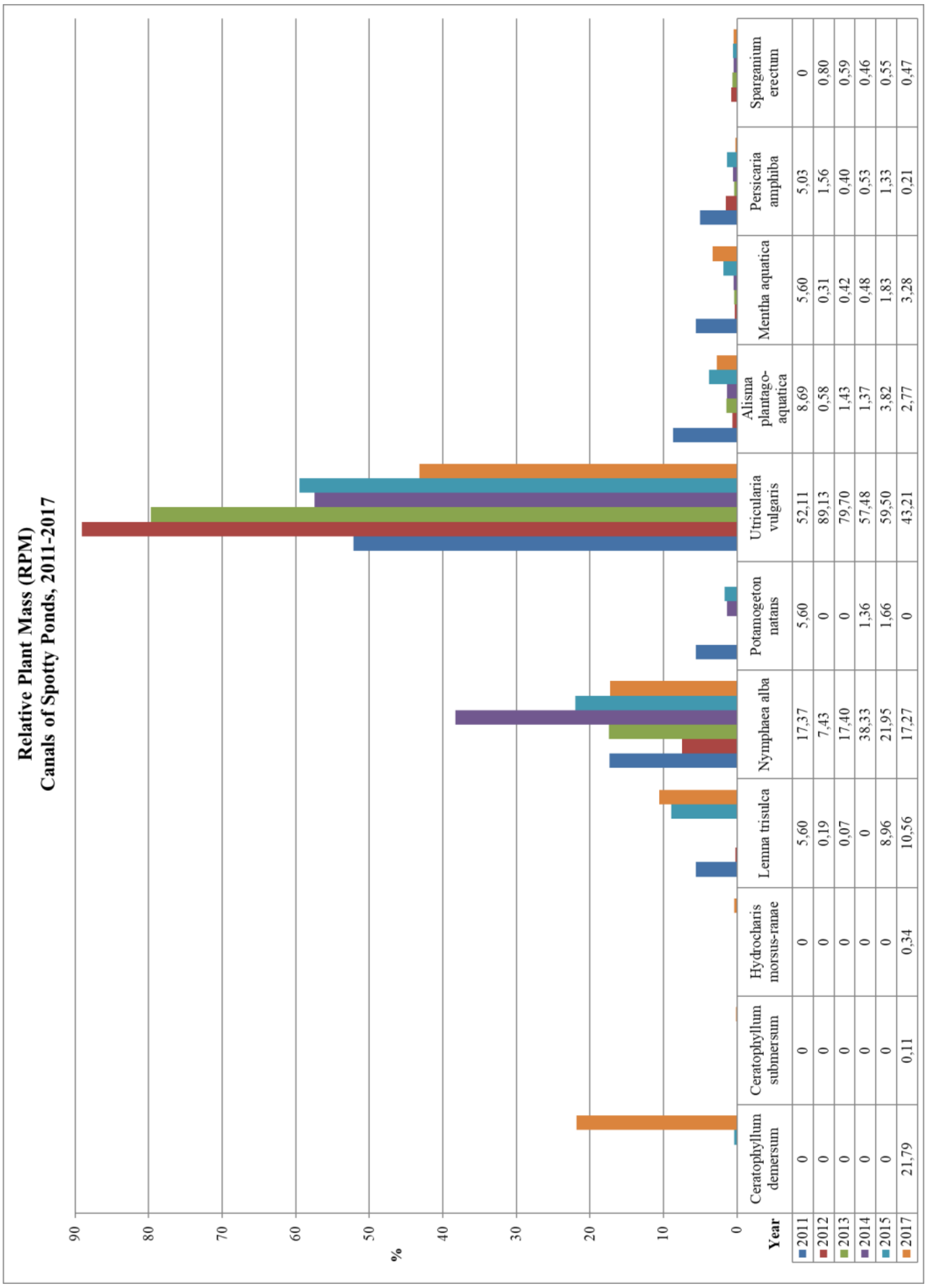

Figure 7. RPM values for the species of the Spotty Ponds channels 2011–2017

Studying the share of relative plant mass of Borhidi's social behaviour types in the case of the Spotty Ponds area which were rehabilitated from more closed reed stand without existing canal (Figure 8.), natural pioneers dominate each year between 2011 and 2017, although a moderate downward trend could be observed in the long term.

As in the case of the Great Water, the same could be detected that the category of natural disturbance tolerant (DT) species was only given by single species, *Persicaria amphibia*. The variable values for the generalists (G) were associated with populations of amphiphytes restricted to margins showing first decline and then a slight increase.

The shar of competitors (C), which group also indicate stabilisation, was fluctuate, although a slight increasing trend could be observed. Post-reconstruction recovery, presumably due to the limited access of propagule source was a slower process. Altogether it can be stated the rate of introduction of species present in Lake Kolon’s flora into the Spotty Ponds area is slower than in the case of Great Water.

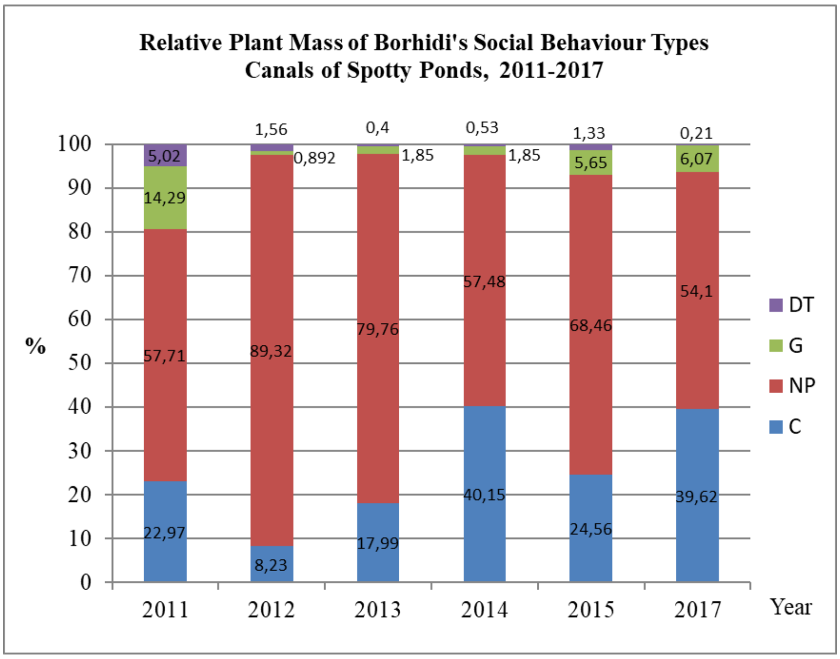

Figure 8. RPM values aggregated by Borhidi’s social behaviour types in canals of Spotty Ponds between 2011–2017

4.4. Detailed results of the edge vegetation in Spotty Ponds

From the set of hierarchical cluster analyses based on coenological recordings in the edges only the first from 2011 and the latest from 2017 were selected for interpretation (Figure 9. and 11.) To explain the parameters behind the separation of clusters principal component analysis was attached (Figure 10. and 12.).

In 2011 several weed species, such as *Arctium lappa*, *Cirsium arvense*, *Eupatorium cannabinum*, *Conyza canadensis* and *Solidago canadensis* were present in deposition sites, none of which presence could be proven in 2017.

Based on the data from 2011 two clusters, one larger and one smaller (marked with a black line in Figure 9.) included almost all the records of deposition sites (marked with D at the end). The smaller cluster of 4 members was separated by the dominance of *Sparganium erectum*. The larger cluster separated due to the open ground surface and higher cover of *Calystegia sepium* and *Typha latifolia* (Figure 10.).

The results of 2017 (Figures 11–12.) represented a much more dissolved picture for the deposition sites. A clear clustering of deposition sites could be observed in two smaller and one larger (dotted) cluster. The lower smaller cluster in the bottom was distinguished from the otherwise *Phragmites australis* dominated dotted edges by the 15–25% cover of *Salix cinerea*. The upper distinct cluster showed a dominance of *Typha angustifolia* over subordinate *Phragmites australis*.

Although our results confirm that deposition sites over 7 years additional remarks should be taken. Sampling from the water there is no significant difference in the vegetation of 0.5–1m depth of the edges, but the vegetation of the inside area of deposition sites may still be different, see more in the Conclusions and suggestions chapter.

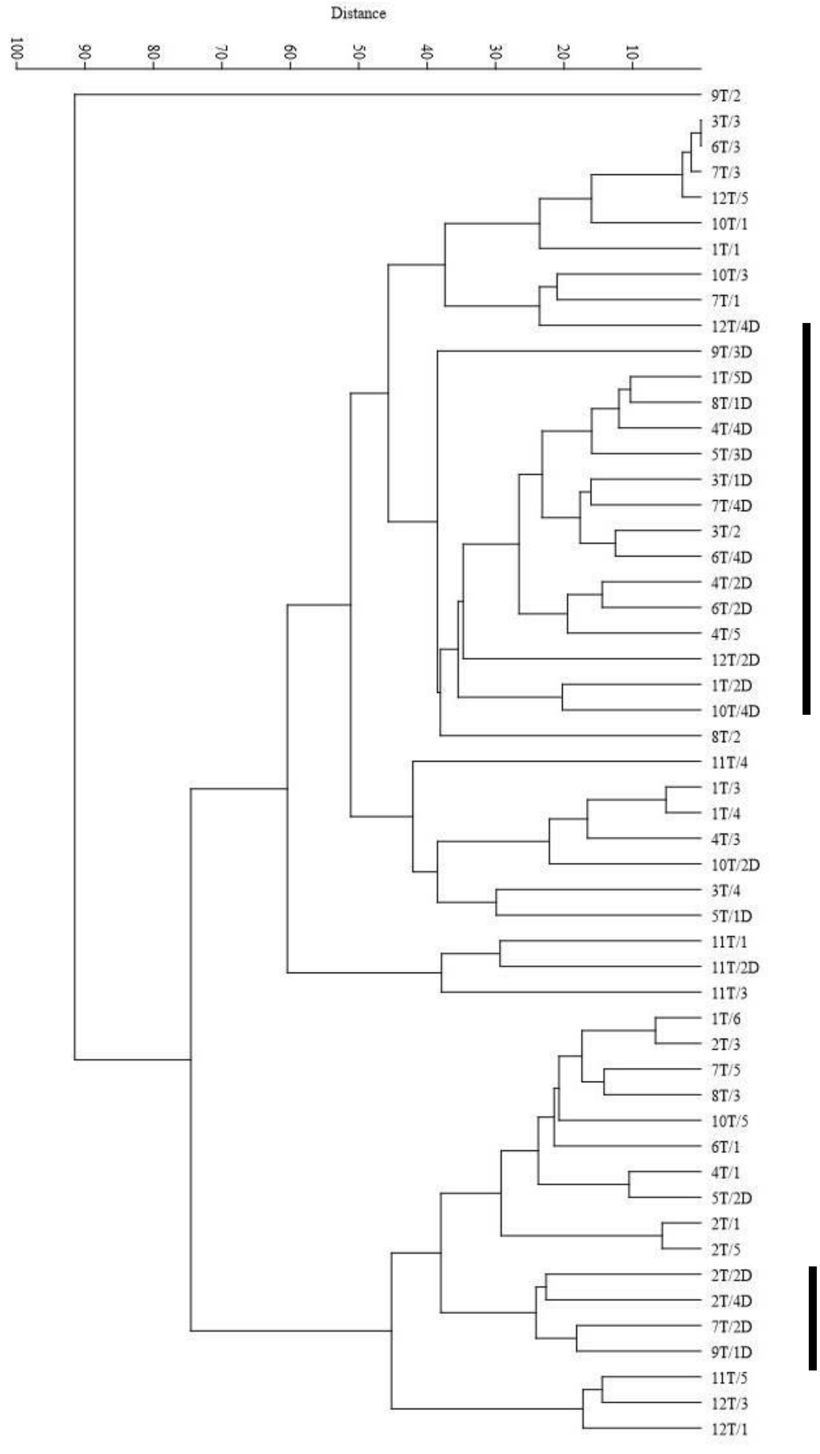

Figure 9. Cluster analysis of edges, Spotty Ponds in 2011

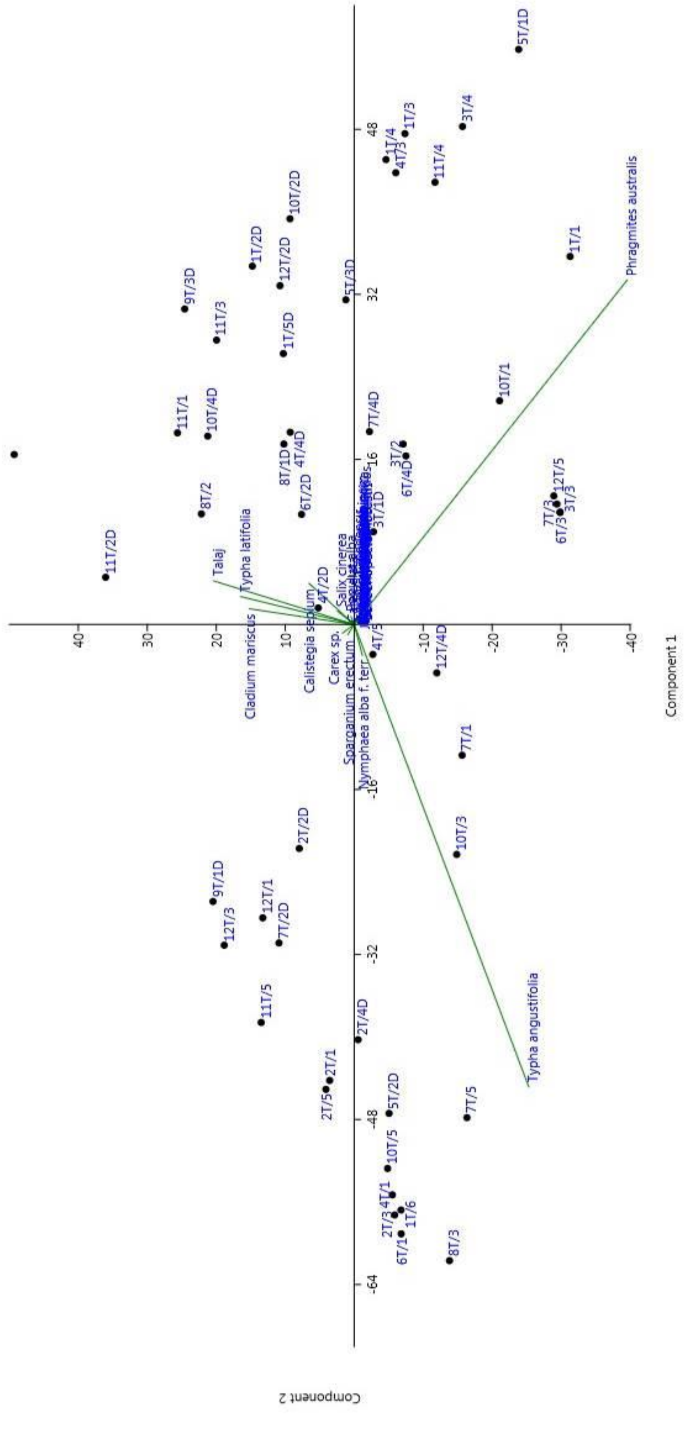

Figure 10. Principal Component Analysis of edges, Spotty Ponds in 2011

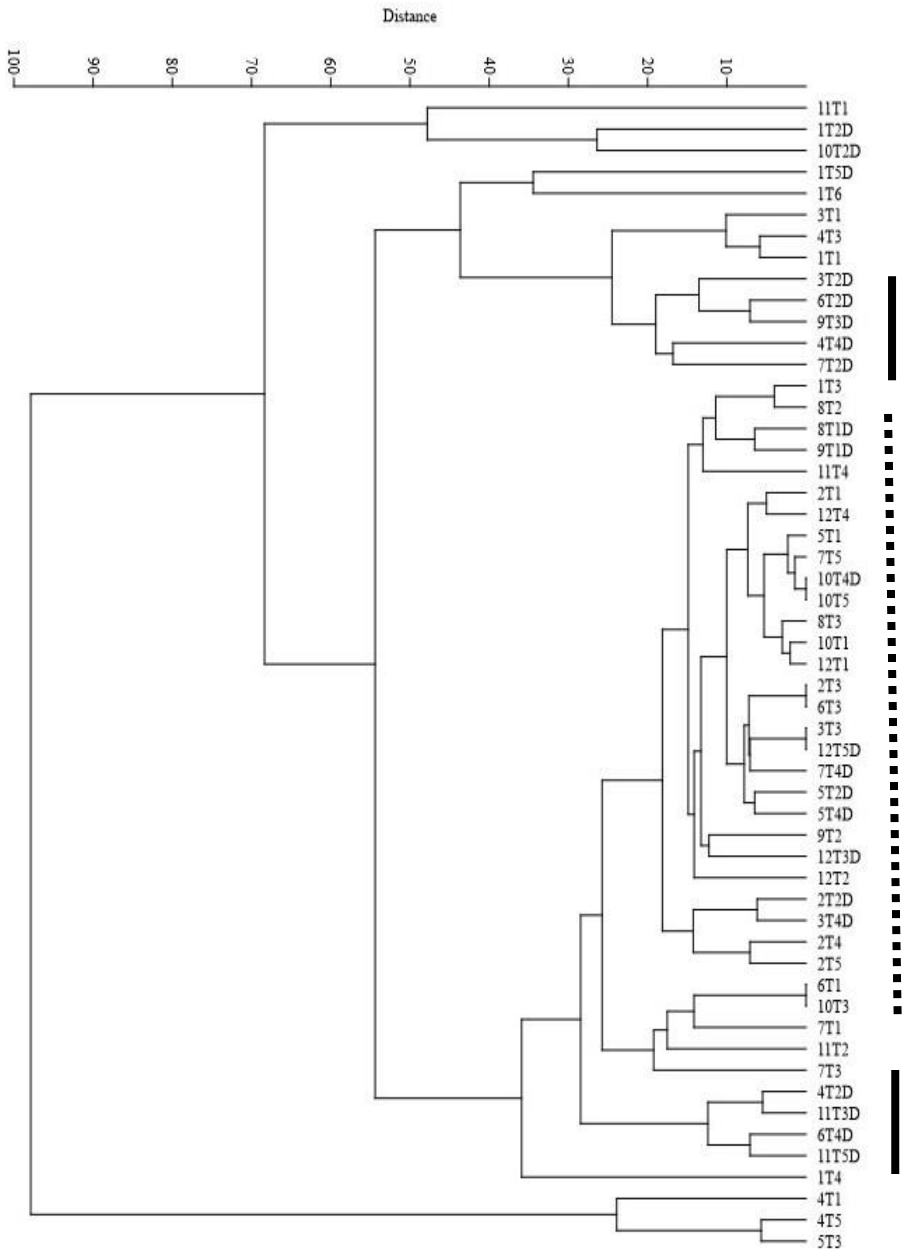

Figure 11. Cluster analysis of edges, Spotty Ponds in 2017

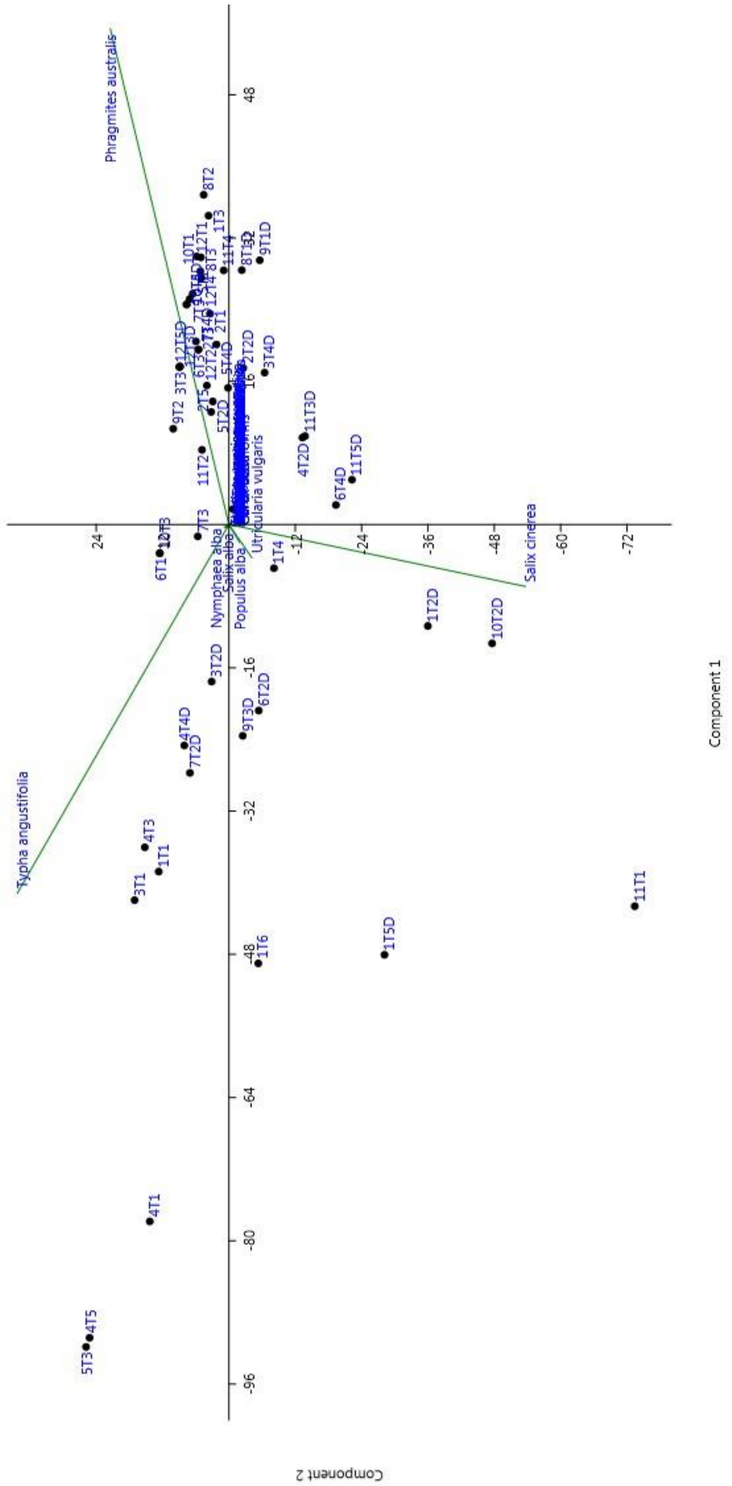

Figure 12. Principal Component Analysis of edges, Spotty Ponds in 2017

5. Discussion and suggestions

The rehabilitation projects had the primary objective of increasing open water surface and creating a mosaic habitat structure to reach higher habitat diversity and associated species diversity. The optimum size of the open water area suggested by Hawke and José (2002) depends on the overall size of the existing reed bed, but generally should not exceed 20% of the total reed bed area which was fulfilled in the case of Lake Kolon.

From a botanical point of view the Spotted Water and the Great Water have partly different regeneration paths, due to their design and the availability of propagule sources.

The pioneer character of the open waters of Spotty Ponds and Great Water was dominant, in relation to observations of Bölöni et al. (2011) that the species of *Nymphaea alba* dominated “Ac” habitat-type are mostly annual (hydro-therophytes) and perennial (hydro-hemicryptophytes) species that reproduce by fruiting and/or stolonial growth. According to Bölöni et al. (2011) it is also important to consider the morphology and plant traits of associated species of the “Ac” habitat-type in order to assess naturalness discussed above. In the case of *Trapa natans* individuals found in the Great Water area, which were not indicated previously in the flora of the Lake, the emergent, rosette leaves are small and the submerged leaves are typically absent or undeveloped, which, based on field experience, could be the result of the unfavourable habitat conditions, but also of the scarce nutrient supply. Results of the Great Water also confirmed that it is a vegetation type with a good regeneration capacity and fast regeneration time, up to 1–2 years in case of available propagule sources.

Comparing the two sites in the case of Spotty Ponds the process was much slower in terms of species richness and plant mass. The channel network, functioning as ecological corridor, typically fulfilled its role in both reconstruction areas, allowing species to colonize. Furthermore, in the case of Great Water, the other main habitat-type typically associated with such elements were *Startiotes aloides* stands subdominated by *Utricularia* *vulgaris* and *Ceratophyllum submersum*. These distrophic stands belong to the best regenerating subtype of the “A24” habitat category.

Following intermittent drying and/or mechanical disturbance the regeneration potential is high, but here again the presence of a propagule source is essential. The naturalness of the habitat should be determined by the presence and dominance of distrophic species. They are sensitive to eutrophication, so the presence and predominance eutrophication tolerant species could be an indicator of habitat degradation.

As monitoring tasks, we see the following lines as the most important. Nutrient enrichment in the area may be indicated by an increase in vegetative reproduction or mass production of *Ceratophyllum demersum* and *Lemna* species, which were not significantly observed during present survey. Monitoring of *Ceratophyllum demersum* populations could be important in the future. In addition, monitoring of stands of the invasive *Typha laxmannii* in sections 1, 20, 23 of the Great Water is necessary in every 2–3 years. No spreading is currently expected.

Macrophytes in the areas affected by the conservation intervention has been successfully recorded. Further annual monitoring was not considered strictly necessary. For macrophytes, the response to water quality is slow and therefore alsolso in the EU Water Framework Directive the monitoring goes at 3 year intervals. Sections assigned for monitoring should be representative for the typical vegetation types and also sections leading in and out of the site should be involved.

Although the long term monitoring in Great Water proved fast colonization on small-scale, but was not suitable to follow further the expansion of the *Nymphaea alba* towards inner areas of Great Water because the sampling sections were associated with the initial edge zones. Furthermore, populations could be characterised by a strong dynamics, showing considerable variation from year to year in terms of closure and horizontal pattern, and therefore the inclusion of remote sensing data would be relevant in the future to monitor small-scale changes.

In the present study, the edge zone of most established deposition sites of Spotty Ponds had regenerated between 2011 and 2017 as based on their vegetation cover the similarity is high to non-deposition edges. Only a single small cluster was separated where the colonization and increasing cover of pioneer woody species, particularly *Salix cinerea*, was observed, fulfilling the initial objective of increasing habitat diversity. However, to add to the overall picture of the vegetation in deposition sites, as 0.5 m wide sampling units were adapted to estimate cover from the water., we should get out of the boat and there were cases in 2017 when behind the regenerated edge zone areas were observed heavily dug up by wild boar (Figure 13.), which maintains the potential for permanent colonization of ruderal species.

Figure 13. Wild boar tracks on deposition sites of Spotty Ponds

Regeneration of macrophyte populations in both of the reconstruction sites was considered successful. Based on a review of previous floristic literature, there is no need for nature conservational plant reintroduction into the reconstruction sites of Lake Kolon.

The objectives for open wetland creation proposed by Vidéki (2008) and Pallag et al. (2009) for the conservation of natural values have been achieved. The habitat rehabilitation interventions, which were considered successful from a vegetation point of view in the current perspective, are expected to benefit both the fauna and flora furthermore preserve the biodiversity of Lake Kolon.

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NYILATKOZAT

a szakdolgozat nyilvános hozzáféréséről és eredetiségéről

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A Hallgató Neptun kódja:	A7Y9WM
A dolgozat címe:	Macrophyte monitoring in the rehabilitated areas of Lake Kolon, Hungary
A megjelenés éve:	2023
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