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LIFE FOR MIRES

The conference:

Evaluating the success of wetlands and watercourses restoration

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Abstracts

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Long-term monitoring of restored mires and wetlands in the Šumava region

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Hydrological restoration of wetlands and mires in Šumava region started in 1999. However, monitoring of some mires has been implemented since 1995. Within presentation, different phases of monitoring and recorded results will be presented. The main attention will be paid to hydrological and hydro-chemical response of restored sites. Possible impacts of changing climate and related microclimate conditions will also be discussed.

South Bohemian implementations from OPE funds (2014-2020)

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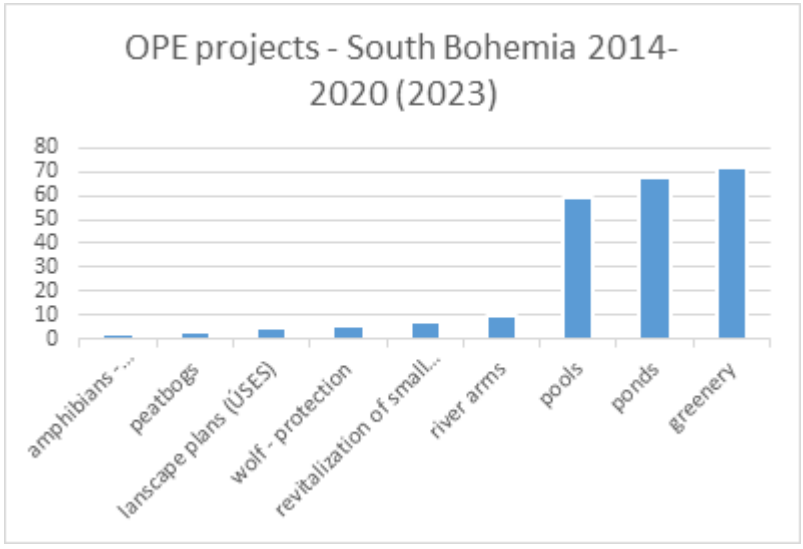
In South Bohemia, 232 projects were implemented from OPE funds in the years 2014-2020.
Projects for the construction or restoration of water features predominated, followed by the care of public greenery. The prezentation focuse on several selected water projects – revitalization of excavated peatlands – Borková (PLA Šumava), Hrdlořezy (PLA Třeboňsko) and Borkovická blata, revitalization of waterways – Straňovický, Chřástalí, Lomnice river near Buzice, Studená, reconstruction of fishponds - Ve Skalicích, Pytlácký potok, Chýnov and restoration of old river branches in the vicinity of the Otava and Vltava rivers (Hašlovice, Bažantnice, Slaník, Kestřany, Skály).



Litorral zone of Blatec fishpond (Foto: Burianová, AOPK ČR)

Successful restoration of the Hučina stream in the Šumava National Park

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Abstract
Stream restoration is becoming an increasingly common method used to improve riverine habitat structure and promote biodiversity. However, the latter goal is often not reached due to several constraints, such as impoverished local species pool, persisting low water quality, or unsuitable restoration design. Complex, technical restoration of Hučina stream and two other brooks in the Šumava National Park is somewhat rare, since in this case, none of the abovementioned constraints apply. Streams, that were previously transferred to the forest edge, narrowed, and entrenched to facilitate timber floating and drain surrounding meadows consequently used as pastures and fields, were re-meandered according to historical maps and clues provided by vegetation patterns. Restored streams were monitored for 3–5 years, focusing mainly on colonisation by benthic macroinvertebrates. Due to contiguity to natural streams in the proximity to restored stream sections and favourable conditions in the catchments, macroinvertebrates colonised them rapidly. Species richness in restored sections of the Hučina stream had plateaued two years after restoration and reached values comparable to its natural section upstream. Furthermore, restored streams continuously undergo self-dynamic development of habitats, changing pool-riffle-flow proportions, and alterations in substrate characteristics. Additionally, several stream sections have recently been transformed by beaver activity. Even though restored streams have not yet reached stability, they were colonised swiftly, and they continue to develop by natural processes.

Revitalization of peatlands in Lower Saxony, NW-Germany: Goals, predictions, proxies, and how to define success from the practical perspective

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Revitalization of peatlands pursues various aims, e.g. preservation and restoration of natural habitats or populations of relevant animal and plant species, soil conservation, mitigation of greenhouse gas (GHG) emissions, water and nutrient retention, development of the biotope network, but also scientific investigations or practical trials of rewetting. Each objective requires specific instruments to determine the current state and deduce the need for action, predicting the effects of planned measures, and estimating target achievement, respectively. This affects the all project phases, that is, development of project proposals, planning and implementation of concrete measures, and after project completion (e.g. long-term monitoring).
While hydrogeological models and similar data-based reports generally take high effort, their accuracy is sometimes limited, particularly regarding accurate prediction of water levels on the large scale. In many cases, well-chosen proxies may provide sufficient estimates of the actual hydrological and ecological state and help to predict rewetting perspectives, while avoiding high costs and time delay.
In addition to technical issues of rewetting, there are specific regulations of funding schemes which usually correspond to the directives of EU-, national, federal or regional (legal) directives of nature protection. For example, EU member states are obliged to report their measures undertaken for subjects of the Natura 2000 guidelines (habitat types and species of annexes I, II, IV; wild birds directive annex I). In contrast, funding of climate protection measures in peatlands often requires estimates of GHG reduction. To meet these demands, projects of peatland revitalization should ideally clearly define their specific goals, control parameters and possibly long-term monitoring plans in advance. However, in practice the approaches may differ from case to case. To depict this, the situation in the German federal state of Lower Saxony is shortly presented.

Hydrological indicators of restoration – peat wetness monitoring

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The main goal of wetland restoration measures is to correct the disturbed water regime. The basic hydrological parameter of the success of the restoration consists in the assessment of the rise in the groundwater level, the reduction of its fluctuations and the increase in soil moisture. Due to the increase in water accumulation in the basin, there are also changes in runoff conditions and water chemistry. There are many ways to monitor the effect of restoration measures on the hydrological regime in the landscape. Individual methods differ in their time, financial and equipment requirements. As part of the Life for Mires project, for measuring outflow we use combined weirs, chemistry is monitored by regular sampling at selected sites (18 water quality parameters), and the amount of water in the soil is measured with submersible pressure probes (TSH 22) and hygrometers (TMS - 4). The advantage of monitoring several aspects of the success of restoration is the search for possible correlations of individual processes with each other in different habitats. In view of the complexity of monitoring, the effect of restoration measures on soil moisture in the wider vicinity of dammed drainage channels has not yet been observed, especially in places where the increase in the groundwater level is no longer significant, but the effect can be manifested in those places by an increase in soil moisture. In this way, the overall reach of the restoration measures can be described more precisely. Hygrometers of the Tomst - TMS 4 type were used in the project, the key advantages of which are easy installation, operation and low purchase price. However, the use in hydromorphic soils has proven to be quite problematic due to the difficulty of data processing and the correct use of calibration curves. The project can thus contribute to the overall knowledge of changes in moisture and water conditions in the landscape and individual hydrological indicators when evaluating the success of wetland restoration measures.

Created and natural salt marshes: Their similarity, differences and response to disturbances

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Louisiana salt marshes comprise 40% of all coastal wetlands in the continental USA. However, these wetlands have been disappearing at a rapid rate since the 1950's, due to both natural and human causes. To combat these losses, dredged material has been used to restore and create coastal salt marsh habitat in Louisiana. It is questionable whether this method is successful in producing salt marsh systems whose structure and functions mirror nearby natural salt marshes. A study was conducted to compare structural and functional aspects of six created salt marshes, formed by pumping dredged material into formerly open water areas, to natural salt marshes in the Hog Island area of the Sabine National Wildlife Refuge in southwest Louisiana. At the time of the study, the created marshes ranged in age from 3 to 19 years since creation. The dredged material has higher clay and bulk density contents. Vegetation succession followed a predictable pathway, from open mud flat to dominance by salt tolerant succulents, especially *Salicornia bigelovii* in the first year or two after creation. By year three, *Spartina alterniflora* became the dominant species, remaining so over time. However, vegetation structure and succession were greatly affected by site elevation, with woody species (*Iva frutescens*, *Baccharis halimifolia*) co-dominating in the highest elevations. Decomposition rates of *S. alterniflora* were similar in natural and lower created marshes but were slower in the elevated zones of the created marshes. Natural and created marshes also differed in above and especially belowground plant production, as well as organic matter content. A dieback event during the study allowed for determining the resiliency of the oldest (19 years) created marsh. Shoot density of *S. alterniflora*, the most affected plant species to the dieback, returned to pre-disturbance levels within one year after the end of the disturbance. The greater genetic diversity noted post-dieback indicates high levels of outcrossing as well as establishment of an increased number of genotypes, which would increase the resiliency of the site at least in the near-term.

Restoration Effects on Peatland Vegetation – Integrating Field and Landsat Data

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The United Nations Decade on Ecosystem Restoration (2021-2030) aims to address global environmental challenges, including biodiversity loss and climate change. Ecosystem restoration emerges as a crucial strategy, offering diverse benefits such as biodiversity conservation and climate change mitigation. Notably, the restoration of peatlands stands out as a potent approach, given their dual role as carbon sinks and habitats for specialized species.

Human activities, including peat extraction, drainage for afforestation or agriculture, have caused varying degrees of degradation in peatlands. In Germany, drained peatlands currently contribute to 7% of greenhouse gas emissions, emphasizing the urgency of restoration efforts and ensuring restoration success. Thus, it is crucial to study restoration impacts on peatlands to inform future projects and enable adaptive management. Peatland vegetation, influenced by water tables and a key component for peat formation, can serve as an indicator for ecosystem response.

This research studies the effect of restoration measures on peatland vegetation in the National Park Bavarian Forest, Germany, using a combination of vegetation and remote sensing data. Five intact peatlands and one unsuccessfully restored site serve as a reference.

Leveraging Landsat satellite data from 1985 and field data from 2014 onwards, we analyze vegetation development, focusing on species composition, diversity, and Normalized Difference Vegetation Index (NDVI) trends. Time series decomposition of Landsat data and Non-Metric Multidimensional Scaling (NMDS) analysis reveal that degradation significantly influences species composition, diversity, and peatland response to restoration. Other variables, such as distance to drainage ditches and peatland type, also contribute to shaping vegetation response to restoration.

NDVI trends highlight varying extents of restoration measures, emphasizing the potential of Landsat data as a valuable tool in monitoring restoration efforts. Hence, integrating Landsat time series analysis of NDVI complements traditional field-based monitoring, enhancing our understanding of the dynamics of restored peatlands.

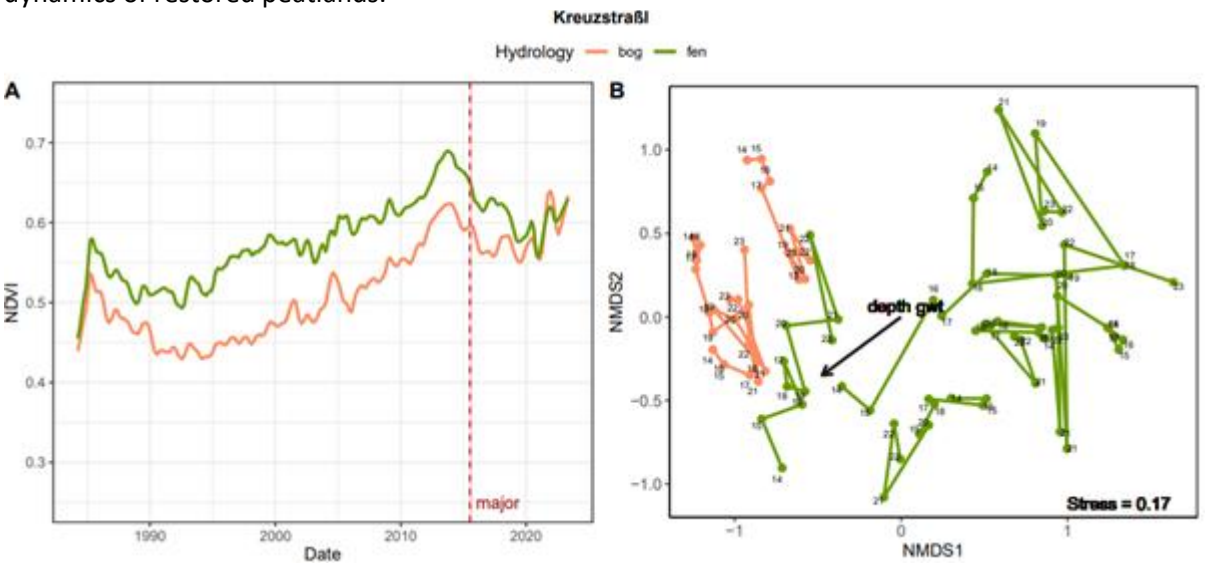

Figure 1: NDVI trends show similar patterns as the NMDS analysis - different reactions to restoration depending on the peatland type. The fen part of the soliombrogenous slope bog Kreuzstraßl reacts stronger to rewetting than the bog complex.

Using biotope type data for estimating greenhouse gas emissions on bogs - Towards a better integration of restoration measures into the German GHG inventory

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Greenhouse gas emissions from peatlands contribute an important share of the greenhouse gas (GHG) balance in Germany. Therefore, reliable GHG emission estimates of peatlands on a national scale are necessary. However, GHG balances of peatlands based on direct measurements of GHG exchange can only be established for few sites; a comprehensive direct monitoring is currently unfeasible. Therefore, GHG emissions need to be estimated based on readily available data. Currently, a method focusing on water level and coarse land use classes is used for emission estimation and reporting for organic soils within the German land use sector. This does not allow for scenarios and cannot take management changes, e.g. restoration, directly into account. Models estimating GHG emissions from vegetation surveys exist, but require detailed vegetation data not available on a nationwide scale.
We are developing a model for GHG-emissions of unused or extensively used peatlands in Germany based on available vegetation data ("Biotoptypen"), which have been mapped on the ground for all of Germany. The resulting model is meant to complement the existing water-level-based method in emission reporting for these areas. The model will be build based on a collection of annual greenhouse gas balances from temperate Europe, which are assigned to clustered vegetation types. Mixed effects modelling is used to estimate emissions per vegetation type and their relationship to mean water levels.
First results for bog vegetation types indicate differences especially between wet extensive grassland (high CO_2-, low methane emissions) and semi-natural bogs (CO_2-uptake, higher methane emissions), with different degeneration stages laying in between. Data availability for some types is sparse and uncertainties therefore large. Most types do not have sufficient data or variation to establish robust relationships between annual CO_2 exchange and water level.
In the future we will include bogs and fens in the model, and apply it to the collected Germany-wide vegetation data. Eventually, the model will allow for a better representation of restoration measures in the emission reporting, if vegetation types are changed by restoration actions and changes reported.

Thermal monitoring of restored wetlands

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Wetlands play important role in the landscape because of their many ecosystem services (biodiversity, water retention, energy balance, esthetic function etc.). In particular the water retention and energy balance are critical for mitigation of climatic and hydrologic extremes in context of recent climate change. While many studies about wetlands are focused on biological monitoring, there are lack of studies, which are solving wetlands ecosystem functioning and their dynamics. The main aim of our study was to describe changes Surface temperatures due to process of wetlands revitalization. The revitalization in our case means in general the increase of soil water tale in the drained wetlands. We hypothesized the decrease Surface temperature after the of soil water table rising, while the drained wetlands have high Surface temperature which is supported by low thermal conductivity of peat. Our research area contains 10 representative wetlands across entire National park Šumava (Zhůří, Nová hůrka, Slučí tah, Skelná, U Tremlů, Vlčí jámy, Nové údolí, Černý kříž, Dobrovodské Louky and Raškov) and selected wetlands in Bavarian Forest National Park (Kreuzstrassl, Groser Filz, Siebenellen, Kleine Au, Finsterauer Filz). All the above mentioned wetlands in Šumava NP have been revitalized within the project Life for mires in last 5 years. The wetlands from Bavarian Forest NP were revitalized are since 2008 to 2017 and they are used as a control areas. The Surface temperatures were acquired using unmanned aerial system (UAS – drone Matrice 600) with thermal cameras (Wiris 2ND generation, Wiris PRO). We captured the thermal data in two times: 1) in year in spring-early summer period (late June – early July) and 2) in late August – early September. The Surface temperatures were normalized to the relative values to avoid the temperature difference due various weather conditions at the time of data acquisition. The results showed that the Surface decreases after the revitalization, however the temperature differences corresponds with the severity of the prior drainage and/or with the re-wetting the area after the revitalization. There is also different time-lag of decreasing the temperatures after the revitalization. Except the revitalization the Surface temperatures also reflect the soil water table fluctuation in dry periods (e.g. summer 2023) which shows the temporary Surface temperature increasing. Because the Surface temperatures reflect the soil water table together with bio-climatic function of the wetlands they may be used among indicators of the success of wetland revitalization.

Fish in the newly built and revitalised south moravian wetlands: effects on ecosystem and management options

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There is an increasing number of small wetland-like waterbodies (SWB) being constructed or revitalized in South Moravia. Large number of such projects is funded from the public sources (Operational Programme Environment) and declares biodiversity support as one of the main project goals. As presence of fish is undesirable in such SWB, they host no planned fish stock. Collateral records of fish in macrozoobenthos samples from these SWB provoked our intense interest, resulting in a preliminary dataset gathered on 50 SWB constructed within the last ten years. These data show that approximately 70 % of the SWB hosted fish assemblages, 60 % hosted invasive fishes and in 40 % fish invaders dominated the fish assemblage. Topmouth gudgeon *Pseudorasbora parva*, Prussian carp *Carassius gibelio* and rudd *Scardinius erythrophtalmus* were the most common species detected. The fish presence was unaffected by SWB age, suggesting fish colonisation is not a sole manifestation of SWB natural succession. Increasing SWB size and depth, on the other hand, strongly supported fish presence, suggesting the fish assemblages may be formed by constant propagule pressure and extinction driven processes, related mostly to desiccation and oxygen deficiency. Fish presence was negatively associated with water quality, amphibian presence and zooplankton assemblage structure and richness. Larger dataset is being collected to (i) determine main factors driving fish colonisation of the newly built/revitalised SWB (considering also anthropogenic vectors) and (ii) study fish effects on the SWB biota in more detail. Management/eradication efforts are currently in progress in several experimental SWB, aiming (i) to detect an effect of fish stock removal/reduction on biota and water quality restoration and (ii) to design a low-cost, 'DYI' fish stock management methodology.
Research was supported by TAČR grant No. SS06010189.

The diversity of pools created by the activities of the European beaver (*Castor fiber*)

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The European beaver (*Castor fiber*) serves as a key ecosystem engineer, shaping landscapes and impacting biotic and abiotic factors. Amidst global changes and human-driven alterations like landscape drainage, beavers play a crucial role in creating new wetlands, essential in light of the recently reported decline in species diversity. Beaver activities directly influence surrounding vegetation and impact local fauna. Simultaneously, humans create artificial ponds to counteract global changes. Our study, centered on the Boletice military area in South Bohemia, Czechia, investigates fish, amphibians, and aquatic insect biodiversity. Using diverse sampling methods, including electrofishing, funnel and light traps and specialized nets, we aimed to comprehensively understand aquatic life. Throughout our sampling, we found noteworthy species in beaver-created ponds, including conservation-interest species like *Phoxinus phoxinus, Notonecta obliqua*, *Aeshna juncea* or *Leucorrhinia rubicunda*. These findings highlight the ecological importance of beaver-induced alterations, contributing to the conservation of unique species. Our preliminary results offer valuable insights into the interplay between beaver activities and aquatic biodiversity in Central Europe.

Restoration of mined peatlands in the Třeboň region

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Třeboň Basin represents one of the peatland biodiversity hotspots in the Czech Republic. However, most localities were negatively influenced by drainage and peat extraction in the past. Peat extraction finished in the last three localities (Branná, Člunek and Hranice) in 2019.
Thanks to the Lesy ČR, the Agency of Nature Protection of the Czech Republic and the town Třeboň two restoration projects were started almost immediately after the cessation of peat extraction. These projects included blocking of drainage channels, creation of several shallow water pools and mulching the soil surface with *Sphagnum* spp. and *Carex rostrata* from nearby shallow sand pits. Additionally, one restoration project was started in the Borkovická blata peatbog in 2021 where peat extraction was finished in 1988. Both spontaneous succession and pine plantations were used as a standard restoration approach according to the law until 1990th. Blocking of a part of drainage system in 2002 led to an increase of water table in the area close to the former nature reserve bringing about the development of several shallow water pools and establishment of minerotrophic peaty vegetation. Monitoring of several permanent vegetation plots and water table depths brings important knowledge of post-restoration succession.

Hydromorfologické mapování a systematický návrh opatření na vodních tocích – představení projektu Pasportizace vodních toků
Hydromorphological mapping and systematic proposal of measures on watercourses - presentation of the project „Pasportizace vodních toků“

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AOPK ČR zahájila v květnu 2023 realizaci projektu Pasportizace vodních toků financovaného z NPO-POPFK. Hlavním cílem projektu je zmapování současného hydromorfologického stavu vodních toků terénním průzkumem a návrh opatření/managementu úseků vodních toků. Návrhy opatření jsou zaměřeny na zlepšení nebo ochranu hydromorfologických podmínek ve smyslu identifikace úseků vodních toků vhodných k renaturaci, k revitalizaci nebo ochraně stávajícího stavu. Na začátku projektu byla zpracována metodika záznamu parametrů a návrhu opatření a byla vytvořena mobilní aplikace pro sběr dat (s využitím ArcGIS Survey123). Hlavním výsledkem projektu je vytvoření veřejně přístupné databáze sesbíraných dat a navržených opatření. Výstupy projektu budou sloužit zejména jako podklad pro plánování v oblasti vod a ochranu přírody. K zmapování bylo vybráno 26 032 km převážně drobných vodních toků, které budou pokryty mapováním a návrhy opatření do listopadu 2025, kdy projekt končí. Návrhy opatření budou ještě v rámci doby řešení projektu projednány se správci vodních toků.
V rámci mapování jsou zaznamenávány nejen upravenost říční sítě nebo počet příčných překážek, ale také intenzita a míra pokročilosti působení renaturačních procesů včetně převažujících typů procesů, míra renaturace opevnění koryta nebo příčné překážky nebo ovlivnění průtoků pod překážkou, šířka a kvalita příbřežní zóny nebo prostorový potenciál území pro realizaci opatření/managementu (majetkoprávní vztahy nejsou prověřovány). Projekt cílí zejména na systematické posouzení potenciálu úseků vodních toků k samovolné i řízené renaturaci a další management/ochranu úseků v uspokojivém přírodním nebo přírodě blízkém stavu - zde není myšleno v dobrém ekologickém stavu podle Rámcové směrnice o vodách 2000/60/ES. Pokud použijeme slovník konference, jedná se vlastně o hodnocení úspěšnosti působení renaturačních procesů za posledních 35 a více let a posouzení potenciálu úseků vodních toků ke zlepšení hydromorfologického stavu, to znamená mj. také potenciálu obnovy přirozených funkcí vodního toku, příbřežní zóny a nivy. Návrh opatření tak může spočívat v nutnosti provedení revitalizace úseku před ponecháním dlouhodobému a málo intenzivnímu působení renaturačních procesů nebo před rizikem odnosu opevnění a zahlubování vodního toku, ale také v dílčích zásazích na podporu renaturace nebo „jen“ v ochraně současného stavu, případně návrhu na zrušení vodního díla.

Temporary (1960-67) spontaneous Self-Restoration of a Drained Shallow Pannonian Lake and Recent Intentional Restoration of two Wetland Patches within its Former Area (Abstract)

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The Lake of Kobylí (Kobylské jezero), a shallow lake in S.E. Moravia (CZ, about 1000 hectares), drained in mid-19th century, experienced its spontaneous revival on about 2/3 of its original area in the rainy years 1960-66 (only 1964 was dry). A succession sere of wetland plant communities rapidly colonized this shallowly flooded or waterlogged area. Within 5 years, stands dominated by *Typha latifolia* or *Phragmites australis* occupied most of it. A dense population of muskrats (*Ondatra zibethicus,* up to some 57 individuals per hectare in September), preferably feeding on *Typha* leaf bases, consumed 5-10 % of the aboveground net primary production of the *Typha* stands. The muskrats´ preferential feeding on *Typha* reduced its density by 100 to 10% within the average radius of 14 m from each muskrat mound. In this way, muskrats facilitated the intrusion of *Phragmites* into *Typha*-dominated stands with eventual complete substitution of the dominance of *Typha* by that of *Phragmites.* This process occurred on a large part of the flooded or waterlogged area of the Lake of Kobylí until summer 1967, when the entire lake area was again completely drained. Since 2010, two small areas of the former wetlands have been restored. By now, they have become somewhat similar to the wetlands which most probably predominated on the shallowly inundated or waterlogged sites in and around Lake of Kobylí prior to its drainage in the 19th century. Both restored areas, each occupying about 4 and 2 hectares, respectively, provide an educationally valuable demonstration of a typical Pannonian wetland interspersed with small shallow pools. Various information tools teach the public a lot about the value and importance of such wetlands.

Our research base at the edge of the temporarily (1960-67) re-flooded part of the former Lake of Kobylí in Moravia. (Photo: Josef Svoboda, July 1966)

Transect of 8 m length and 1 m depth revealing the distribution of *Phragmites australis* rhizomes+roots penetrating into the soil below those of *Typha latifolia*. Nov. 1967.

All three photos by Josef Svoboda

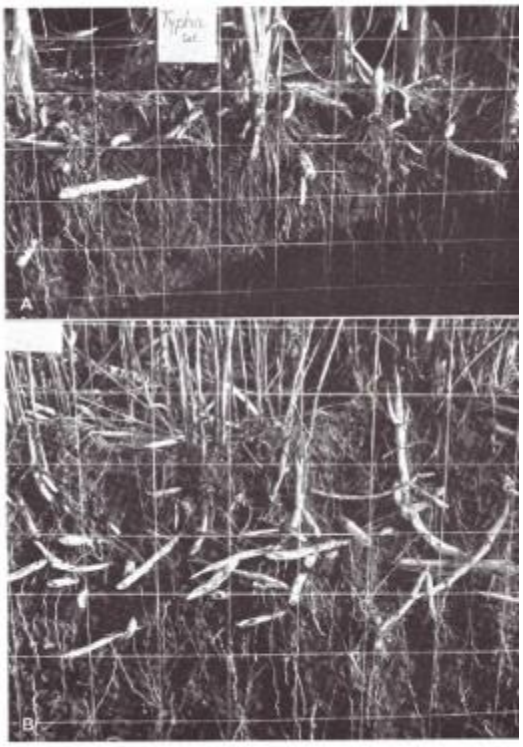

Fig. 1A and B. Underground organs in situ of *Typha latifolia* (A) and *Phragmites com*
(B) with deeper penetrating rhizomes grid: 10 cm by 10 cm. (Photo: J. Svoboda)

Restoration of drained peat soils

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Peat and soils rich in organic matter in general are a frequent object of ecological restoration. However, in practice as applied in Czechia, they are rarely given adequate comprehensive attention. Revitalisation efforts usually focus mainly on the water regime and biodiversity, while the treatment of organic substrates and relief design are often neglected. Some foreign approaches consider these attributes of revitalisation to be fundamental. First of all, according to the extent of the damage to the relief and the degree of degradation of the organic horizon, revitalisation measures are designed. Only if revitalisation measures are designed in a way that is appropriate to the damage, can full restoration of the water regime and, consequently, biodiversity be expected. We recommend incorporating this somewhat 'opposite' approach into the ecological restoration practice, as it brings new perspectives and inspires novel solutions.
The issue of protecting organic soils from degradation is also coming to the fore in the context of climate change. Drained mineralising organic soils are a significant source of CO2 at up to over 30 t CO2/ha/year, which means a destruction of the organic horizon of up to over 1 cm per year. In the Czech Republic, these are former wet to peat (or peat) meadows and surrounding sites with a significant representation of organic soil horizons with a total area (as agricultural land) of about 55-60 thousand ha. The negative trend can be reversed by sensitive revitalisation. In suitably revitalised areas, mineralisation ceases, peat-forming processes are restored and the areas become active natural CO2 sinks again. For testing and development of revitalization procedures on drained organic soils, the project LIFE+ LIFE in drained soils (LEDOS) was proposed in 2023 (in cooperation with partners South Bohemian University in České Budějovice, VRV, a.s., Menard Building Foundation s.r.o. and DHP Conservation s.r.o.).

RESTORATION OF WETLAND COMPLEXES AS LIFE-SUPPORTING SYSTEMS IN THE DANUBE BASIN

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Restore4Life aims at developing an online **Wetland Restoration Decision Support System** that will allow large-scale holistic wetland restoration activities in the Danube basin and in Europe as part of the EU Mission "Restore our ocean and waters by 2030".

Why?:

1) large **disparities** exist in Europe regarding the knowledge, expertise, and tools for holistic wetland restoration, impeding their transferability to and implementation in other regions;
2) an urgent need for a long-term **decision support platform** for knowledge, tools, and expertise to facilitate implementation and boost wetland restoration in Europe.

Aims of the project are as:

1. foster a **digital water knowledge system** to better understand, monitor, and forecast the health of wetlands, based on existing and planned European infrastructures and services;
2. stimulate **EU-wide, large-scale holistic restoration** of Danube wetlands, floodplains, and coastal wetlands to restitute their ecosystem services; and
3. promote a **participatory governance** system based on the mobilization and engagement of the public, civic, and private sectors.

Interactive effects of temperature rise, nitrogen eutrophication and nutrient status of the underlying peat affect *Sphagnum* carbon uptake capacity – a greenhouse experiment

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Climate change and nitrogen (N) eutrophication are expected to have adverse effects on the production potential of *Sphagnum* paludicultures in temperate zones, particularly where established on degraded sites. We conducted a nine month greenhouse experiment with *Sphagnum papillosum* planted on packed bog peat columns. Three water level (WL; 0, -7 and -15 cm relative to peat surface) and mean air temperature (T_{air}; ambient, +1.5 and +3 °C) treatments, three amounts of N input (5, 25 and 50 kg N ha^{-1} a^{-1}) and two types of peat substrate (weakly and strongly decomposed) were combined in a fully factorial design. Four measurement campaigns with manual chambers were conducted from July 2021 to March 2022 to quantify *Sphagnum* carbon (C) uptake capacity.
Frequent irrigation from above probably masked effects of decreased WL, while C uptake capacity was negatively affected by elevated air temperatures in summer, but positively in cooler seasons. During the vegetation period, C uptake capacity was slightly reduced under increased N deposition. Negative effects of increased N input were aggravated at elevated air temperatures and more pronounced on strongly decomposed peat, where *Sphagnum* was exposed to extremely high pore water ammonium concentrations at the beginning of the experiment. Furthermore, fluctuating N supply (due to fluctuating pore water N concentrations) appears to have negatively affected Sphagnum C uptake capacity. Besides water management, nutrient management will be a key element of successful *Sphagnum* paludicultures in the future.

What revealed repeated vegetation sampling on extracted peatlands after 10 years?

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The chronosequence approach, that is, analyses of several stages differing in age since disturbance or restoration but more or less comparable in site conditions, may well demonstrate, despite some limitations, a long-term ecosystem development. Earlier, we described spontaneous vegetation succession in 11 differently aged industrially harvested raised bogs and suggested that spontaneous recovery of plant cover gradually proceeds toward the reference state of natural raised bogs. We repeated the analyses after 10 years and asked: (1) Are the successional trajectories of spontaneous restoration really directing toward reference natural sites? and (2) How do typical peatland plant species participate in re-vegetation? Artificially afforested extracted peatland sites were used for comparison. We concluded that spontaneous recovery of plants does not proceed toward the reference sites. Instead it directs more toward the artificially afforested sites. Despite this, the spontaneously developed vegetation harbored many more peatland species. To turn the development toward the natural reference sites would require a substantial rise of the water table after ceasing peat extraction. The study demonstrates the importance of repeated analyses, which may give more reliable signs of the re-vegetation direction than one-time analyses.

Restoration of mined peatlands through the process of spontaneous succession – possibilities and limitations

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Central European peatlands, especially raised bogs, are unique and fragile ecosystems inhabited by specialists of higher plants, fungi, insects, etc., so-called tyrphobionts. The most destructive disturbance is the industrial peat extraction but also other disturbances may affect the ecosystem. Possibilities and limitations of spontaneous recovery of the disturbed peatlands will be evaluated. The respective specialists and their abundances can serve as good indicators of restoration processes, and various taxonomic groups exhibited very similar responses to the processes. Generally, spontaneous succession mostly proceeds towards a woodland predominantly composed by tree generalists, especially Scots pine, birches and Norway spruce, while open sites dominated by the specialized tyrphobionts are rare. It seems that habitat limitations, especially low water table, play a more important role than dispersal limitations in the recovery processes. More successful restoration might be possible by substantially increasing the water table in the extracted peatlands. On the other hand, the spontaneously developed woodland exhibits in any case much higher natural value than monotonous tree plantations which are still often practiced.

Mlýnský potok - 25 years since the revitalization of the stream bed

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The revitalization of the Mlýnský potok (stream) was carried out in 1998 as one of the first revitalizations within the "Revitalization of river systems" program in the Czech Republic. According to the project, the goal of the revitalization of the Mlýnský potok was to restore the basic parameters of the stream biotope, slow down the outflow of water from the landscape, increase the water's self-cleansing ability and restore life in the stream bed.
Before the restoration, the stream bed was made of concrete blocks laid in 1966, the stream was artificially straighten and deepened to 1 - 1.5 m. The subsurface drainage from the surrounding pastures was discharged into the stream in the 80's. The total length of the revitalized stream bed in 1998 was 1,692 m, the concrete blocks were removed here. 4 types of objects were selected for stream bed restoration: 1) rough boukler ramp (5x), 2) fish refuge (26x), 3) stone weir (27x), 4) stone current deflector (53x).
A total of 621 pieces of trees with a trunk circumference of at least 8-10 cm and a maximum distance of 1.5 m from the bank edge were to be planted along the stream.
After the revitalization, the stability of the banks and the growth of trees were repeatedly checked, but the monitoring of the effectiveness of the revitalization was not part of the project.
The research team at the Faculty of Agriculture and Technology is monitoring the effectiveness of revitalization of Mlýnský potok as part of comprehensive research on experimental watersheds in this area. An evaluation 25 years after the revitalization shows that modifications to the stream bed mainly enabled the return of the fish population (Salmo trutta and Cottus gobio) and the growth of wetlands macrophytes (Glyceria fluitans, Veronica beccabunga, Juncus effusus, etc.). There was a slight increase in water depth in the stream due to the removal of flat concrete blocks in the bottom and insertion of various objects into the stream. Revitalization probably helped to improve water chemistry, reduce conductivity, concentration of nitrates, bicarbonates, etc. However, even after the revitalization, the mill stream remained deepened and straightened, and due to the restoration of the underground drainage, it was not possible to improve the parameters of the overall water runoff and its fluctuation. Row planting of trees along the water course also remained unnatural.

Figures. Mlýnský potok before revitalization (left) and 6 years after revitalization (right)

Can Sphagnum removal reverse the undesired succession of rich fens under different alkalinity and fertility levels?

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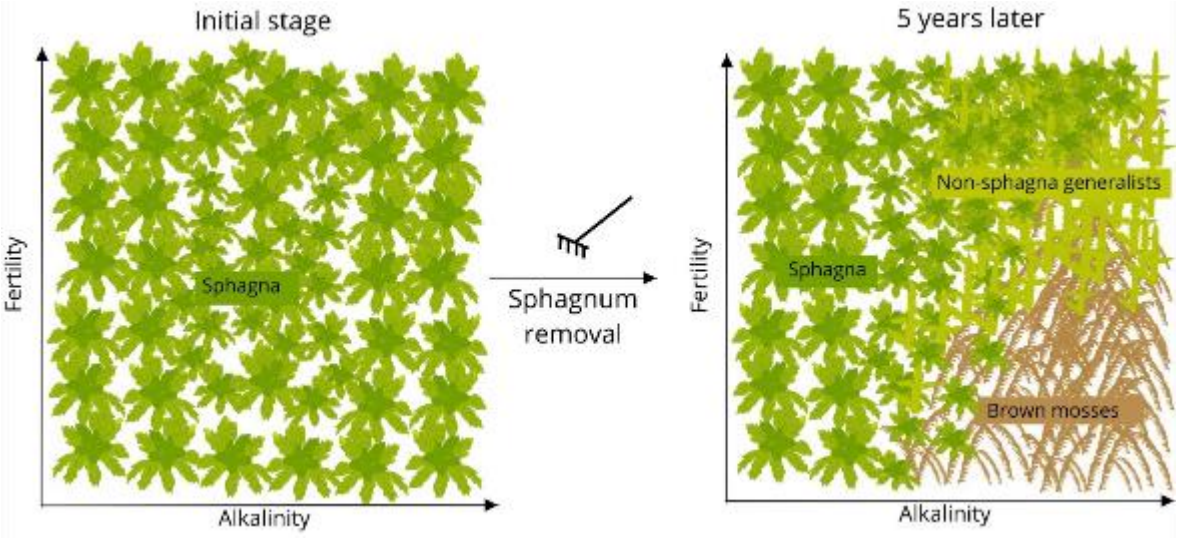
An undesired succession of rich fens leads to the formation of dense Sphagnum carpets that outcompete brown mosses and some vascular plants, resulting in biodiversity loss in fen habitats of high conservation importance. Small-scale *Sphagnum* removal is a rarely implemented conservational measure, whose success may depend on soil alkalinity and fertility (i.e., nutrient availability). Therefore, characterizing the effects of pH and fertility levels would potentially allow for the development of better Sphagnum removal strategies. Two experiments were conducted across 24 rich fens of different alkalinity and fertility located in an area of ~32,000 km2 spanning from the Bohemian Massif to the Western Carpathians (Europe). We hypothesized that high alkalinity and low fertility support the restoration of rich fen vegetation after Sphagnum removal. Our study focused on four different Sphagnum groups. In Experiment 1, the treatment plots remained unfenced. In Experiment 2, the treatment plots were fenced off and target brown mosses were transplanted from the surroundings to overcome dispersal limitations. A repeated-measures design was used, with vegetation composition recorded over a 5-year period. High alkalinity rather than fertility facilitated species richness and the appearance of target brown mosses. High alkalinity generally hindered Sphagnum recovery, whereas high fertility supported the recurrence of S. teres and S. recurvum agg. Under high pH conditions, enhanced fertility further correlated with the spread of nonsphagnaceous generalist bryophytes of low conservation value. Despite sustaining a significant overall reduction, all Sphagnum taxa began to recover throughout the experiment, albeit less obviously in fens with S. warnstorfii. Sphagnum removal may reverse biodiversity loss and allow for the restoration of brown mosses in rich fens where Sphagnum cover had increased due to slight eutrophication, acidification, or a decrease in the water table. In alkaline and nutrient-poor conditions (e.g., *S. warnstorfii* fens), the effect is evident and long lasting and the intervention may not be extensive. In fens dominated by S. teres or S. recurvum agg., repeated or large-scale removal may be needed if high nutrient availability (potassium, phosphorus) or low alkalinity supports Sphagnum recolonization. Treatment plots with S. subgenus Sphagnum exhibited the least promising brown-moss restoration prospects.


Initial stage
Fertility
Sphagna
Alkalinity
Sphagnum
removal
5 years later
Fertility
Non-sphagna generalists
Sphagna
Brown mosses
Alkalinity

Biodiversity research of newly built pools in the agricultural landscape of South Moravia

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The number of newly built pools and small reservoirs with the function of water retention in the landscape and supporting biodiversity is increasing, especially in connection with climate change. Currently, large investments are being made in these projects, especially in the lowland areas of the Czech Republic, which are significantly threatened by drought. In the last decade, there were hundreds of projects within the South Moravian region alone. Unfortunately, the new water bodies are often built in rare and endangered habitats, such as wet meadows or temporal field wetlands, resulting to destruction of these precious habitats and disappearance of a number of important species. The value of newly built waterbodies for local biota is often questionable, regarding mostly: (i) very poor water quality, (ii) rapid overgrowth of reeds caused by insufficient management and (iii) presence of fish, including invasive species. There is also a significant lack of a more comprehensive assessment of the contribution of the new pools within the scope of the declared purposes, including biodiversity support. For that reason, we began to study these habitats in detail. Our research includes mapping important groups of organisms (aquatic invertebrates, zooplankton, fish, amphibians and wetland birds) and the environmental quality of the new water bodies. So far, we have found that zooplankton and amphibians are mainly affected by the presence of fish, wetland vegetation and environmental parameters such as water turbidity, chlorophyll *a* concentration or water depth. Land use in the vicinity of new water bodies is also an important factor influencing amphibians. To evaluate the significance of the new pools, we will compare their biodiversity with other similar wetland habitats in the agricultural landscape of South Moravia, smaller fishponds and naturally formed permanent and temporal wetlands. It is already being shown that the new wetlands host poor amphibian communities compared to the natural wetlands (only 2 species versus 8 species on average) and that many of the new pools are more similar to commercial fishponds than natural habitats. As part of our project, we are also preparing a map of areas unsuitable for building new ponds in southern Moravia and a comprehensive methodology for the management of new wetlands for the long-term sustainability of functions and biodiversity with regard to their degradation due to eutrophication, reed overgrowth and the introduction and long-term presence of fish.

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Restoration of the Sedmihorky peatland

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Peatlands are a rare ecosystem and important environment in the landscape, however many of them has been drainaged in the past. This restoration project presents the locality near Karlovice-Sedmihorky municipality with a mezotrofic peatland in the Bohemian Paradise PLA. The Sedmihorky peatland and the Libuňka floodplain were under massive ameliroation during the komunism era. Around 600 hectares were drainaged and around 12 kilometers of the stream was destroyed and regulated. This wetland is the largest residue of wet areas in the floodplain with size of 25 hectares. Within the restoration project there have been 6 hectares of the wetland restored. Amelioration channels were interrupted by a soil backfill, flat amelioration site was cut with clay screen and 14 small pools were built by heavy technique on belts. The excavated soil was plowed on arable land next to the wetland.

The project is typical example of cooperation of the non-goverment organization with many landowners (tens) and cooperation with state departments of environment and foundations. The project was funded by European Union from The Operational Programme Environment 2014-2020. Restoration took place within the years 2021-2022. Results of the restoration are visible already in the first years. Vegetation under management of pasture and regular mowing of the grass has being change. Several new species of birds have nested here, many amphibians have appeared and some new species of waterbirds has regularly stayed here since then. The most important is the influence on the water regime of the wetland. We estimate that the retention capacity of the wetland was incresad by 26 500 cubic meters. Considerable number of the created pools keep water on the maximum level within the year. Now we placed 7 automatic level meters and the water surface level is studied in both areas, in restored area with not-working melioration system and in the rest of the wetland with still functioning drainage. Measures of the water level surface in currently restored area were carried out also before the restoration - in 2014, so that after current measures it should be possible calculate the changes in retention capacity more precisely. The research is in the beginning, so it is too early to evaluate it, however some brief notes we can discuss. More information about the locality, organization structure and other details of the restoration project you can find on the website www.sedmihorskemokrady.cz.

The Sedmihorky peatland after the restoration from drone. Photo by Petra Stráníková.

The summarizing article of the restoration is placed in the Ochrana přírody journal - Šťastný, Bendářová (2022) - link: https://www.casopis.ochranaprirody.cz/pece-o-prirodu-a-krajinu/revitalizace-sedmihorskych/?action=download

Horna Orava peatlands and their problems

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The northernmost territory of the Slovak Republic, Horna Orava, is one of the 3 most important peatland areas in Slovakia. A large part of the peatlands was destroyed in the past as a result of conversion to agricultural land (mainly in the 60-70s), peat extraction or flooding during the filling of the Orava dam (1953). However, raised bogs, transitional mires, fens and large complexes of waterlogged peat forests have been preserved to this day.
In the past, the non-forested wetlands (mostly transitional mires, fens and wet meadows) were regularly managed and mown. However, with the intensification of agriculture and forestry, they have begun to drain. Extensive hydro-melioration of the surrounding agricultural landscape has been carried out. These changes set in motion processes that accelerated the process of succession by hundreds to thousands of years. Peatlands that have been drained or affected by extraction lead to desiccation and loss of species or a change in species composition. Such sites with modified water regimes spontaneously become overgrown with emergent woody plants that suppress native peatland species.
With the declaration of small-protected areas (mainly in the 60-70s) and later the Horna Orava Protected Landscape Area (1979), many of these rare sites began to be protected. Sometimes, however, too much. Prohibition of access and limited use of these wetlands discouraged even the last local farmers from the original cultivation of these areas. We now know that these measures were partly counterproductive, because today these measures have to be carried out by the protected area management, which does not have the necessary resources to do so.
The most common conservation measures taken by nature conservation authorities in non-forest areas include mowing and the reduction of tree encroachment. Often with the help of volunteers. This solution is only maintenance and does not address the root of the problem - the water regime. We have only been able to regulate it at some sites. Moreover, management is carried out irregularly and especially in the most valuable parts of peatlands, which of course does not have the desired effect, even in extreme cases with negative consequences. Nature conservation is interested in preserving these habitats, which requires mainly the restoration of the water regime, regular mowing and other necessary management interventions. As almost all of these activities take place on privately owned land, they require cooperation with the owners and managers of the land. Involving them in cooperation with protected area management would be the cheapest but probably also the most effective way of saving these indispensable ecosystems.

Peat biogeochemical indicators of peatland ecosystem recovery after re-wetting

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All different peatland types, including bogs, fens, spruce mires, have been drained during the 20th century in the Sumava Mountains regions and under current time, they are restored using re-wetting. We evaluated the effect of long-term drainage on physico-chemical and biological properties of peat in these three peatland types and compared it to undisturbed (control) peatlands. This allows us to evaluate the intensity of peat degradation due to drainage and estimate its potential for recovery after re-wetting. Moreover, the state before restoration serves as a „starting point" for evaluation of the restoration effect on peat and contributes to the evaluation of the success of the restoration measures carried out.

We investigated the effect of long-term drainage and rewetting on peat physico-chemical and biological properties in bogs, spruce mires and fens. Long-term drainage (few decades) led to an overall ecosystem degradation, indicated by increased peat bulk density, reduced decomposability of peat, decreased pH, reduced soil microbial biomass and activity and reduced methane production compared to pristine sites. The effect of drainage was most apparent on fens, followed by spruce mires and lowest on bogs.

Rewetting of formerly drained peatlands is reflected in stabilization anaerobic conditions by increased pH and increased potential of methane production. Slight changes in microbial community composition towards the original composition were observed. Based on the measurement, following below ground indicators of ecosystem recovery after the rewetting were selected as suitable: pH, microbial biomass, anaerobic respiration, methane production and microbial community composition (especially methanogens). However, the measurement showed that 5-15 years after rewetting is not sufficiently long period for new peat layer accumulation, thus the peat physico-chemical properties are still strongly influenced by previous drainage and spreading of original (peat forming) plants is crucial for ecosystem functioning recovery.

Hydrological response to re-wetting is a relatively fast process, while ecosystem recovery and peat bio-geochemical properties recovery will take up decades. Response to re-wetting depends on peatland type and on the level of disturbance before re-wetting.

Fungi (macromycetes) as indicators of peatland condition

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Fungi represent a heterotrophic part of ecosystems, and as decomposers, symbionts and parasites significantly influence other organisms and their environment. Macromycetes are fungi that produce fruitbodies visible to the eye, and this is the reason their ecological requirements and distribution are much better known than these of micromycetes (molds, yeasts). Therefore, macromycetes can be effectively used to assess the habitat condition.

The disadvantage of macromycetes is mainly ephemeral occurrence of their fruitbodies. This could be overcome by environmental sequencing. Therefore, we tested its practical use by comparing environmental sequencing data and fruitbody data from 10 peatlands (Třeboňsko). Unfortunately, both datasets agreed mostly on dominant species. Furthermore, we sequenced substrates (decayed Sphagnum) under fruitbodies of 6 peatland indicator species (144 samples) and did not always find their sequences (86%). This together with patchily distribution of rare fungi limits the use of environmental sequencing. We also found out that the studied peatland indicator species prefer sites with a combination of rare peatland plants. If there are many of similar sites, macromycetes survey enables to choose the most valuable, because rare fungi require time to establish and may indicate habitat continuity.

In the years 2017-2021, we conducted fruitbody survey in the restored bog Soumarský Most (Šumava), since 2018 we have been studying the disturbed bog Vlčí Jámy. Their vegetation is not resembling undisturbed bogs and as we expected there is only a minimum of target peatland indicator species (SM: *Sarcoleotia turficola, Cortinarius tubarius*; VJ: *Russula sphagnophila, Cortinarius uliginosus*). Nevertheless, these sites are mycologically valuable because they host species of disturbed sites (*Gymnopilus fulgens, Psilocybe turficola*, VJ: *Jaapia argillacea*), which are very rare in the Czech Republic. These initial stages should be preserved also in case of further management.

Whereas colonization of peatlands by rare fungi usually takes a long time, they tend to survive much longer than we think. By comparison of fungal communities of preserved and degraded plots in 10 peatlands (Třeboňsko) we realized that they occur in both types and can survive under studied degradation. Thus from fungal point of view it makes sense to invest into management of successively advanced peatland stages.

Modelling carbon water relations in rewetted peatlands – challenging ecosystem structure

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Rewetting of drained peatlands is a much-discussed measure for reduction of greenhouse gas emissions and climate change mitigation. However, if rewetting is done insufficient, vascular plants (VP) are able to encroach into *Sphagnum* moss dominated peatland ecosystems and gain dominance. Implications of this VP encroachment in peatlands are not fully understood yet but recent studies suggest an alteration of the carbon balance and hydrological regime.
Here we present different emission behaviour of a *Sphagnum* dominated and a VP encroached temperate raised bog site of the same rewetted area (but with different rewetting success), where alteration of vegetation composition was demonstrated to be the consequence of a lower water table.
We use process-based modelling to reproduce the observed carbon dioxide (CO_2) and water fluxes of both sites and to infer whether changes in fluxes were solely driven by vegetation composition or moreover by an alteration of plant physiological traits and/or soil properties. To achieve this aim, we use a soil-vegetation-atmosphere transfer (SVAT) model, whose input parameters are either measured or optimized by using Shuffled Complex Evolution (SCE-UA) algorithm.
However, there are numerous challenges regarding water table modelling in peatlands, that we additionally aim to address here. Most important issue was to implement a multidimensional microstructure (hummock and hollows) into a one-dimensional SVAT model. In consequence we needed to consider different surface elevations, water holding capacities, water recharge from ponding and highly heterogeneous VP leaf area indices (LAI), resulting in different radiation and water fluxes for hummocks and hollows.
Future work shall include simulating management scenarios for removing VP vegetation using the optimized model and evaluate most appropriate measures regarding CO_2 and water balances.

Measures of the BUND in wetland areas at the Green Belt

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Measures of the BUND in wetland areas at the Green Belt
Close to the Former Iron Curtain a significantly higher proportion of areas with high ecological value could be persevered. Due to relatively high precipitation at the slopes of the Inner Bavarian Forest there are is a huge amount of small to medium sized fens and ombrotrophic bogs along the Bavarian Green Belt. The BUND has a strong effort on preservation of these sometimes quite small wetlands. Though being subordinate in terms of area, they play an enormous role for the local micro climate and serve as considerable stepping stones for different sorts of wetland species.
Therefore the BUND department green belt is involved in the project life for mires, where different purchased areas almost directly at the border to Czech Republic were chosen as project sites. But also on many other sites the BUND tries to use its areas for retaining water in the landscape. Several types of measures were taken in the last years to rise or stabilize water level in these places. Sometimes ditches had to be blocked or filled to stop drainage of water but on the other hand former irrigation trenches could be reactivated in order to increase moisture.
Although the second project in this region, Crosslinking Green Belt, primarily treats cultural landscapes, the project management puts a special focus on the revitalisation of the water conditions on project sites. There is also a huge variety of measures even in cultural landscapes that have positive effects on moisture. New installed structures like hedges or stone bars mitigate wind driven desiccation. Drainages that formerly ran subterraneous, were brought up so water now can flow slowly in looped trickles at the surface. More than one kilometre of former irrigation trenches of meadows could be reactivated in order to increase the moisture of the areas below or beside them. Several ponds were installed. But there was done explicit wetland restoration too, for example the revitalisation of the Mauthler Filz by wooden sheet piling. At the project site Wagenwasser pasturing with cattle in a very low density was installed for the conservation and development of semi-open cultural landscapes on one side but also enabling wetland restoration in the project life for mires on the other side. Some species like the birch mouse (*Sicista betulina*) need both.

LIFE FOR MIRES

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