



13th SWS Europe Chapter Meeting

Management of Wetland Ecosystem Services: Issues, Challenges and Solutions

Exploring novel approaches for wetland conservation and wise use, water management, sustainable use and ecotourism, restoration of degraded or lost sites, pollution control and climate change

Program and Abstracts

Ohrid, Macedonia, April 30 – May 4, 2018
St. Clement University of Ohrid, Faculty of Tourism and Hospitality

Kej Makedonija 95, 6000 Ohrid

Programme

April 30

18.00-20.00 Registration

20.00 Welcome reception – Royal View Hotel, Jane Sandanski 2, Ohrid

May 1

08.00-08.45 Registration, St. Clement University of Ohrid, Faculty of Tourism and Hospitality
Kej Makedonija 95

08.45-09.00 Welcome to the meeting – Matt Simpson, Slavco Hriskovski, Jos Verhoeven

09.00-10.00 Keynote lecture - **Slavco Hristovski** and **Valentina Slavevska-Stamenkovic** "Natural values of Ohrid Prespa system with emphasis on Studenchishte wetland"
- Chair: Jos Verhoeven

10.00-10.30 Coffee

10.30-12.30 **Oral session A – Wetlands and water quality** - Chair: Matt Simpson

10.30 - A1 – *Jan Vymazal* - Removal of nutrients, organics and suspended solids in vegetated agricultural drainage ditch

10.45 - A2 – *Hristina Bodin* - Attenuation of pharmaceutical substances: Phytoremediation using constructed wetlands

11.00 - A3 – *Mette Carstensen* - Increased hydraulic loading rate to full-scale subsurface flow constructed wetlands decreased phosphate and methane release

11.15 - A4 – *Rory Harrington* - Management of limestone quarry drainage: a new challenge for the Integrated Constructed Wetland (ICW) concept

11.30 - A5 – *Ines Cindric* - Removal of SDBS from wetland water using eggshell as a low cost adsorbent

11.45 - A6 – *Jasna Halambek* - The influence of orange peel powder and orange peel charcoal on copper adsorption on soil

12.00 – A7 – *Ruud Kampf* - The role of wetlands in the urban water cycle: Amsterdam to Kisumu, towards a circular economy?

12.15 - A8 – *Geoff Sweaney* - How to convince regulators that wetland treatment is effective

12.30-14.00 Lunch

14.00-15.00 Keynote lecture – **Aleksandra Cvetkovska** "Quaternary climate change in the southern Balkans: Lake Prespa diatom paleolimnology from the last interglacial to present"
- Chair: Keith Edwards

15.00-15.30 Coffee

15.30-17.30 **Oral session B – Ecological quality and restoration of wetlands** - Chair: Matt Cochran

15.30 - B1 – *Keith Edwards* - Nutrient and hydrologic effects on plant structure and functions in two wet grasslands

15.45 - B2 – *Scott Winton* - Managing hydrology and waterfowl grazing to reduce wetland methane flux

16.00 - B3 – *Stefan Lorenz* - Exposure and vulnerability of small lentic water bodies to pesticides

16.15 - B4 – *Ülo Mander* - Riparian grey alder forest ecosystem response to sudden flooding: The FluxGAF experiment

16.30 – B5 – *Thomas Hein* - Riverine landscapes and their floodplains in transformation – challenges for utilization of ecosystem services and biodiversity conservation in the Danube River

16.45 – B6 – *Kimberli Ponzio* - Development of hydrologic criteria for managing subtropical wetlands in Florida, USA

17.00 – B7 – *Kris Decler* - Flanders (Belgium) lost 75% of its wetlands during the past 50-60 years. But restoration pays back

17.15 – B8 – *Christopher Craft* - Tidal marsh restoration: Tracking 50 years of wetland soil development

17.30-18.00 Coffee

18.00-19.30 **SWS Europe Business Meeting**

May 2

09.00-10.45 Guided tour through the old town of Ohrid

11.00 **Field trips to Studenchishte Wetland and River Drim**

20.00 Conference dinner. Royal View Hotel, Jane Sandanski 2

May 3

08.00-08.30 Registration, St. Clement University of Ohrid, Faculty of Tourism and Hospitality
Kej Makedonija 95

08.30-09.30 Official session (Chair: Jos Verhoeven):

- Mayor of Ohrid
- Representative of Ministry of the Environment
- Dean of the Faculty of Tourism and Hospitality, Ohrid University

09.30-10.30 Keynote lecture - **Trajce Talevski** "Lake Ohrid - Current Situation and Dangers"
- Chair: Matt Simpson

10.30-11.00 Coffee

11.00-13.00 **Oral session C – Wetland conservation and the Ramsar Convention** - Chair: Keith Edwards

11.00 - C1 – *Rob McInnes* - Challenges with describing the ecological character of Ramsar Sites: a case study from Myanmar

11.15 - C2 – *Patrick Grillas* - The contribution of seed bank mapping to conservation programmes: *Lythrum thesioides* case study

11.30 - C3 – *Martina Eiseltová* - The challenge of wetland conservation under the intensification of agriculture

11.45 - C4 – *Rob McInnes* - The SWS/WWN 2017 citizen-science survey of the state of the world's wetlands: issues and results

12.00 - C5 – *Daniel Montagud* - Proposed measures for restoration of Studenchishte wetland (Ohrid, Macedonia)

- 12.15 - C6 – *Mateja Germ.* - Macrophyte community structure affects the presence and abundance of the Dytiscidae aquatic beetles in waterbodies along the river
12.30 - C7 – *Alenka Gaberščik* - Invasive alien vines alter characteristics of riparian vegetation habitats
12.45 - C8 – *Igor Zelnik* - Diversity of diatom communities in different habitats of the pool spring Zelenci (Slovenia)

13.00-14.00 Lunch

14.00-15.00 Keynote lecture – **Marina Talevska** "Macrophyte vegetation in Lake Ohrid and Lake Prespa" - Chair: Matt Cochran

15.00-15.30 Coffee

15.30-17.00 **Oral session D – Biogeochemical aspects of wetlands** - Chair: Jos Verhoeven

- 15.30 - D1 – *Keith Edwards* - Distribution of mineral nutrients in littoral vegetation of an ancient shallow reservoir
15.45 - D2 – *Fons Smolders* - Oxygen prevents eutrophication and can make turbid waters clear again
16.00 - D3 – *Mateja Grašič* - Silicon accumulation in the wet meadow species *Deschampsia cespitosa* from different habitats
16.15 – D4 – *José Orellana* - Updating the hydrogeological model of the Gallocanta Lake (Spain): a contemporary approach
16.30 – D5 – *Valentini Maliaka* - Sediment quality investigations in Lake Lesser Prespa (Greece): tracking the impact of eutrophication through new knowledge
16.45 – D6 – *Ülo Mander* - Nitrous oxide emission from nitrogen-rich organic soils

17.00-17.30 Closing session

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Abstracts of Keynote Lectures

Diversity and conservation of Studenčišta wetland

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INTRODUCTION

Studenčišta wetland is an integral part of Lake Ohrid. Despite of the fact that the values and the importance of the marsh have been known for long, the inappropriate management and conservation and series of developments lead to reduction of the wetland surface area and destruction of certain significant components of biological diversity.

The most important current international agreement for the protection of Studenčišta is the UNESCO's Convention on the Protection of World Cultural and Natural Heritage under which the region of Ohrid, from cultural, historical and natural point of view, was enrolled on the List of World Heritage in 1980. Out of the important natural values this site includes Lake Ohrid, part of Galičica National Park, Studenčišta wetland, Belčišta wetland and parts of Jablanica mountain.

Biological diversity in Studenčišta wetland has been studied from different points of view, though it has never received the deserved attention despite the fact that it is part of the exceptional Ohrid Lake. In this communication we will present the biological diversity and values of Studenčišta wetland from today's and historical perspective.

HISTORICAL CHANGES OF THE WETLAND AREA

Studenčišta wetland has undergone severe man-caused gradual degradation and drying, similarly to other Macedonian wetlands over the last century. While the whole wetland area covered at least 120 ha in the first half of the XX century, at present significant remnants of the wetland are only covering 50-70 ha. Over the last 60 years, the wetland area has suffered severe alterations of the land use. Large portions of the marsh have been converted into agricultural land, and various permanent buildings and facilities have been constructed such as for the Lake police, the Macedonian army and for a plant nursery. The natural connection with the lake has been lost over the last decade as a paved recreational path has been built along the shore. Moreover, presently vast wetland areas are covered with construction waste. Recent analysis by remote sensing has revealed that during periods of heavy rains and flooding, the wetland area covered with water was 24 ha (Apostolova et al. 2017).

DIVERSITY OF SPECIES AND HABITATS

Diversity of plant communities

Although the analyzed area of Studenčišta wetland is rather small, several plant communities have been identified. Five wetland communities were recorded: Scirpeto-Phragmitetum W. Koch 1926, Oenantheto-Roripetum Lohm. 1950, Sparganio-Glycerietum fluitantis Br.-Bl. 1925, Caricetum elatae W. Koch 1926 and Cyperetum longi Mic. 1957 (Micevski 1957) and one community of wet meadows (Trifolietum nigrescentis-subterranei Mic. 1957) (Micevski 1969). Special attention draws the relict association Caricetum elatae which in Macedonia is known only from Studenčišta wetland. It is recognized by conspicuous tussocks of *Carex elata*, occurring in mesotrophic to slightly eutrophic, still waters. Water regime is characterized by deep flooding in spring with fluctuations during the rest of year (Hájková et al. 2011). This association was spread in Struga wetland before its complete destruction.

Diversity of species

The flora of Studenčišta wetland consists mostly of wide spread wetland species. We should bear in mind that wetland plants in Macedonia are under strong anthropogenic pressure due to the drainage of swamps and marshes. Research has indicated that until recently, Studenčišta wetland hosted 10 species that are rare in Macedonia. More than half of those, i.e. five species, are extinct, two species are probably extinct from Studenčišta wetland while three species are endangered by extinction from the wetland.

Diatom flora of Ohrid Lake is relatively well studied. A total of 89 diatom species were identified in Studenčišta wetland. Presence of 11 endemic and four rare flora species in Macedonia was confirmed, as well as one species to which Studenčišta wetland is the first finding for Macedonia.

Although there is a huge gap in the knowledge about some macroinvertebrate groups, the detailed review of the available data showed that Studenčišta wetland is inhabited by relatively high number of species (103). Among them 66 macroinvertebrate species occur in Studenčišta swamp, 24 in the springs Biljanini izvori and 19 species inhabit the Studenčišta channel near the Hydrobiological Institute in Ohrid.

The fauna of Studenčišta wetland and the fauna of Ohrid Lake differ significantly. Common species for Lake Ohrid and shore waters around the lake reach 16% for gastropod fauna, 20% for tricladiid fauna, 35% for oligochaetes and 22.5% for Chironomidae. Based on this, we may conclude that Studenčišta wetland ecosystem contributes to much greater diversity of the overall Ohrid Lake system. There is high level of endemism among planarians (60%) and aquatic snails (88%). Most of them inhabit only Ohrid Lake and its watershed which additionally contributes for high biological values of Studenčišta wetland and Biljanini Izvori springs. Gastropod species *Gyraulus albidus* and *Ohridohoratia polinskii* are considered as vulnerable, *Gyraulus crenophilus* as endangered and *Ohridohauffenia minuta* critically endangered according to the IUCN Red List of Threatened species (IUCN 2017.3).

Dragonflies are the very diverse group with presence of 35 species (Spirovska et al. 2012). The most important species are *Coenagrion mercuriale* and *Gomphus flavipes* whose conservation requires the designation of Special Areas of Conservation (SACs) within the Natura 2000 network as well as *Cordulegaster bidentata* which is classified as Near Threatened (IUCN 2017.3).

Table 1. Overview of diversity of species of Studenčišta wetland

Group	Number of known species	Number of endemic species	Rare species	EU Habitats Directive/ Birds Directive	IUCN red list
Plants			10		
Sponges (Porifera)	1		1		
Planarians	10	6	6		
Aquatic snails (Gastropoda)	8	7	7		2 NT, 2 VU, 1 EN, 1 CR, 1 LC
Oligochaeta	12	2	2		
Leeches (Hirudinea)	10	1	1		
Amphipods (Amphipoda)	3	1	1		
Isopods (Isopoda)	1				
Chironomidae	6				
Mayflies (Ephemeroptera)	9	2	2		
Caddisflies (Trichoptera)	8				
Dragonflies (Odonata)	35			1	32 (LC) 1 (NT)
Ground beetles (Carabidae)	39	1	9		
Fish (Pisces)	14*				
Amphibians (Amphibia)	9	1		6	
Reptiles (Reptilia)	4			3	
Birds (Aves)	52				
Diatoms	89	11		4	

* Three more species are introduced

** 5-7 species are extinct or probably extinct from the wetland

Very interesting or rare species for the fauna of the Republic of Macedonia are found among the family of ground beetles (Hristovski & Guéorguiev 2015). Many of the wetlands species were common for both Ohrid and Struga wetlands.

We should bear in mind though that many of these data are outdated and some of the mentioned species are rarely found today.

In Studenčišta Canal, as one of the water suppliers to the wetland, at present, in certain periods of the year, there are 14 (out of the total of 17) autochthonous fish species of Lake Ohrid, as well as three allochthonous (introduced) species. In the period preceding the commencement of hydro amelioration interventions in the wetland, autochthonous fish species used to occur in major part of the wetland, while trout was entering into the then existing river Studenčiška with its spring branches. Communication between fish from the lake and the former areas of the wetland was carried out mainly in the periods of natural spawning of individual fish species, as well as in the period of their hibernation (Spirovska et al. 2012).

Unlike fish, numerous amphibian species have sustainable populations in the wetland. At least nine species are present, all included in Annexes 2 and 3 of the Bern Convention. The most important are the Macedonian crested newt and yellow-bellied toad. Also, at least four reptile species are found in Studenčišta.

The wetland of Studenčišta used to be one of the most important shelters and nesting sites for water birds along Ohrid lake shore, but this significance has almost gone completely. With an exception of few species of warblers, waterfowl and the little bittern, there are practically no other nesting bird species in the wetland. There are data on nesting of around twenty bird species in the past. On occasions of migrations or search for food from the surrounding areas, other bird species may occur as well, primarily different species of herons, ibises, waders (the peak of their autumn migration corresponds with the peak of the tourist season and thus they occur on the Swamp in minimum number), harriers and ducks.

Mammals in the wetland have been insufficiently studied. Presence of otter is the most important.

CONCLUSIONS

Although largely reduced, Studenčišta wetland still holds great biological values and offers a number of ecosystem services. Nevertheless it is facing serious plans for infrastructure development which may lead to its complete destruction. Protection of the wetland and its restoration is a priority accompanied by a proper management based on its sustainable use, mostly for tourism (Apostolova et al., 2016).

ACKNOWLEDGEMENTS

The “Integrated study for the status of the remains of Studenčišta wetland and measures for its revitalization” was financed by Municipality of Ohrid.

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Quaternary climate change in the southern Balkans: Lake Prespa diatom paleolimnology from the last interglacial to present

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Balkan Lake Prespa, as part of the ancient “sister” lake system of Ohrid and Prespa is renowned for its great age and exceptional biodiversity. The lake contains an important paleo-archive, which places it among the very few locations worldwide with unique opportunity for Quaternary climate research and evolutionary studies. Within this study, and for the first time, we focus on the fossil diatom flora of Lake Prespa. A detailed taxonomic approach is used for obtaining ecological information and creating the first diatom-based paleolimnological interpretation of a ca. 91 ka of sediment sequence from Lake Prespa, core Co1215, spanning the end of the last interglacial to the present.

The diatom analysis reveals high diversity and presence of different endemic species from the genera *Cyclotella* and *Surirella*, yielding to the importance of Lake Prespa as a biodiversity “hot-spot”. The results of the paleolimnological study of core Co1215 show that fluctuations in the diatom data are driven primarily by changes in lake level as a function of shifts in moisture availability. Additional evidence for fluctuations in trophic status links in part to lake-level change, but also reflects nutrient enrichment from catchment processes. Warmer interglacial (MIS5, MIS1) and interstadial (MIS3) phases exhibit increased lake level despite enhanced evaporative concentration. Low lake levels during glacial phases indicate extreme aridity, common to all Mediterranean lakes. The detailed study of the Late Glacial and Holocene part of the sequence confirms previous tentative inferences that Late Glacial to Holocene moisture availability has strong affinity with other sites in the Eastern Mediterranean. It also tracks the pattern of North Atlantic forcing. Two shallow phases at 1.0 cal ka BP and at ca. 100 years ago probably represent an aridity response which is added to increased human impact in the catchment. On a suborbital timescale, the diatoms clearly reflect the impact of short term, ice-rafting events, suggesting the dominant influence of North Atlantic forcing in this region. Although the highest amplitude shift in diatom ecology occurs between 40 and 38 ka BP, the response may be imprinted on the impact of the 39.28 ka BP Campanian Ignimbrite volcanic eruption. In fact, the diatoms from Lake Prespa core Co1215 display the first strong evidence for the impact of Italian volcanic activities on lacustrine biota in this region.

The results underline the complexity of the diatom response thresholds in different studies across the region. In the case of Lake Prespa, the diatoms emphasize the role of precipitation for maintaining the hydrological balance of the lake and indirectly its biodiversity.

Lake Ohrid - Current Situation and Dangers

Trajce Talevski

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Lake Ohrid and its catchment area are one of the main hotspots for biodiversity in Europe and is a great example of a lake with a wide range of endemic taxa. The Lake itself is shared by the Republic of Macedonia and Albania.

Lake Ohrid is considered one of the most diverse ancient lakes in the world in terms of the number of endemic species. According to some studies, Lake Ohrid has the greatest number of endemic species if compared to the surface of other ancient lakes in the world. This has been an important reason for inclusion of Lake Ohrid and its surroundings in the UNESCO World Heritage list as a Natural and Cultural Heritage of the Ohrid region in 1979/80. In the Lake there are approximately 1,200 native species, of which about 600 animal species. At this moment at least 212 species are endemic, of which 182 are animal species.

Previous research of the flora and fauna in Lake Ohrid, which has been carried out for almost a century, has identified several biodiversity hotspots within the area. One of the most significant ones is located between the Gradishte peninsula and the village of Trpejca, especially in the localities Veli Dab and Velja pesht along the karstic east coastline of the lake, as well as in the littoral zone near Saint Zaum, Saint Naum and the locality Tushemishta in Albania.

Currently, there is no significant endemism in plant species with exclusion of the Characeae and silicate algae. Fish fauna is most recognizable and its endemism is particularly important, but also the great vulnerability of almost all species living in the Lake. The final list of plant and animal species probably has yet to be completed, especially for the groups of diatoms and benthic fauna.

Anthropogenic effects are observed throughout the lake, especially near localities where rivers (Sateska, Koselska, Velgoshka and Cherava) are flowing into the Lake. It is a fortunate coincidence that anthropogenic pressure in locations with the highest percentage of endemism is still small, so the impact in these regions is rather minor.

The greatest danger to the flora and fauna of the lake is formed by several activities in the coastal area and in the lake itself. These are primarily the removal of certain parts of the reed belt, drainage of wetlands, artificial regulation of the level of lake water used for the production of electricity as well as the construction of buildings near the Lake. Also, in the summer tourist season there is a very large number of guests, as well as poor functioning of the wastewater treatment systems that occasionally leak into the Lake due to deficiencies in the purification system.

Macrophyte vegetation from Lake Ohrid and Lake Prespa

Marina Talevska

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The Ohrid-Prespa area is located in the South-western part of the Republic of Macedonia, and this region covers the Ohrid-Prespa lake system which is one of the largest in Europe of its kind. *Lake Ohrid and Lake Prespa* are of special value at national and international levels due to their great biodiversity of *flora and fauna* with unique characteristics, primarily the presence of endemic species.

Macrophyte vegetation is common in the littoral zones of lakes and plays a significant role in the cycling of materials. The first researches devoted exclusively to macrophyte vegetation of Lake Ohrid and Lake Prespa started at the beginning of the 20st century by Petkov (1910). Afterwards these researches have continued until the present day.

In the littoral zones of Lake Ohrid and Lake Prespa, various populations of macrophyte vegetation (emergent, floating and submerged) are commonly found. The dominant emergent plant species in these two lakes is Common reed (*Phragmites australis* (Cav.) Trin. Ex Steud.) which forms natural discontinuous belts. The other emergent plant species (*Typha latifolia* L., *Typha angustifolia* L., and *Shoenoplectus lacustris* (L.) Palla) have become rare in recent decades. Floating plants in both lakes are very rare and are represented by *Nuphar lutea* L. (Sm.), *Persicaria amphibian* (L.) Gray and other species. The most commonly present submerged macrophytes are: *Potamogeton perfoliatus* L., *Stuckenia pectinata* (L.) Börner, *Potamogeton lucens* L., *Myriophyllum spicatum* L., *Vallisneria spiralis* L., and *Najas marina* L. In Lake Ohrid there are also several representatives of the Charophyta, some of which are found endemic to this lake. The most common species is *Chara tomentosa* L., followed by *Chara ohridana* (Kostic) Krause, a species endemic to the Balkan.

The results obtained from the performed long-term researches of macrophyte vegetation from Lake Ohrid and Lake Prespa show differences in biodiversity of macrophytes between these lakes. These differences *are related to differences in lake altitudes, surface area and depth*, as well as in ecological conditions present in their littoral zones, especially with respect to nutrients. According to our researches the greatest biodiversity of macrophytes in both lakes is found in the areas in the littoral zone where environmental conditions are favorable for their growth and development, while lower biodiversity is evidenced in areas where environmental conditions are unfavorable.

In recent years the anthropogenic influence in the lakes has increasingly been present, and provoked changes in the composition of macrophyte vegetation. In certain areas new macrophyte associations have started to occur (mostly emergent and submerged), while some macrophytes that in past were frequently present, now occur sporadically and are in danger of disappearing (floating plants). Due to the significant role of macrophyte vegetation, in the following period it is necessary to undertake certain measures for its protection against the negative anthropogenic impacts.

Tuesday 1 May - 10.30-12.30 **Oral session A – Wetlands and water quality** - Chair: Matt Simpson

A1. Removal of Nutrients, Organics and Suspended Solids in Vegetated Agricultural Drainage Ditch

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INTRODUCTION

Drainage ditches have been shown a suitable tool to mitigate agricultural pollution from diffuse sources in agricultural landscape due to multiple interfaces among water, sediment and aquatic vegetation (Needelman et al., 2007; Zhang et al., 2016). There is a clear evidence that vegetated drainage ditches provide efficient removal of nutrients, suspended solids and organics as compared to unvegetated ditches (Moore et al., 2010). Macrophytes growing in the ditches provide surface area for absorption of nutrients and microbial attachment, reduce velocity of the flow and filter out suspended solids, thus add to removal of nutrients and other agrochemicals from the water (Kröger et al., 2009; Bundschuh et al., 2016).

The objective of this study was to evaluate the ability of naturally vegetated drainage ditch to remove nitrogen, phosphorus, organics and suspended solids. The removal was evaluated on the basis of two-years monitoring.

METHODS

The study was carried out during the period January 2015 to December 2016 in a naturally vegetated ditch in south-central Bohemia, Czech Republic. The water in the ditch is an overflow from a fishpond that is fed only by drainage waters from adjacent agricultural fields. Total length of the monitored part of the ditch was 200 meters and the flooded area was 360 m². The first 70 meters of the ditch is only sparsely vegetated with *Epilobium hirsutum*, *Lythrum salicaria* and *Filipendula ulmaria* while the rest of the monitored stretch is densely vegetated with *Phragmites australis* (140 m²), *Glyceria maxima* (64 m²) and *Typha latifolia* (20 m²).

Samples were taken biweekly from January 16, 2015 to December 8, 2016 in the fishpond outflow and in the ditch after 200 meters. In the field, samples were analyzed immediately for dissolved oxygen and pH. In the laboratory, the samples were analyzed within 24 hours for BOD₅, COD, total suspended solids, total nitrogen, nitrate-N, ammonia-N and total phosphorus. Samples of three major plant species (*P. australis*, *G. maxima* and *T. latifolia*) were taken in four replicates within the ditch area from the quadrants 0.25 m² (0.5 x 0.5 m) at the end of August 2015 and 2016 and content of nitrogen and phosphorus were measured.

RESULTS and DISCUSSION

The average concentration of N-NO₃⁻, TN and TP decreased from 3.37 to 1.66 mg l⁻¹, from 5.0 to 2.7 mg l⁻¹ and from 0.57 to 0.27 mg l⁻¹, respectively. Removal of nitrogen load (Fig. 1) averaged 1070 kg ha⁻¹ yr⁻¹ with 804 kg ha⁻¹ yr⁻¹ being removed through denitrification of nitrate nitrogen. Plant uptake was responsible for 26.3% of the removed nitrogen. Both removals of TN and N-NO₃⁻ load were strongly temperature dependent (Fig. 1). Removal of phosphorus load averaged 142 kg P ha⁻¹ yr⁻¹ and the removal was temperature independent and plant uptake was responsible to 14% of the removed TP load. The values of removed TN and TP loads are

comparable with values obtained in free water constructed wetlands treating agricultural drainage (Vymazal, 2017; Diaz et al., 2012).

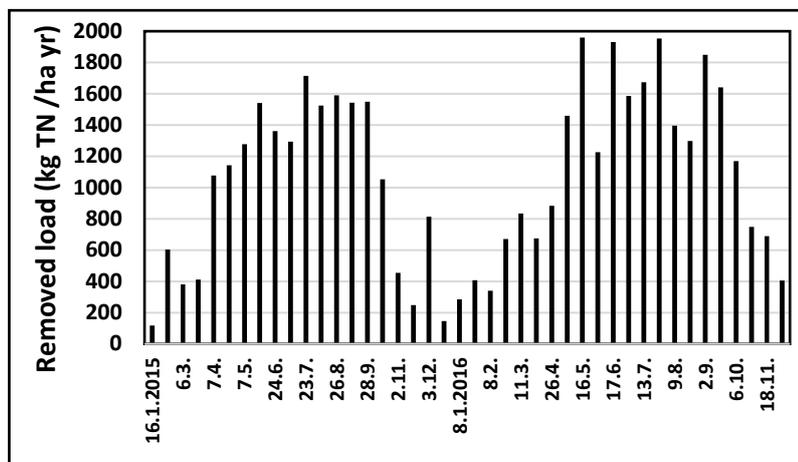


Fig. 1. Removal of TN load in a vegetated drainage ditch during the period 16.1.2015 – 8.12.2016.

Removal of organics is usually not the major target in agricultural drainage waters as these waters usually do not contain elevated concentrations of organics. BOD₅ and COD concentrations were reduced by 48% and 44%, respectively and the removed loads averaged 1150 kg BOD₅ ha⁻¹ yr⁻¹ and 7 000 kg COD ha⁻¹ yr⁻¹. Removal of total suspended solids (TSS) has been reported high in vegetated ditches due to very dense growth of macrophytes which act as a filter and in addition, slow down the velocity of the flow, thus enable sedimentation of particles. The removal of TSS averaged 20 450 kg TSS ha⁻¹ yr⁻¹. Both BOD₅ and COD load removals were strongly temperature dependent and removal exponentially increased with increasing water temperature. TSS removal was temperature independent.

CONCLUSIONS

The two-year monitoring of a ditch overgrown with *Phragmites australis*, *Glyceria maxima* and *Typha latifolia* revealed high removal of nutrients, organics and suspended solids. The removal of nitrogen and organics was strongly dependent on water temperature while removal of phosphorus and suspended solids were temperature-independent. The results of this study revealed that the naturally vegetated drainage ditch has comparable treatment efficiency with constructed wetlands in terms of nutrients, suspended solids and organics.

ACKNOWLEDGEMENTS

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A2. Attenuation of Pharmaceutical Substances: Phytoremediation using Constructed Wetlands

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INTRODUCTION

Currently, wastewater treatment plants (WWTPs) do not efficiently remove pharmaceutical substances (PS). Thus, such substances are now frequently found in aquatic ecosystems worldwide. Also, concentrations of some PS in treated effluents exceed Environmental Quality Standards proposed by EU legislation. One resource-efficient option for increasing PS removal in WWTP effluents is to use constructed wetlands (CWs) as an attenuation step (Breitholtz et al. 2012; Li et al. 2014). However, very little research has been done on how to maximize the PS attenuation capacity of CWs. Therefore, a project with the aim to investigate **reduction of different pharmaceutical substances in CWs** with different vegetation compositions and water depths, was performed at the Experimental Wetland Area (EVA) located 20 km north of Halmstad, Sweden.

METHODS

EVA consists of 18 similar rectangular surface-flow CWs each 10 x 4 m² (surface area). Five pharmaceutical substances (diclofenac, carbamazepine, ibuprofen, sulfamethoxazole and naproxen) were spiked to nine CWs at concentrations typically found in secondarily treated wastewater. Three different types of CWs were used: A) unharvested wetlands with mixed vegetation and high mean water depth (0.55 m); B) similar to A) but with a low mean water depth (0.40 m); and C) harvested wetlands dominated by reed and high mean water depth (0.55 m). Samples for pharmaceutical concentrations were taken at the inlet and outlet of the CWs on day 0, 14, 21, 28, 42 and 56 after spiking. Also, oxygen, temperature and pH was measured. The hydraulic loading rate to the CWs was 120 mm day⁻¹ (\pm 14 mm day⁻¹) throughout the study period (Aug-Oct 2015).

RESULTS and DISCUSSION

Results show that the relative reduction (% reduction of total loaded PS mass) was highest for ibuprofen (>94 %) followed by diclofenac (85-88 %) and sulfamethoxazole (54-66%). Both carbamazepine and naproxen had relative reductions below 37 % (Fig. 1). No significant difference were found between the treatments.

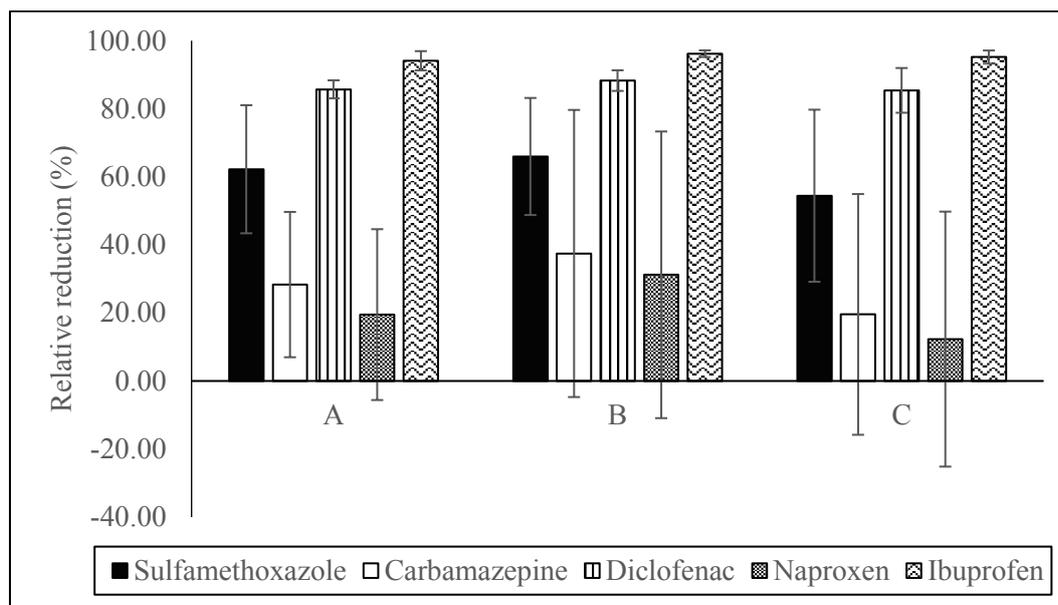


Fig. 1. Relative reduction (as % reduction of total loaded mass) of five pharmaceutical substances in the surface-flow constructed wetlands (CWs) consisting of: A) unharvested CWs with mixed vegetation and high mean water depth (0.55 m); B) similar to A) but with low mean water depth (0.40 m); and C) harvested CWs dominated by reed and high mean water depth (0.55 m). Error bars show standard deviation. $n = 3$.

The present study found higher relative reductions for ibuprofen, diclofenac and sulfamethoxazole compared to those reported by Verlicchi and Zambello (2014) (Table 1). Also, the reduction of naproxen and carbamazepine was within the rates reported by the cited study. Berglund et al (2014) conducted an experiment in EVA using sulfamethoxazol (spiking concentration 1 $\mu\text{g/L}$) and found a 77 % relative reduction, which is very close to the rates reported in the present study (Table 1). Matamoros and Salvadó (2012) reported similar mass reduction as the ones found in the present study for ibuprofen (92%), carbamazepine (43%) and diclofenac (93%) for a polishing tertiary wastewater treatment system consisting of a pond and surface flow CW. Recently, Nuel et al. (2018) reported that the reduction efficiency of PS was higher in warmer seasons compared to colder ones. The study at EVA was conducted during 25 August-19 October, and thus, the reduction could be very different if the study was conducted in peak summer or a cold winter period.

Table 1. Substances used in the present research project, their substance class, typical relative reductions in surface flow constructed wetlands receiving secondary treated wastewater (Verlicchi and Zambello 2014) and reductions reported in the present study (bold italic).

Substance	Substance class	Relative reduction (%)
Sulfamethoxazole	Antibiotic	16-24 (<i>54-66</i>)
Carbamazepine	Anti-epileptic	12-90 (<i>20-37</i>)
Diclofenac	Anti-inflammatory	8-79 (<i>85-88</i>)
Naproxen	Beta-blocker	14-52 (<i>12-31</i>)
Ibuprofen	Anti-inflammatory	48-76 (<i>94-96</i>)

Despite keeping a somewhat constant HLR to the CWs during the study period, the area-specific mass reduction of ibuprofen and diclofenac, respectively, increased with mass load (Fig. 2). In contrast, area-specific mass load of carbamazepine and naproxen, respectively, led to a decrease in area-specific mass reduction of these substances.

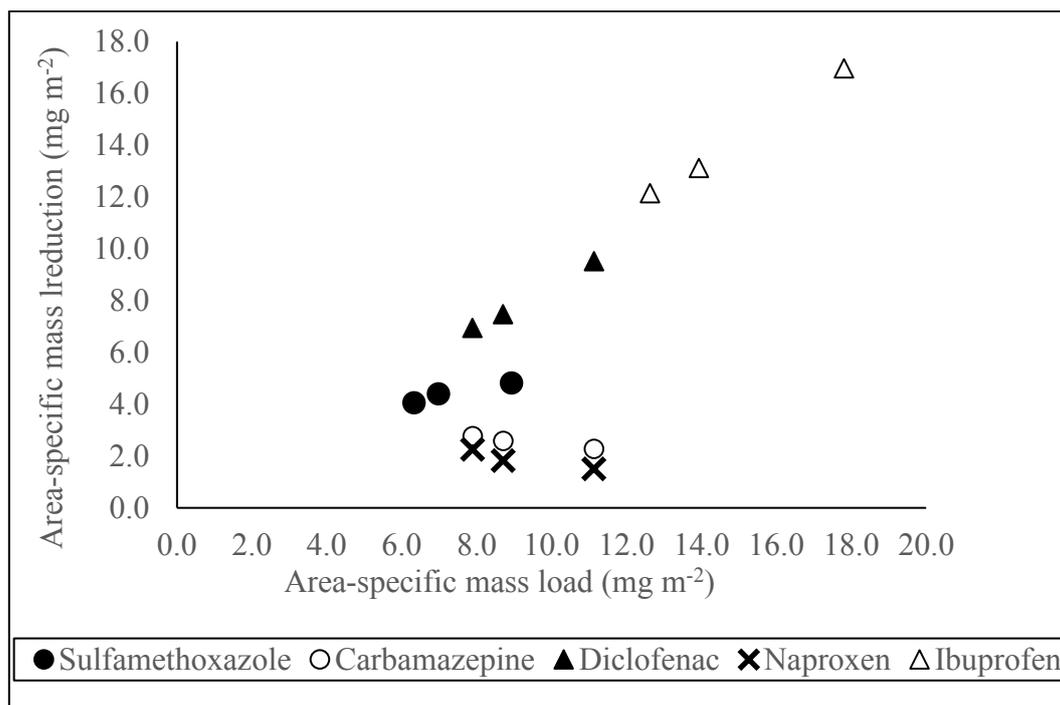


Fig. 2. Area-specific mass reduction as a function of mass load during the whole study period of five pharmaceutical substances in the surface flow constructed wetland system EVA. $n = 3$.

Area-specific mass reduction of sulfamethoxazole reached a plateau at around a mass load of 9 mg m^{-2} (Fig. 2). Currently, published literature seldom reports PS reduction in CWs using the unit *area-specific mass reduction*. A more regular use of this parameter is proposed when reporting PS reduction in CWs. This would make comparisons between different CW systems regarding their capacity to reduce PS much more relevant.

CONCLUSIONS

Relative reductions of PS achieved in the present study suggests that surface flow CWs could aid in reducing concentrations of these substance at levels typically present in secondary treated wastewater. Still, additional studies are needed to evaluate the long-term and seasonal behavior of PS reduction on CWs. Also, future studies should report reduction as area-specific mass removal to be able to make relevant comparisons between different CW systems regarding their capacity to reduce PS.

ACKNOWLEDGEMENTS

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A3. Increased hydraulic loading rate to full-scale subsurface flow constructed wetlands decreased phosphate and methane release

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INTRODUCTION

Subsurface flow constructed wetlands with filterbeds (SSF-CWs) seem to be a promising mitigation measure to reduce nitrogen (N) loss from agricultural drainage systems to surface water. However, during warm seasons with low hydraulic loading rate (HLR) and high hydraulic retention time (HRT), the SSF-CWs can remove nitrate completely, and create low redox conditions that promote sulphate reduction. Sulphate reduction is associated with several negative effects such as methane production and phosphate release.

The aims of this study was to investigate if seasonal increase of the HLR can decrease nitrate reduction and thereby reduce sulphate reduction, and if this subsequently decreased phosphate and methane release. Furthermore, the aim was to investigate how the increased HLR affect the yearly N and phosphorus (P) removal rates and efficiencies.

METHODS

The subject of interest was two SSF-CWs (CW1 and CW2) with horizontal flow located in river Gjern catchment (114 km²) in Mid Jutland, Denmark (UTM, ZONE 32, ETRS 89, x, y: 546104, 623014). Each CW (10 m x 10 m x 1 m) was lined with a 1 mm thick watertight membrane (Fig. 1), and the filterbed matrix consisted of willow wood chips (8 – 32 mm) mixed with crushed mussel shells (2-4 mm) in volume ratios of 50:50 in CW1 and 75:25 in CW2. Upon establishment of the SSF-CWs in 2012, *Phragmites australis* was planted in CW1, while CW2 was without vegetation.

Total N, nitrate, total P, phosphate, and sulphate were monitored by composite sampling of inlet and outlet water during 2013 to 2017. Water flow from the outlet of the SSF-CWs was monitored continuously with an electromagnetic flowmeter, and inlet water flow was calculated by subtracting net precipitation from outflow. This data enable us to calculate yearly nutrient and water balances for five years.

HLR was increased during summer-autumn in 2015 to 2017 (07/01 to 09/13) and compared to corresponding periods with unregulated HLR in 2013 and 2014. Dissolved methane concentration in inlet and outlet water and redox potential of the filterbed were also measured during two of the periods (2014 and 2017).

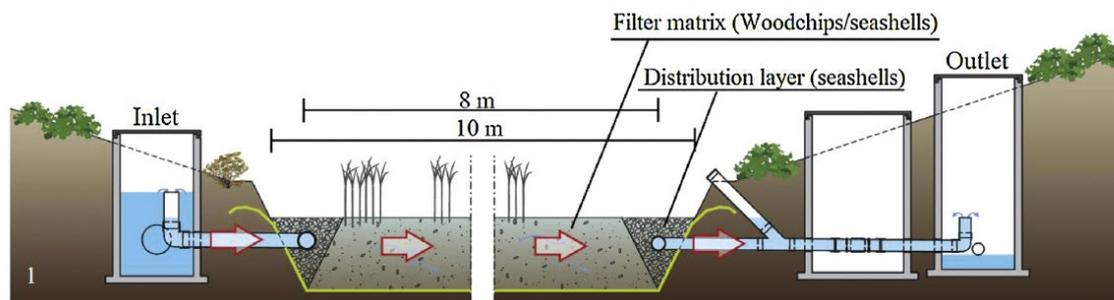


Fig. 1. Conceptual diagram of subsurface flow constructed wetlands (SSF-CWs) with horizontal flow including inlet well, distributions pipes, distribution layer (seashells), filter matrix (willow

woodchips and seashells), membrane, outlet well with flow-meter and outlet well with effluent sampling and aeration of the outlet water. The red arrows indicate the direction of water flow.

RESULTS

Increased HLR and lowered HRT during late summer-autumn resulted in nitrate reduction that ranged from 27 to 58 %, while the nitrate reduction was 99 to 100 % in corresponding periods with unregulated HLR. The SO_4^{2-} reduction was -1 to 4 % in periods with high HLR compared to 26 to 71 % in unregulated periods. The release of phosphate was 0.01 to 0.03 flow weighted (FW) mg L^{-1} in periods with high HLR, while in periods with unregulated HLR it was 0.07 to 0.11 FW mg L^{-1} . The loss of dissolved methane was 0.3 to 0.5 FW mg L^{-1} in high HLR periods compared to 4.3 to 5.8 FW mg L^{-1} in unregulated periods.

The data on yearly reduction rates and efficiencies is still to be processed.

CONCLUSIONS

In conclusion, our results showed that increased HLR to SSF-CWs in warm periods with low flow reduced nitrate removal, which led to lower sulphate reduction. A corresponding reduction in the release of phosphate and methane release was also observed in the periods with high HLR. Thus, the findings of this study suggest, that in order to avoid potentially negative side effects of the SSF-CWs, a solution is to design and implement them with the possibility to control inflow rates.

ACKNOWLEDGEMENTS

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A4. Management of limestone quarry drainage: a new challenge for the Integrated Constructed Wetland (ICW) concept

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INTRODUCTION

Situated 11.5 km from Dublin city centre, the Roadstone Ltd. Belgard limestone quarry is Ireland's largest. It supplies stone aggregates for civil engineering. The drainage of the excavated 120m deep quarry site comprises groundwater largely generated from intercepted precipitation runoff from the c.100ha site. Intercepted drainage is pumped from the quarry base to a sediment interception channel with flows that vary from 100l/s to 225l/s and with an average flow of <170l/s. A significant challenging pollutant is ammonium-N that may reach concentrations of 2mg/l that exceed environmental discharge limits to an adjacent stream that flows to Dublin's canal system.

Following previous Integrated Constructed Wetland (ICW) successes in the management of polluted water, including those focused on ammonium-N reduction, South County Dublin Local Government suggested the ICW approach for the Belgard quarry. Given the wide experience of VESI Environmental Ltd. in the design, construction and management of ICWs, it was contracted to undertake the challenge of design, construction and operational instruction for an appropriately sized ICW for the quarry.

METHODS

Using an ammonium-N loading rate of 3–7kg/ha/day (Kadlec and Knight, 1996; Scholz et al. 2007 and Harrington and McInnes, 2009) a two-cell ICW of 1.2ha was considered sufficient. An area was selected within the quarry's curtilage, excavated, shaped and the upper weathered clay-rich soil used to line the retaining berms and base of the two-cell wetland infrastructure. Associated water channels were similarly constructed and the final discharge was directed to the receiving stream. All excavated soils were incorporated into the site and on its adjacent lands. More than 2,000 physiologically mature helophyte (emergent aquatic) plants, comprising 6 species, formed the main vegetative base. The influent from the quarry was progressively introduced after the vegetation had rooted into its rewetted soil substrate.

RESULTS and DISCUSSION

Operational since 1st August 2017, the ICW treats all water from the quarry before it discharges. Treatment efficiency measurements already indicate an average reduction of greater than 50% for ammonium-N and full compliance for all other mandatory parameters including petrochemicals. Notwithstanding the long and persistent wet 2017/18 winter weather, most recent analyses of discharges to the receiving stream (January 2018) indicate >80% reduction in ammonium-N concentration in the discharge water. Greater ammonium-N reduction is expected as spring advances with warmer temperatures and increasing day length,

along with the ecological development of the wetland. It is already evident and noteworthy that a functional reanimated wetland can be operational within a year of construction commencing.

The approximate average 14,000 m³/day through-flow of this quarry's drainage is c. 25 times the flow that is generally accepted for combined municipal sewage wastewater and generally, for more contaminant loaded ICW systems, of which there are now >120 in Ireland. This project suggests that where source waters, typically in flood-prone situations or where high hydraulic contaminated flows may exist, ICW systems may be effectively applied in attenuating both flow and intercepting/treating associated vectored pollutants.

Appropriate tree planting and landscaping were incorporated into the adjacent lands and borders of the ICW, and these together will give the site an anticipated heightened amenity/environmental value. This project has demonstrated to Roadstone Ltd., the quarry owners, how the lands and waters associated with quarrying may be optimally managed - with significant savings in quarry operational cost, effectively addressing obligations in environmental management and providing for society.

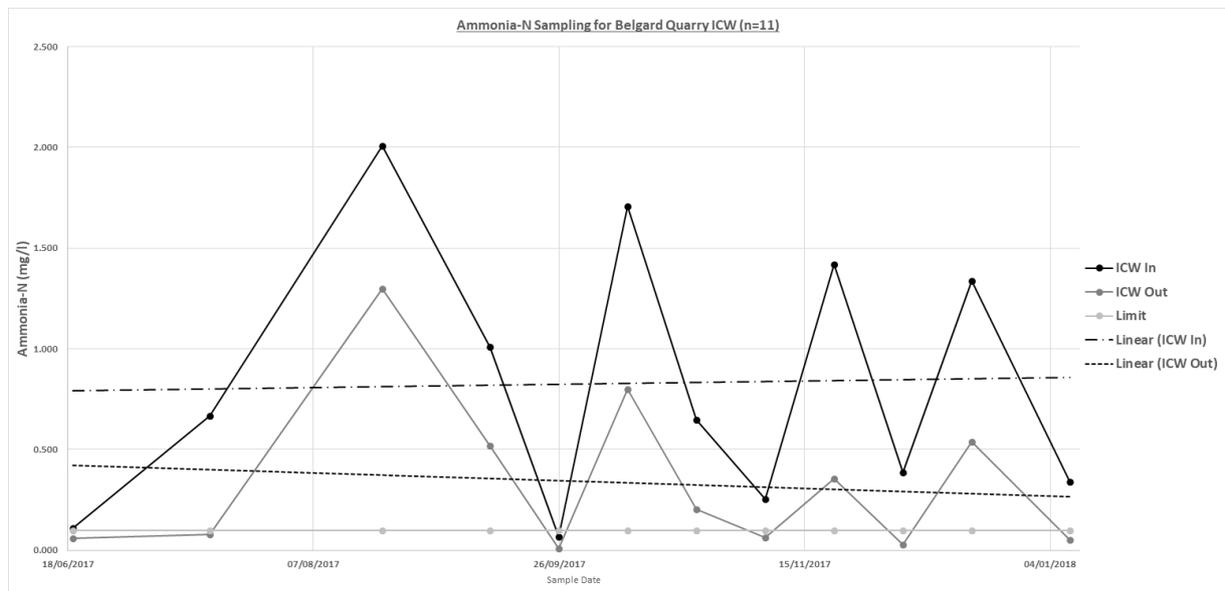


Fig 1. Ammonium-N concentration (mg/l) reduction for the Belgard limestone quarry Integrated Constructed Wetland, Co. Dublin showing influent and effluent trending lines.

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A5. Removal of SDBS from wetland water using eggshell as a low cost adsorbent

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INTRODUCTION

Sodium dodecylbenzenesulfonate (SDBS) is a negatively charged surfactant commonly used in the industrial applications and household. It can cause serious ecological problems, since natural decomposition is very slow in stagnant water. In the literature, various techniques were reported for the removal of SDBS from aqueous media. Adsorption of pollutants onto green adsorbents is the most widely used method, being fast, low-cost and environmentally friendly techniques.

METHODS

Chicken eggshells were obtained from small bakery within in city of Karlovac, washed thoroughly with distilled water and dried for 4 days at 55°C. Eggshell was then ground into powder with particle sizes less than 0.5 mm. Water samples were taken from an urban wetland area in Karlovac, Croatia. The characteristic of the wetland water samples were determined using Hach LCK kits. The SDBS was diluted using wetland water and stirred for 24 h. The SDBS concentration of solutions was determined by spectrophotometer (Shimadzu UV-Vis 2600 model) at the λ 223 nm.

Adsorption experiments were carried out in a batch method. Experimental parameters such as pH (7.0-12.0), adsorbent dose (0.5, 0.75 and 1 g /100 ml) and contact time (20, 40, 60, 80, 120 and 180 min), initial SDBS concentration (1, 2.5, 5, 10, 20 and 40.0 mg/L) and temperature (15, 25 and 55°C) were evaluated during the present study in order to determine optimized conditions for adsorption.

Adsorption tests were carried out by mixing of different amount chicken eggshell powder with 100 mL solutions pH of 7 at 25°C in a thermostatic shaker bath.

Kinetics of adsorption was investigated by varying the concentration of SDBS while other conditions were held constant at pH 7, at 25°C, 1 mg eggshell and shaker speed 200 rpm. Concentrations of SDBS over time (Ct) were determined at different time intervals.

The adsorption capacity of an adsorbent at equilibrium with solution volume V, was calculated using the following equation:

$$q(\text{mg/g}) = [(C_i - C_e)/m] \times V$$

where C_i and C_e are the initial and final concentration of SDBS in solution, respectively. V is the volume of solution (V) and m is mass of adsorbent (g) used.

RESULTS and DISCUSSION

Based on the experimental results, SDBS removal was relatively fast with more than 50 % removed in the first 30 min. The effect of pH on SDBS removal from wetland water by untreated eggshell powder demonstrated that the optimum removal occurred at pH 7. Amount adsorbed SDBS decreases when decreasing the pH value of solution, which was correlated with the change in eggshell surface charge and SDBS charge.

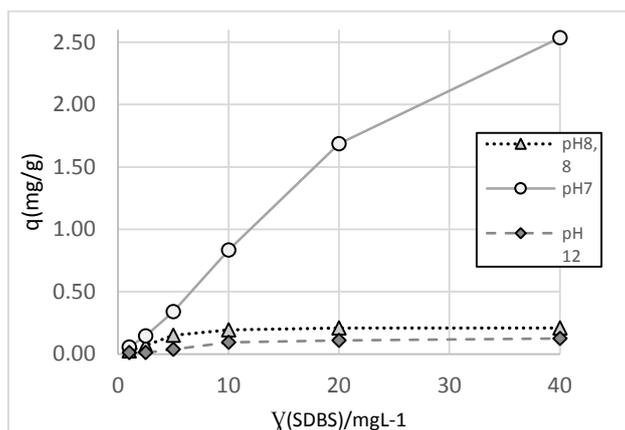


Fig. 1. Effect of pH on SDBS adsorption onto powdered eggshell (contact time 60 min, volume 100 mL, dosage 1 g, 25 °C)

The equilibrium adsorption results were complied with a Langmuir isotherm model and its maximum monolayer adsorption capacity was 2,537 mg/g for SDBS. Adsorption kinetics studies indicated that the pseudo second order model yielded the best fit for the kinetic data. The parameters of kinetic models parameters and the correlation coefficient (R^2) values for different initial concentrations are listed in Table 1.

Table 1. Kinetic model parameters and correlation coefficients for adsorption of SDBS at different initial concentrations onto eggshell (25 °C, pH=7, 200 rpm)

γ_0 (mg/L)	q_e (mg/g)	Pseudo first order		Pseudo second order	
		K_1 (min^{-1})	R^2	K_2 ($\text{g}/\text{mg}^{-1} \text{min}^{-1}$)	R^2
1.00	0.0696	0.0160	0.9939	0.0062	0.9963
2.50	0.2088	0.0120	0.9906	0.0094	0.9946
5.00	0.3150	0.0155	0.9893	0.0162	0.9953
10.00	0.8425	0.0016	0.9141	0.0354	0.9910
20.00	1.7692	0.0216	0.8334	0.0499	0.9867
40.00	2.5092	0.0146	0.9852	0.1047	0.9903

CONCLUSIONS

The adsorption study showed that the maximum adsorption of SDBS onto untreated eggshell powder was obtained at pH 7 and room temperature at the constant time of 45 minutes. A high yield (85.04 %) of SDBS adsorbed onto eggshell powder indicate that this method could be utilized as a low cost ecofriendly method for SDBS pollution control in wetlands area.

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A6. The influence of orange peel powder and orange peel charcoal on copper adsorption on soil

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INTRODUCTION

Since copper is a widely used metal in industry and households, there are many potential sources for copper pollution of surface water and soil. One of the most effective treatments for heavy metal removal at low concentrations is adsorption on solid adsorbents (Fu, Wang, 2011), while removal at high concentrations can be achieved by chemical precipitation or electrochemical methods (Dillon et al., 2006). Numerous studies have established effective results for treatment of wastewater by Soil Aquifer Treatment (SAT). Moreover, the ability of natural soils or natural soils mixed with different types of natural adsorbents for adsorption of heavy metals has been studied previously (Yu et al., 2001). In this study efforts have been made to compare adsorption capacity of untreated orange peel powder and orange peel charcoal in combination with soil as adsorbents for Cu(II) ion removal from high concentration solution.

METHODS

The orange peel was washed with double distilled water and dried at 60°C for 24 h. The product was crushed using a crushing mill and sieved (0.08 mm). The obtained dry orange peel powder (DOP) is used in adsorption experiments without any further treatment. Orange peel charcoal (OPC) was prepared from well dried orange peel which was carried out in a muffle furnace (Nabertherm Model B180) by placing a sample in a silica crucible at 300 °C for one hour. Soil is collected from wetlands that are located in the area of Karlovac, namely Šumbar. The soil samples were dried to constant mass at 85°C, homogenized, and stored in desiccator prior to use. Adsorption studies were carried out by batch process. The investigations were carried out in batches with different concentrations of Cu(II) solution (from 0.2 to 2.5 mg/mL) and different pH values (4, 5, 6). For all experiments 100 mL of prepared Cu(II) solutions (prepared from CuCl₂ x 2 H₂O) was taken into each conical flask with different amounts of adsorbents, shaken at 150 rpm in a thermostatic shaker for 15 min at 25°C, and left at stationary state for the next 24 h. After adsorption, the mixtures were filtered and the copper ion concentrations in the filtrate were determined by using an UV-VIS Spectrophotometer (Shimadzu Model UV-2600).

RESULTS AND DISCUSSION

Adsorption methods are based on physical and chemical phenomena that occur when the adsorbate molecules accumulate on the adsorbent surfaces. The amount of Cu(II) adsorbed (adsorption capacity) (q_t) and its removal percentage (RE%) were determined for soil and mixture of soil and orange peel or orange peel charcoal using a following equation:

$$q_e = \frac{(\gamma_0 - \gamma_e) \cdot V}{m} \quad (1) \quad \text{and} \quad RE\% = \frac{(\gamma_0 - \gamma_e)}{\gamma_e} \times 100 \quad (2)$$

Where γ_0 and γ_e represent the initial and equilibrium metal ions concentrations (mg/mL) in solution, respectively; V is the volume of the solutions (mL) and m is the amount (g) of adsorbent. Figure 1.a) shows the amount of copper adsorbed on soil, soil with orange peel powder (DOP) and soil with orange peel charcoal (OPC), while the effect of pH on removal percentage (%) is shown in Fig. 1b).

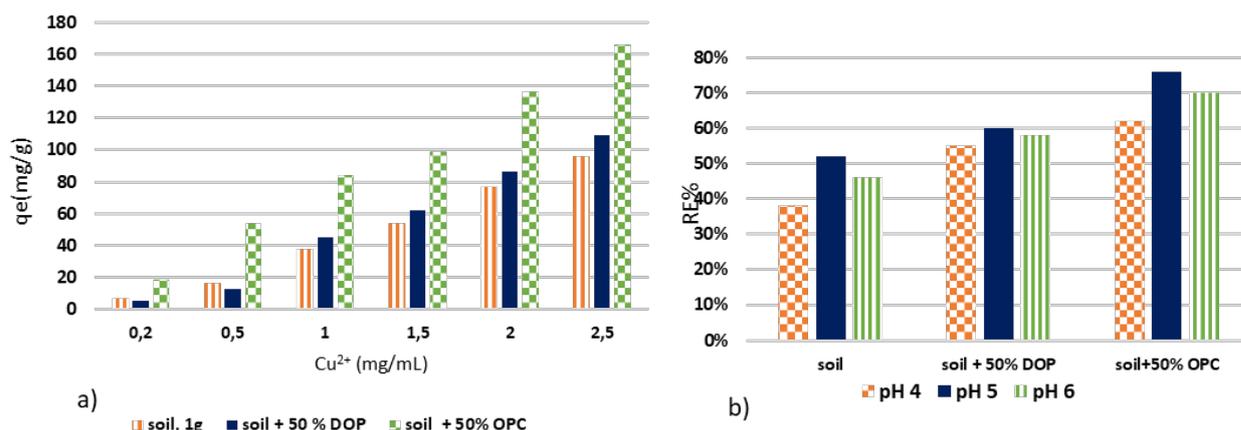


Fig. 1. a) Comparison of the capacity of copper adsorption between soil, soil with addition of DOP, and with addition of OPC at 25°C and b) effect of pH solution on copper removal percentage.

In case of addition of orange peel powder to soil sample, maximum adsorption level of 109 mg/g was achieved, while these values reach a maximum for addition of orange peel charcoal (166 mg/g). The effects of pH on metal ions adsorption have been studied by many researchers previously, and the results indicated that pH of solution have a strong effect on uptake of metal ions. For this study the highest removal percentage (%) of Cu(II) is observed at pH 5. These observations can be explained by the fact that at lower pH values, the surface charge of the adsorbent is positive and metal cations adsorption is not favourable.

CONCLUSIONS

The adsorption process can be a valuable tool for controlling the level of aqueous copper pollution, even for relatively high initial concentration (max. 2.5 mg/mL). The maximum copper removal was obtained for addition of 50% of orange peel charcoal to soil sample (76%), while for addition of orange peel powder this value is lower (60%). This study reveals that investigated soil enhanced its removal efficiency of copper by orange peel charcoal addition, which can be used as cheap biosorbent of heavy metals.

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A7. The role of wetlands in the urban water cycle, from Amsterdam to Kisumu, towards a green circular economy

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INTRODUCTION

Most publications on wetlands are either on existing sites or on special applications of wetlands, seen from the viewpoint of a wetland specialist. Given the current emphasis on circular economies and future proofing cities, it is interesting to take the urban water cycle as a starting point: how do wetlands fit in the urban water cycle? In December 2017 I got invited by the Dutch drinking water organisation VEI (Vitens Evidens International) initiated support for KIWASCO (Kisumu Water and Sanitation Company) to convene a workshop on wetland solutions - Water harmonica - to lower the nutrient load through treated waste water to Lake Victoria (www.rekel.nl/water/landen/kenya/Kisumu/).

This created an opportunity to compare the urban water cycle of two big cities, Amsterdam on the border of Lake Marken in The Netherlands, and Kisumu on the border of Lake Victoria in Kenya.

VALUES OF HUMAN WASTES OR WASTED WATER?

Human wastewater is by far the most important source of water pollution in residential areas. It is good to realise that historically human waste were seen as valuable, many cities had central collection places, rented out to commercial enterprises for successful reuse of human wastes. As an example, in Amsterdam the Maatschappij voor Landbouw (*Society for Agriculture*) had a license for using house hold garbage (mainly ash), human wastes and (organic wastes) from markets and industry. The need for nutrients in agriculture made it economically attractive. This led in the second half of the 19th century to a huge controversy between *hygienists* in favour of delivery clean drinking water into houses, *politicians* (in favour of cheap discharge of polluted water), *agronomics* (promoting the use of human excrements for improvement of agriculture, even shipped by boat to remote areas) and *engineers* in favour of applying the new techniques, especially from England.

Actually in those days a large city like Amsterdam was close to being a ‘circular city’; this changed, however, due to several reasons. The human excrements became diluted, because piped drinking water became available to flush toilets, this led to a strong increase in the amount of waste water. The solution was to build sewer lines and develop sewage treatment plants. Agriculture did not need ‘human manure’ anymore because of the availability of fertilizers. It must be said, that a system of piped high-quality drinking water is attractive and has contributed strongly to human health. The ease of a water closet, a good sewer system and waste water treatment plants is evident but can only be realized at relatively high cost. The total cost per family per year in The Netherlands is over 700 Euro per year, of which around 125 for drinking water, 360 for sewers and waste water treatment, and 150 for maintaining the water system (in 2015: NN, 2018c). However in less fortunate areas in this world is this not affordable, certainly not in Kisumu. It is not likely that a close to 100 % connection will be reached in the next decade. a total “Ecological sanitation solution” with separate treatment of human wastes will not likely happen, especially not in a big city.

A MIXED APPROACH

A mixed approach of a combined sewage system might be a good solution, as Mels et al already proposed in 2005. See figure 1.

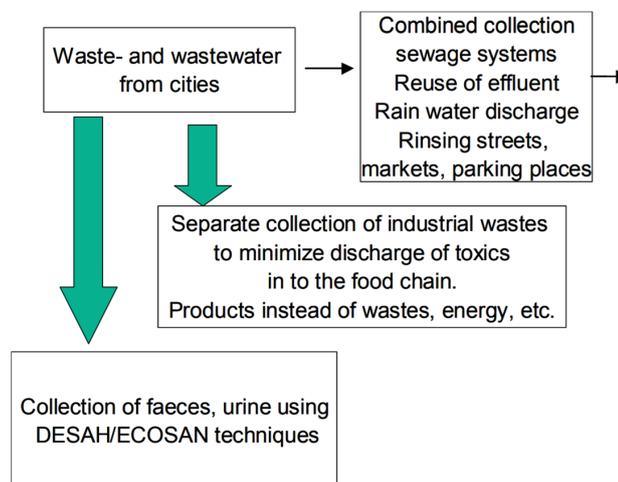


Fig. 1. Disconnecting and reuse of faeces and urine, industrial, hospital wastes etc. makes treatment and reuse of waste water much more simple (after Mels, et al, 2005).

Introduction of flow separation has a huge influence on waste water composition. Carbon (COD), most of the phosphates, most of the pathogens do come from excreta and urine, from our toilets. Above that, it is the only affordable way in the developing world to lower the discharge of medicines into the environment, as nearly all medicines in wastewater do come from excreta, and in a lesser extent from urine.

Separation of flows, as described above, needs a good organisation of the practical aspects as existed in Amsterdam around the 1900s, like the Liernur waste collection system and, like the Amsterdam Maatschappij voor Landbouw (*Society for Agriculture*) an organisation to handle the wastes and to produce fertilizers.

One of the issues raised is logistics of separate collections, especially cost. The volume of faeces and urine is not more than 2.5 l per person per day, or say 10 l per day for a family of four (see for an overview Niwagaba, 2009). Actually the recent developments in separate waste collection in The Netherlands show that the private waste companies are very able in organising a quite varied waste system. It is for families in semi-urban areas, towns quite accepted to have four 200 l containers (blue = paper, green = compostable material, orange = plastic, black is other wastes). Collection is one to two times per container per month, largely done in The Netherlands by private enterprises. In cities and urban zones where there is less space separate waste collection is in underground containers (GPGroot, 2018). Besides that all communities in The Netherlands do have waste collection centres where the inhabitants bring special waste like old household appliances, metals, stones, wood, etc..

The recent shift to “Circular thinking” is striking, it became a part of long-term government wide planning in The Netherlands (NN, 2018a). Naturally Amsterdam took up the national plans: Circular Amsterdam ((NN, 2018a) as a part of the Smart City initiatives. Waternet, the water company in the region of Amsterdam was already dedicated to the entire water cycle, with a large scale demonstration of urban source recycling in a part of Amsterdam, Buiksloterham (Gladek, et al, 2015). More info on the so-called ‘New sanitation’ in The Netherlands on <http://nieuwesanitatie.stowa.nl>.

KISUMU

The recent input of VEI (Vitens Evidens International) improved the operational quality of KIWASCO. The drinking water production is on the increase to the goal of 35,000 m³/day, quite reasonable for 500,000 people, around 70 l per head per day. The operational management of the two waste water treatment plants had been optimized. The two plants do function better than could be expected. The Kisat plant is a 70 year old conventional plant with trickling filters, with not more than a reasonable effluent quality. The Nyalende oxidation ponds have recently been upgraded, effluent quality is much better than the Kisat plant. Overall, both plants are well operated and maintained by a young and dedicated staff. It took a while, however, before I found out that the total flow for both plants is not more than 12,000 m³/day. That is 23,000 m³/day less than the delivery of drinking water, only 30 % is connected to the sewer system. It is not likely that a close to 100 % connection will be reached in the next decade.

WHAT DOES THAT MEAN FOR KISUMU?

It is obvious that the city of Kisumu could make use of these recent ideas and actually make a leap towards a modern circular city, in the way The Netherlands are heading.

Kisumu is one of the few Eastern African cities with a sewerage system (Letema, 2012), the other two large cities in Kenya are Nairobi, Mombasa and Nakuru. However, in all cases only a fraction of the waste water is treated.

As Kisumu is bordering Lake Victoria, water is leading, the centre. This is illustrated in a practical, simplified scheme for one of the possibilities to draw an urban water cycle with focus on the 'urban water cycle': figure 2. A circle does not have an end or a beginning, it is also good to realise that all these boxes in figure 2 are interconnected. The deteriorating quality of Lake Victoria has a huge influence on the drinking water production, also because of algae blooms and water hyacinth plagues. Bringing piped drinking water to houses lead to more waste water. This is actually a benefit, as the effluent of a good sewage treatment is usually very clear. It is still a "dead water" though, only organisms originates from "polluted water like organisms". A next step in the circle before entering Lake Victoria again is a Waterharmonica, to give the treated 'city water' a soft landing in nature. (Kampf et al, 2017, www.waterharmonica.nl)? This Urban Water Cycle way of thinking, with integrated 'New-sanitation' could be a good idea for Kisumu. It needs a human waste collection system to lower the input of carbon, nitrogen and phosphorus in the urban water cycle. The existing sewer system can still be used for houses, offices with 'old-fashioned' flush-toilets, 'gray water' from washing machines, showers etc.

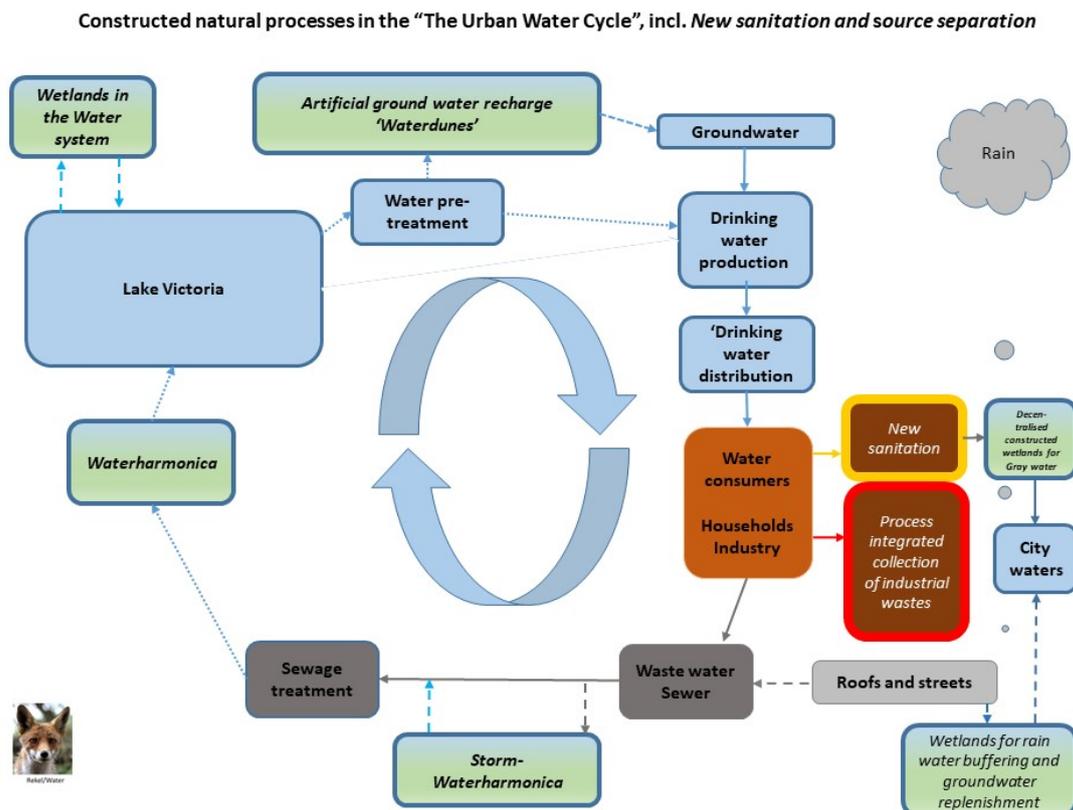


Fig. 2. Constructed natural processes in the “The Urban Water Cycle”, incl. *New sanitation and source separation*.

The volume of ‘human wastes’ in a city like Kisumu is surprisingly low: roughly 2-5 l per person per day. This contains most of the nutrients excreted by humans (60 – 80 % of nitrogen, half of phosphorus, all pathogens, and nearly all pharmaceuticals). The around 400,000 people not connected to the Kisumu sewer systems produce between 720 and 2100 m³ black wastes per day. Depending on the organisation 10 – 40 trucks will be able to transport 120 – 350 truckloads per day. When this system is picked up cleverly then it is even possible to tackle a big part of the pharmaceutical pollution, by separate collection of wastes from hospitals. When these loads would be transported to new digesters and “fertilizer production by drying, composting, etc.” it would not only produce fertilizer but also a considerable amount of “green gas”, also to be used for the trucks. It could be worth expanding incentives for involving and developing private enterprises as household waste management by including a basic business model: Producers of human waste get money per tank, or per day, a privatised company produces and sells fertiliser cheaply, farmers can buy it and increase their income?

WHAT DOES THAT MEAN FOR WETLANDS?

In figure 2 several wetland applications are distinguished:

- a- “Water dunes” and lakes for artificial groundwater recharge for drinking water production;
- b- Wetlands for rain water buffering and water harvesting, also for and groundwater replenishment;
- c- “Stormwaterharmonica’s” for storage of sewage during stormwater event to prevent discharge of diluted sewage during rainy periods;
- d- Waterharmonica’s to change treated waste water into a living and usable surface water;
- e- Natural and constructed wetlands along rivers and lakes.

Above that, when the carbon-load from human wastes is collected separately it becomes attractive to have constructed wetland on a decentralised scale throughout the (semi-) urban area of Kisumu. These constructed wetlands will contribute to human health and well-being, but can also contribute to urban livelihood.

IS THIS CIRCULAR WETLAND APPROACH POSSIBLE IN KISUMU?

To the opinion of the attendants of the workshop (involved were representatives of Water Resources Authority (WRA), Water Services Regulatory Board (WASREB), Lake Victoria South Water Services Board (LVSWSB), Kisumu Water and Sewerage Company (KIWASCO), National Environment Management Authority (NEMA), Lake Victoria Environment Management Project II (LVEMPII), County Government of Kisumu, Mixta farm and also the Nyanza Golf Club). Just some headlines from the workshop: Improve the WWTP Kisat with simple means. The idea of the Waterharmonica seems to be feasible for Kisat and could well be combined with the Nyanza Golf club, situated between the plant and Lake Victoria and fish spawning areas, similar to Waterharmonica's in The Netherlands (Kampf and Van den Boomen, 2013). For the Nyalende ponds the most important conclusion was see the Nyalende ponds as a part of the surroundings, see fig 3 (Kampf, 2017).



Fig. 3. The Nyalende ponds could be a part of a “green-blue lung” of Kisumu

Further recognised aspects are to optimize the ponds, by disconnecting the “human wastes”, including gas production. Thus also lowering the methane losses from the sewage treatment ponds. An important issue is to prevent people from entering the ponds, make a good fence (safety for people and health aspects as people are taking untreated waste water for farming on, even, grabbed land), also to prevent disturbance of birds on the ponds. And include more natural constructed ponds with reed and submerged water plants to turn the water into a more natural water (Waterharmonica approach), as there is a large need for good quality water for irrigation farming and fishponds. And last not least saving wetlands for nature and eco-tourism. This fits well within the plans of the Lake Victoria Environmental Management Project (Bard, 2015).

ACKNOWLEDGEMENTS

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A8. How to convince regulators that wetland treatment is effective

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Constructed wetlands are widely used for treatment of effluent from domestic septic tanks. However many different methods have been used with varying degrees of success.

In the UK, this situation had led to confusion among regulators regarding the capability of Wetland Treatment, and sometimes an over-simplified view that wetlands could not achieve nitrification, or even that wetland treatment “did not work”.

This situation was a source of frustration and concern to UK members of the Constructed Wetland Association, and was brought into focus by a proposed change in regulation in 2014 to make many small sewage discharges exempt from permitting if they were treated by a package treatment plant complying with the appropriate manufacturing standard.

This paper describes the Constructed Wetland Association’s project to allow Wetland treatment Systems an equivalent status to package treatment plants. This was done by bringing together the leading UK designers to agree a UK standard design with specified treatment outcomes.

15.30-17.30 Oral session B – Ecological quality and restoration of wetlands – Chair: Matt Cochran

B1. Nutrient and hydrologic effects on plant structure and functions in two wet grasslands

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INTRODUCTION

Both nutrients and hydrology affect wetland structure and function. Increased nutrient inputs can lead to decreased species diversity with plant communities dominated by competitive species. These species allocate more biomass to aboveground structures with greater plant tissue nutrient contents, which results in more rapid decomposition rates and faster cycling of C and N. Water stress due to drought leads to more biomass allocated to belowground structures, which are nutrient poorer due to slower nutrient uptake rates. Conversely, prolonged flooding leads to greater aboveground growth, but again resulting in structures with lower nutrient contents arising from the onset of anaerobic conditions.

The impact of increased nutrient loading on wet grassland structure and functions have been studied under changing site hydrologic conditions in the South Bohemian region of the Czech Republic. The aim of this presentation is to give an overview of the results - emphasizing the impacts of nutrient additions and hydrologic changes, both singly and their interactions, as well as to address possible future research questions.

METHODS

Field study

Field experiments were established in 2006 in two wet grasslands, one with organic and the other on mineral soil. Nutrient treatments, consisting of 0, 65 or 300 kg NPK * ha⁻¹ * yr⁻¹ of a commercial NPK fertilizer, were added to randomly selected plots in each site. Plant and soil measurements were done in 2007, 2008, and 2012, representing 2, 3, and 7 years of nutrient additions. Hydrologic conditions varied during these years with 2007 and 2008 being dry while 2012 was a wet year with prolonged flooding. Net above and belowground primary productions (NAPP – sequential harvests; NBPP – in-growth bags, respectively) were calculated for both sites in all years as well as the NAPP: NBPP ratio. Also, nutrient contents (C, N, P) of the plant structures were determined as well as their stoichiometric ratios.

Laboratory experiments

Two ¹³C-labeling experiments were conducted to determine the effect of plant species and nutrient addition on C and N cycling in the plant-soil system of two dominant wet grassland species, *Carex acuta* (conservative type) and *Glyceria maxima* (competitive). Specifically, the carbon allocation patterns, production and C fluxes, especially rhizodeposits, were compared between the two species.

RESULTS and DISCUSSION

Plant species composition and diversity did not change over time, however, the differences between the nutrient treatments increased for several of the diversity indices. Aboveground biomass was significantly larger with greater nutrient inputs in 2007 and 2008, but this effect

disappeared by 2012. NAPP increased over time in the organic site, but decreased in the mineral site. NAPP (positive) and NBPP (negative) were differentially affected by changes in site hydrology resulting in significant increases in the NAPP: NBPP ratio with increased flooding. The proportion of total NAPP attributed to particular dominant plant species was also significantly influenced by flood duration. N and P contents were especially affected by nutrient additions and changes in site hydrology.

Belowground biomass increased with greater nutrient inputs in both *C. acuta* and *G. maxima*. However, *G. maxima*, which allocated more belowground C to root exudation under control conditions, greatly decreased this exudation allocation with increased nutrient inputs, a change not seen in *C. acuta*. Thus, mass-specific root growth and rhizodeposition did not change in *G. maxima* with fertilization, while it greatly increased in *C. acuta*. Overall, there is a stronger connection between *G. maxima* and soil microbes. This significant species effect can greatly impact C and N fluxes in wetland ecosystems.

ACKNOWLEDGEMENTS

Financial support for the studies and experiments that make up this presentation came from grants from the Grant Agency of the Czech Republic (526/09/1545 awarded to KRE and 16-21743S awarded to EK). We thank all of the numerous technicians and students who assisted with the field and laboratory aspects of the study.

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B2. Managing hydrology and waterfowl grazing to reduce wetland methane flux

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INTRODUCTION

Hydrologically managed wetlands provide critical habitat for migratory waterfowl. Such ‘waterfowl impoundment’ systems are hosting increasingly dense aggregations of birds as populations have increased and natural wetlands have been lost over the past century. Because of the intense grazing pressure they receive and a prescribed hydrologic regime, these waterfowl wetlands represent ideal settings for unravelling effects and interactions of plants, herbivores and hydrology on dynamics of methane (CH₄) emissions at field scale. Despite the ubiquity of waterfowl impoundment systems, they have been almost completely ignored by studies of wetland greenhouse gas biogeochemistry.

METHODS

To test for grazing effects on methane, we implemented a 2-year herbivore enclosure experiment in a waterfowl impoundment at a wildlife refuge in North Carolina, USA. We measured methane emissions using transparent static chambers.

RESULTS and DISCUSSION

We found that exclusion of waterfowl led to a dramatic increase in the density of the emergent *Eleocharis quadrangulata* and reduced mean cumulative CH₄ flux by 29 to 84 percent, presumably because of radial oxygen loss from plant roots into wetland sediments as indicated by soil pore water chemistry. In addition the arrival of a new refuge manager in the second year of our study allowed us to test the impact of a change in the timing of prescribed impoundment dewatering. We found that hydrologic management leading to exposed wetland surface soils a month earlier in the second year’s growing season led to a major decrease in CH₄ emissions (roughly 70%).

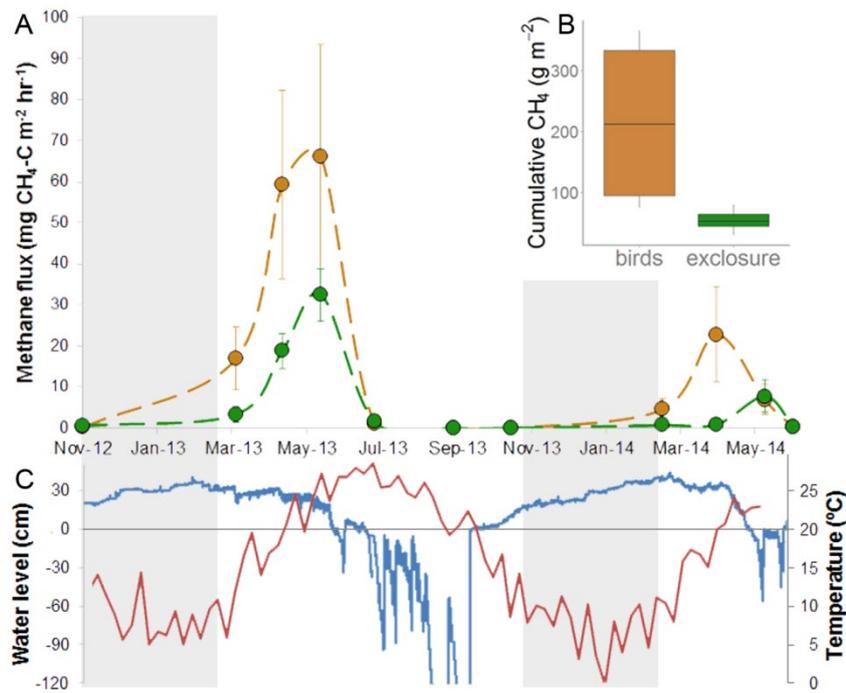


Fig. 1. Effects of waterfowl on seasonal methane flux and long-term cumulative emission in context of site conditions. (A) Seasonal mean (\pm standard error) methane (CH₄) flux measured in bird-affected (brown) and exclosure (green) plots at Mattamuskeet National Wildlife Refuge in North Carolina, USA from December 2012 through June 2014. (B) Tukey boxplots (whiskers represent 1.5 of interquartile range) of cumulative CH₄ emitted over the course of the study based on extrapolation of flux between sampling periods. We found mean cumulative CH₄ flux to be significantly higher from “bird” plots ($p = 0.026$; Welch’s one-tailed t-test). Data were log-transformed to conform to the assumption of variance homogeneity. (C) Water level (blue curve) and water temperature (red curve) are the principle abiotic factors influencing seasonal fluctuations in CH₄ flux over the course of the experiment. Gray shading delineates peak waterfowl seasons. Maximum depth of water level recorders in soil is approximately 120 cm.

These results suggest that relatively minor adjustments to waterfowl impoundment management protocols can lead to significant abatement in seasonal CH₄ flux, and may represent a promising avenue for greenhouse gas mitigation given the inventory of 1.5 million hectares of federally-owned waterfowl production areas in the United States.

ACKNOWLEDGEMENTS

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B3. Exposure and vulnerability of small lentic water bodies to pesticides

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INTRODUCTION

Small water bodies (SWB) are freshwater ecosystems of high ecological relevance. However, they receive considerably higher inputs of pesticides compared to larger water bodies owing to their close connection to adjacent agricultural fields in combination with their low water volume or discharge. It was recently shown that a disproportionately low amount of studies addresses pesticide occurrence and impacts in SWB with largely limited available data on pesticide effects for natural lentic SWB (ponds, kettle holes, small lakes) (Lorenz et al. 2017). Successful management of pesticide risks for lentic SWB requires knowledge concerning the environmental concentrations of chemicals. Particularly the monitoring of the pesticide contamination of lentic SWB is challenging as spatial and temporal factors affect pesticide concentrations in the water bodies.

This presentation exemplifies the magnitude of pesticide contamination across the north-eastern German pondscape. Furthermore, we relate occurrence of pesticides and calculated toxicities to near-distance landscape parameters to identify key drivers of contamination.

METHODS

Grab water samples were collected from April to May in 2013-2017 at 92 SWB over Northern Germany, stored at 4°C and analysed as soon as possible. We monitored in total 71 pesticide active substances (32 herbicides, 22 fungicides, and 17 insecticides). All water samples were analysed using a multi method validated for 81 active substances (Lorenz et al. 2018). Water samples were filtered (4-7 µm folded filter) and tebuconazole D6 as surrogate-standard was added. The surrogate-standard was used to secure analytical measurement procedures and result evaluation, and not for result corrections. Liquid chromatography (LC) coupled with mass spectrometry (MS) was used for pesticide identification and quantification after solid phase extraction (Chromabond HR-P cartridges). The limit of detection for the analysed active substances was 0.0002 µg/L and the limit of quantification was 0.001 µg/L. The pesticides were identified by their retention time and MRM transitions using a Dionex UltiMate 3000 LC-system coupled to an AB SCIEX QTRAP 5500-mass spectrometer (LC-MS/MS). The pesticides were quantified with reference standards in solvent and quantification followed the internal standard method.

Landscape parameters such as slope, buffer width, cover of different vegetation types, crop type were mapped on-site during grab sampling or extracted from GoogleEarth (embankment width, area).

RESULTS and DISCUSSION

Our results show that multiple pesticide contamination of SWB located in agricultural fields frequently occurs (Table 1). However, regulatory acceptable concentrations which are considered ecologically relevant (Szöcs et al. 2018) are exceeded only in particular cases. Buffer zones seem to be suitable tools to reduce pesticide concentrations in agricultural SWB resulting from spray drift and run-off. However, only a minor amount of SWB shows artificially created buffer that may sufficiently reduce pesticide entries below ecologically

relevant concentrations. Natural embankment formation emerged as the most prominent predictor of contamination. Furthermore, sub-surface water flow may constantly deliver pesticides to SWB that have been applied either several years ago or at non-adjacent agricultural fields (Ulrich et al. 2018). In this regard, our results point on the importance of local, target-orientated protection schemes such as functional buffer strips (Arora et al. 2010).

Table 1. Overview on the contamination of north-eastern German lentic small water bodies with pesticides.

	agriculture	pasture	reference	small lakes
number SWB sampled	75	3	11	3
number of samples	181	12	14	3
pesticides detected	4.5 ± 2.7	1	0.9 ± 0.9	1
max. concentration	< 2.8 µg/L	< LOQ	< 0.048 µg/L	0.007 µg/L
exceedances of regulatory acceptable concentrations	44	-	-	1

ACKNOWLEDGEMENTS

The authors thank Elke Zeidler, Agnes Wolf, Dominique Conrad, Uwe Gräf and Manuel König for their significant support during the chemical monitoring especially in the retrieval of samples from the fields. We thank Ina Stachewicz-Voigt, Gabi Smykalla, Bärbel Große and Christine Reichmann for the sample preparation and residue analysis.

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B4. Riparian grey alder forest ecosystem response to sudden flooding: The FluxGAF experiment

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INTRODUCTION

Understanding the capacity of ecosystems to adapt to environmental modifications is the key to predict ecosystem responses to global change. The **FluxGAF** campaign (“Biogeochemical **Fluxes** in a **Grey Alder Forest**”) was a large-scale forest manipulation experiment to gain insight into how forest ecosystems during active growth period can respond to flash floods that are predicted to become more frequent in future climates.

METHODS

The study was in a 40-yr old riparian *Filipendula*-type grey alder (*Alnus incana*) stand on former agricultural land (*Umbric Planosol*) in Estonia. Two experimental plots were established in 2017: a flooded plot (FP; 40×40 m) where water was pumped using an irrigation pipe system (2 weeks, each day 55-70 m³), and a control plot (CP; 20×20 m). The study period was divided into three periods: pre-flooding (8 July–7 August), flooding (8-21 August), and post-flooding (22 August –7 November). During flooding, 875 m³ of water was provided to 1600 m² forest area, corresponding to 547 mm precipitation.

From 25 m eddy tower following fluxes were measured: CO₂ & H₂O (Licor Li-7200), CH₄ & N₂O (Aerodyne QCL-Tildas), VOCs (PTR-TOF-MS). In FP, 8 microsites were equipped with CO₂, CH₄, N₂O chambers (automatic soil chambers (Picarro 2508), tree stem chambers (TSC; 0.1, 0.8 and 1.8 m from ground level)), piezometers, automatic groundwater level wells, soil temperature and moisture sensors (0-10 cm). Four analogous microsites were established in CP. From TSCs, during 28 campaigns CO₂ flux was measured by EGM-5 analyser; CH₄ and N₂O gas samples (0, 60, 120 and 180 min) were analysed in the lab by Shimadzu GC2400. In each microsite, during 7 campaigns (three in flooding period), composite soil samples from 0-10 and 30-40 cm were taken for physico-chemical, N₂ flux and transcriptomic analysis in labs. During 8 campaigns, groundwater parameters were analysed. In 8 microsites (four in FP), root C exudation cuvettes around fine roots were installed. In 8 sessions, in situ leaf photosynthesis activity of different plants was measured using portable Walz GFS-3000.

RESULTS and DISCUSSION

The forest sequesters C, whereas NEE of CO₂ decreased during flooding; it was associated with reduced leaf-level photosynthesis in the over- and understory species. Among VOCs, methanol and isoprene showed increasing flux. Eddy fluxes of CH₄ and N₂O showed diurnal pattern with lower values in night-time but no increase during flooding. Soil CO₂ emission

decreased and CH₄ fluxes increased when flooded. It was coherent with water table in wells and soil moisture values. However, the clearest flooding effect was found in N cycles: during flooding cycle, in FP soil N₂O flux significantly increased whereas chambers in CP did not show any trends. Simultaneously, NO₃ concentration in soil of FP decreased and NH₄ concentration increased during flooding, compared to CP. In FP, CH₄ and N₂O fluxes from TSCs of lowest positions increased during flooding. As a direct stress response to flooding, in FP trees grew aerial roots. After flooding, tree root C exudate rate was higher than in CP.

CONCLUSIONS

Our preliminary results show that the intensive flooding event in the middle of the growing season caused a clear stress in some aspects of the riparian grey alder forest ecosystem functions. The clearest effect was observed in alteration of the nitrogen cycle. Further analysis will help clarifying response of microbial communities on flooding stress.

Results of this experiment provide an important opportunity to include such climatic extremes into global models.

ACKNOWLEDGEMENTS

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B5. Riverine landscapes and their floodplains in transformation – challenges for utilization of ecosystem services and biodiversity conservation in the Danube River

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EXTENDED ABSTRACT

Riverine landscapes are key ecosystems providing a multitude of ecosystem services that are vital for human societies. Moreover, rivers have a high strategic importance for global ecological functions and biodiversity. At the same time, in most of the large river systems worldwide, a tremendous reduction of floodplain area has occurred in the last 100 years and this loss continues due to pressures such as land use change, river regulation and dam construction and affect the overall quality of riverine landscapes.

The Danube River and its basin – as many other large river systems in the world – have experienced severe ecosystem changes and alterations due to multiple human-induced pressures, highly threatening the system's ecological integrity. These threats also impair the provision of a variety of ecosystem services that build the basis for human wellbeing in the entire Danube region. In the Danube River Basin, the extent of floodplains for example has been reduced by 68 % compared to their pre-regulation area, with the highest losses occurring in the Upper Danube and the lowest in the Danube Delta. These reductions limit the overall ecological connectivity and thus, threaten biodiversity along the river course as well as in specific floodplain sections.

In turn, the mitigation of human-induced pressures is a key issue for river basin management, aiming to improve the ecological status and integrity, and to guarantee the provision of ecosystem services. With regard to the Danube River Basin Management Plan, several significant water management issues have been identified related to different aspects of pollution and hydromorphological alterations. These management issues are closely related to the current status of floodplains and their restoration potential. In this paper we address several aspects important for floodplain restoration and biodiversity conservation in large riverine landscapes.

B6. Development of hydrologic criteria for managing subtropical wetlands in Florida, USA

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INTRODUCTION

The Upper St. Johns River Basin (USJRB) in central Florida, USA is a complex and diverse ecosystem characterized by a mosaic of marsh habitats that visually resemble the Florida Everglades. It is an ecosystem of national and regional significance and is considered a hotspot of biodiversity that supports numerous threatened or endangered species. The vast wetlands of the USJRB (162,000 hectares) provide important ecosystem services such as flood control, water supply, water quality improvement, carbon storage, habitat, public recreational and cultural uses, and food provisioning. Paramount in managing ecosystem services in the USJRB is the challenge of implementing water management strategies that balance the need for flood protection and water supply with the needs of the biological components of the ecosystem.

Beginning in the early 1900s, over half the historic USJRB floodplain was drained and converted to agriculture (Lowe et al. 1984). Drainage activities not only reduced wetland area, but also significantly altered the natural hydrology of the remaining system by reducing water retention times, lowering water levels, and accelerating downstream flows. Additionally, agricultural runoff directly degraded water quality. To provide additional flood protection, large canals were excavated to divert flood waters directly to the east coast into the Indian River Lagoon estuary (IRL). Recognizing the environmental damage caused by the over-drainage of USJRB wetlands and the diversion of large amounts of freshwater to the coast, the St. Johns River Water Management District (District) and the U. S. Army Corps of Engineers (Corps) partnered in the 1980s to develop the Upper St. Johns River Basin Project (USJRBP) utilizing a “semi-structural” approach to water management. With this approach, wetland storage capacity within the USJRB was expanded through the acquisition of previously drained floodplain, in conjunction with the construction of retaining levees, and water control structures that allowed floodwater to be temporarily impounded and managed on these restored wetlands (Sterling and Padera 1998). In addition to enhanced flood protection, other benefits of the USJRBP were improved water quality, the creation of a water supply source for agriculture, restoration of basin wetlands, and a dramatic reduction of freshwater discharges to the IRL.

Structure operation schedules allow for stormwater storage (Figure 1). To provide excess storage capacity, water levels are lowered prior to the onset of the rainy season (June to Sept) and then allowed to remain higher during the dry season (December to May). When water levels exceed Zone A (Figure 1), the maximum storage capacity of the project area has been reached and large-scale discharges must be made downstream for flood control. However, from a wetland restoration and enhancement perspective, if water levels strictly follow the flood control schedule, basin wetlands would experience hydrologic conditions opposite to those experienced naturally. For example, with Zone A operation, the lowest annual water levels would occur during the rainy summer months and the highest annual water levels would occur during the typical dry season. To allow for the re-creation of more natural hydroperiods, the concept of “Zone B” discharges has been integrated into the operation of USJRBP water control structures (Figure 1). Zone B discharges can be made for environmental purposes whenever water levels are below the flood control regulation schedule.

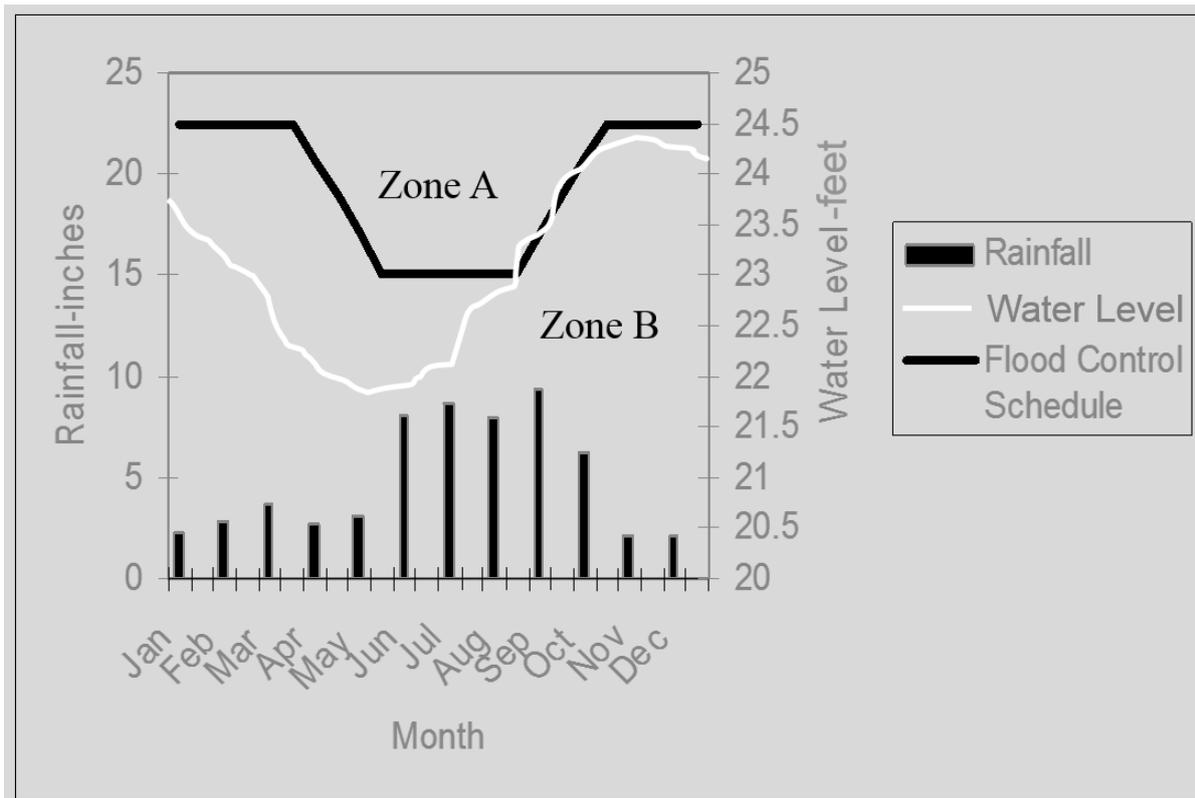


Fig. 1. Flood control regulation schedule for Blue Cypress Marsh Conservation Area (BCMCA) showing Zones A and B. When water levels within this project area are equal to or above the flood control schedule (Zone A), water storage capacity has been reached and downstream discharges from the area must occur to ensure water levels fall below the regulation schedule within 15 days. When water levels (measured in feet NAVD88) are below the flood control schedule (Zone B), no discharges are required by the Corps and the District may make Zone B discharges to meet secondary environmental or water supply goals.

For environmental enhancement and to attempt to restore the spatial and temporal attributes of a more natural hydrologic regime using Zone B discharges, an Environmental Water Management Plan (EWMP; Miller et al. 2003) was drafted to direct operation of water control structures when not being operated for flood control. Zone B operations in the EWMP are an attempt to meet a suite of environmental hydrologic criteria (EHC) that provide numerical targets representing optimal hydrologic conditions for USJRB wetlands. In this paper, we describe the individual EHC, the rationale behind their selection, and how we developed quantifiable numerical targets for each. The EHC have been used with hydrologic modelling to develop optimal discharge schedules and to provide a direct quantifiable method for assessing the long-term environmental performance of each project area.

METHODS

The environmental hydrologic goal of the USJRB is to restore, to the greatest extent possible, the natural hydrologic regime that shaped and maintained the historic wetland ecosystem. Defining a “natural” hydrologic regime was a 4-step process. First, we identified important hydrologic characteristics from the scientific literature. These included depths, inundation frequencies, maximum flooding depths, magnitude and durations of water-level fluctuations, timing of water level fluctuations, and water level fluctuation rates. We then considered historic hydrologic data related to these attributes, in conjunction with plant community distribution, from the more pristine areas of the USJRB. Using topographic information in each project area, we then developed stage-area or wetted perimeter curves, which were used to determine what we termed “reference” elevations. Finally, we established

a set of numerical criteria to quantify targets or EHC, related to the intensity, duration, and return frequency for various water levels relative to the identified “reference” elevations and their observed relationships to soil and plant community distributions. All EHC were compiled into a complete suite of hydrologic criteria that delimited the boundaries of the optimal hydrologic regime in each project area. Overall, the objective was to develop a suite of easily understandable and measurable criteria that would re-establish or maintain the hydrologic characteristics to which this ecosystem had formed and adapted.

RESULTS and DISCUSSION

A summary of EHC, their ecological significance and how they are measured are presented in Table 1. Hydrologic parameters that we deemed most important included: mean depth, inundation frequency, maximum depth, magnitude and duration of water-level fluctuations, seasonality of water level fluctuation, and water level recession rate. Our EHC are similar to the critical components of flow and water level regimes proposed by other researchers to regulate ecological processes in river ecosystems (Richter et al. 1996, Poff et al. 1997). To best meet environmental goals, hydrologic conditions should simultaneously fall within the boundaries delineated for each of the various EHC. For the most part, EHC are also viewed with a long term (30+ years) perspective. This long-term perspective helps account for the natural variability inherent in the hydrologic cycle. Instead of defining a level associated with ecological harm, EHC are used to delimit optimal hydrologic metrics that serve as targets for water management, not regulatory goals.

Description of EHC

To quantify numerical hydrologic targets, we established reference elevations that were based on the inflection points on a stage area curve and on transitional elevations between habitat types (Figure 2). Mean depth and frequency of inundation are considered to be primary determinants of plant and animal community structure and have a major effect on the accretion and subsidence of organic soils (Table 1). In recent studies, we found the rate of carbon loss in deep organic soils, underlying most USJRB wetlands, is accelerated more than two times when water levels fall 10cm below the soil surface (Osborne et al. 2014). In order to protect these organic soils, we instituted a conservative criterion that the 30-yr average water elevation should be no less than the maximum ground elevation occupied by organic soil. In addition, the frequency of inundation at this marsh elevation should be at least 60% to prevent skewed water level data from affecting calculation of a mean. For the BCMCA, the mean water elevation should be no less than 22.5 ft or 6.86 m (Figure 2). Extreme flooding is a natural disturbance in wetland ecosystems. However, the frequency in which those events occur is usually quite low. Prolonged flooding from flood control storage could potentially cause long-term damage and extensive mortality to wetland emergent plant communities. To prevent flood damage to USRBP wetlands, we established 14-day and 30-day maximum flooding criteria of 4.0 and 3.5 ft (1.22 and 1.07 m) above the lowest ground elevation occupied by emergent wetland plants. In the case of BCMCA, 14-day and 30-day levels correspond to 25.5 ft (7.77 m) and 25.0 ft (7.62 m), based on a reference elevation of 21.52 ft. (6.56 m) (Figure 2). These flooding elevations and durations should not be exceeded more frequently than 1 year out of 10.

Periodic seasonal drying of emergent wetlands is important for maintaining species diversity, encouraging recruitment of wetland plants, influencing biological productivity in a host of wetland dependant organisms, and facilitating energy, nutrient and sediment exchange between the marshes and lakes / river channel. However, frequent and intense drying could cause undesirable plant community shifts, like the expansion of woody shrubs (Hall et al., 2017). Considering these factors, we established that the lower elevational limit occupied

Table 1. Summary of hydrologic criteria used to develop Zone B regulation schedules in the Upper St. Johns River Basin Project (Miller et al. 1996).

Hydrologic criteria	Ecological significance	Measured parameters	References
Mean depth; frequency of inundation	Influences plant distribution; Prevents oxidation of organic soils	Mean daily values; percentage of time water levels exceed a given ground elevation	Brooks and Lowe 1984, Lowe 1983, Stephens 1984
Maximum water levels	Prevents prolonged flooding from damaging marsh plant communities	Annual 14-day continuous maxima; annual 30-day continuous maxima; annual 60-day continuous maxima	Biagiotti-Griggs and Girardin 1980, Lowe 1983, Whitlow and Harris 1979
Minimum range of yearly fluctuation	Important to plant germination, plant community composition, wading bird foraging, snail kite nesting	Annual 30-day continuous maxima; annual 30-day continuous minima; annual range between daily high and low	Bancroft et al. 1990, Bernetts et al. 1998, Gunderson 1994, Kushlan et al. 1975, Kushlan 1976, Mitsch and Gosselink 1986
Timing of fluctuation	Important to wading bird and alligator breeding cycles; fish community structure	Julian date of annual one-day maxima and one-day minima	Fogarty 1984, Frederick and Collopy 1989, Kushlan et al. 1975, Kushlan 1976, Loftus and Kushlan 1987
Water level recession rates	Influences wading bird nesting; too rapid recession can cause anoxia and fish kills	Negative difference between daily means at 7- and 30-day intervals	Frederick and Collopy 1975, Kushlan et al. 1975, Toth et al. 1990

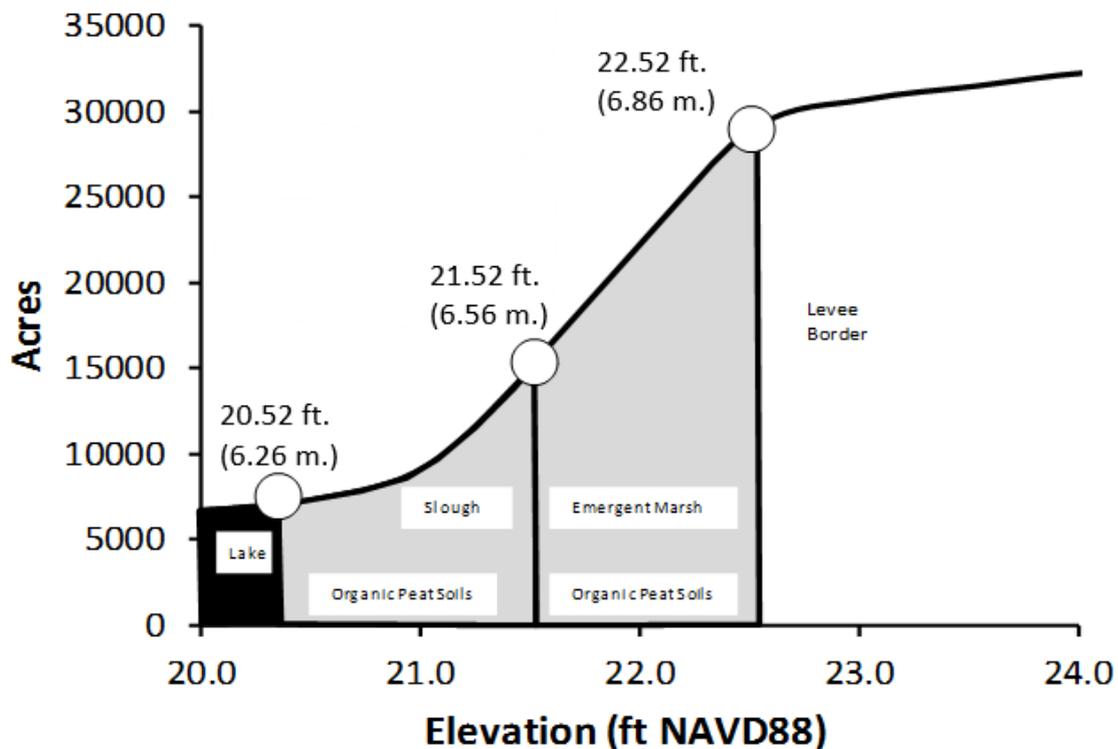


Fig. 2. Stage-area curve for the BCMCA showing elevation breaks between Blue Cypress Lake, slough, and emergent marsh habitats. Circles correspond to the reference elevations determined for this project area. The datum for elevations is feet NAVD88 and values in parentheses are converted to meters. The conversion of acres to hectares is 1 acre = 0.4047 hectares.

by emergent plant communities should be exposed for 30-continuous days at least once every 4 years. For BCMCA, this equates to an elevation of 21.52 ft (6.56 m) (Figure 2). However, to prevent undesirable community shifts, the lowest elevation of the deeper slough communities should not be exposed for 60 continuous days or longer, more frequently than once every 10 years.

Timing of water level fluctuation is extremely important to the reproductive cycles of many plants and animals that have adapted to seasonal rainfall patterns in Florida, such as the endangered Snail Kite (Table 1). Additionally, the proper timing in flooding and drydown is a key factor in providing foraging habitat for migrating waterfowl. We determined that the annual 1-day maximum water elevation should occur during the end of the rainy season in Florida (Aug. 1 – Nov. 30) in greater than 50% of the years. The annual 1-day minimum should occur at the end of the dry season in Florida (Apr. 1 – Jun. 30) in greater than 50% of the years.

Water level recession rates can have dramatic effects on dissolved oxygen levels. In several aquatic ecosystems in Florida, rapid water level recession rates have caused extensive fish kills. We have successfully implemented an EHC based on historic water levels, whereby water levels should not fall more than 1.2 feet (0.37 m) during any 30-day period or 0.5 feet (0.15 m) during any 7-day period.

CONCLUSIONS

In the USJRBP, we have established EHC that numerically quantify what we consider to be optimal hydrologic conditions for wetlands in the basin. The EHC address important hydrologic metrics including mean depth, inundation frequency, maximum depth, magnitude and duration of water-level fluctuation, seasonality of water level fluctuation, and water level recession rate. Our EHC provide a valuable tool for input into hydrologic modelling necessary to develop optimal operation schedules for project water control structures and for assessing overall project performance toward meeting the environmental goals established for the project. We intend to regularly evaluate and refine the criteria and use an adaptive management approach to ensure that the ecosystem services of these valuable wetlands will be sustainable far into the future.

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Flanders (Belgium) lost 75% of its wetlands during the past 50-60 years. But restoration pays back.

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INTRODUCTION

For the case of Flanders (the densely populated northern part of Belgium, covering 13,522 km²), our study (1) tracks the loss of different wetland types since the 1950's as accurately as possible via geospatial mapping; (2) maps two realistic wetland restoration (and creation) scenarios; (3) demonstrates potential socio-economic (ecosystem service) benefits of both scenarios and (4) demonstrates how these insights can be used to support policy making.

METHODS

Wetland classification and mapping of wetland loss and restoration potential

In our study we defined wetlands as temporary or permanently wet, non-marine areas where typical wetland biodiversity is (still) more or less present. Consequently, 'lost wetlands' must be understood as areas that, apart from ditches and small rivers or ponds, can no longer be considered as 'wet' and lack typical wetland communities, including the temporary residing of migrating waterfowl. In our case wetland loss is not to be confused with degraded, damaged or polluted wetlands, as it is sometimes discussed in other literature (Davidson 2014).

We distinguished seven wetland categories (Table 1) based on drainage class (open water, permanently or temporary wet soil, tidal marsh) and trophic state (meso-, eu- or oligotrophic). Open waters (artificial water bodies, lakes and large ponds) were included in the mapping and calculation of historical wetland loss, but were not considered in the restoration scenarios as their restoration/creation preconditions are less stringent.

Spatial analysis considered the following main maps:

- the Flemish Soil Map, based on a detailed soil and drainage survey in (mainly) the 1950-1960's, was interpreted as a reference map for historical environmental conditions and presence of different wetland types;
- the Biological Valuation Map, surveyed in the period 1998-2007, shows the actual distribution of wetlands and was used to assess shifts in drainage class and land use as opposed to the Flemish Soil Map;
- the Flood Hazard Map of 2014 (produced for the EU Floods Directive and adapted by excluding urban areas and arable land) indicates flood plain areas where biological values may actually still be present (e.g. waterfowl) or could be restored;
- maps derived from the innovative 'POTNAT model' which modeled potentials for the restoration or creation of 18 wetland habitat types based on local abiotic and biotic conditions (Wouters et al. 2013);
- Additional maps on tidal marshes, historic forest cover and current land use.

For GIS analysis all maps were transformed into grid cells of 20x20m. The area of water courses was considered constant over time and excluded from the analysis in order to avoid large errors in the calculation of area due to this grid transformation. All currently urbanized areas were considered to be not suitable for wetland restoration. For non-urbanized areas we assumed that on the long term the environmental conditions, as they were recorded in the 1950's, can be restored with appropriate measures.

Table 1. Wetland typology of the study, their encompassing habitat types and indication whether or not potentials for restoration were calculated..

Wetland categories	Main habitat types	Calculation of restoration potential
1. Deep open waters	Artificial water bodies such as extraction pits and harbor docks	No
2. Shallow open waters (oligo-mesotrophic/eutrophic)	Lakes and large ponds	No
3. Wetlands on meso-eutrophic, temporary wet soils	floodplain and polder grasslands and floodplain forests	Yes
4. Wetlands on oligotrophic, temporary wet soils	moist-wet heaths, birch-alder-oak woods on sandy/peaty soil	Yes
5. Wetlands on meso-eutrophic, permanently wet soils	rich fens, reed and sedge marshes, alder and willow swamps	Yes
6. Wetlands on oligotrophic, permanently wet soils	wet heaths, poor fens, peat bogs, birch and alder sphagnum woods	Yes
7. Tidal marsh	salt, brackish and freshwater tidal areas (rivers excluded)	Yes

For the calculation of the area of potential wetlands we distinguished two management scenarios: (1) an open landscape scenario and (2) a closed landscape (forested) scenario. To obtain realistic scenarios, the legal protection ('standstill principle') for existing forests and open habitat types with nature value were taken into account. Further details about maps and spatial analysis are provided in Decler et al. (2016).

Socio-economic potential of wetland restoration

The ecosystem service supply potential of the restoration scenarios is demonstrated by estimating a monetary value for a selection of five services for which reliable monetary data are available from the ECOPLAN project (ECOPLAN 2012-2016):

- Wood production;
- climate regulation (as carbon storage in soils);
- food production
- water quality regulation
- flood risk regulation (as water quantity regulation)

The quantification and valuation methods have all been developed specifically for the Flemish Region (Broekx et al. 2013a, Broekx et al. 2013b, VITO 2014) and adapted to spatial explicit models at high resolution (ECOPLAN-project). This monetization only aims at demonstrating the socio-economic relevance of the multiple benefits from wetlands. For all five services, the two scenarios were compared to the actual land-use as baseline. Further details are provided in Decler et al. (2016).

RESULTS and DISCUSSION

Change in wetland area over time

In the 1950's still 244,000 ha (19% of Flanders) could be considered 'wetland'. Currently only 68,000 ha (5% of Flanders) remains, implying a substantial loss of almost 75% of wetland habitats over 50-60 years' time. 37,000 ha (15%) has been urbanized; the rest was mainly lost as a consequence of intensification of agriculture and to a lesser extent also for an increase in forest production. The proportion of wetland loss differs between categories, with oligotrophic wetlands on temporary wet soils (both open and forested) and open oligotrophic and meso-eutrophic wetlands on permanent wet soils being most affected with a decrease of 95% (table 2).

Potential for wetland restoration

According to our calculations (table 2) there is still a potential to restore 147,000 ha of wetland in Flanders (deep and shallow waters excluded). On the long term this could bring the total amount of wetland to 215,000 ha or 17% of the territory. With appropriate measures to restore the conditions of the 1950s, floodplain grasslands and forests and wet polder areas can theoretically triple in surface area to a significant 120,000 ha. Oligotrophic wetland habitats on temporary wet soils could increase 14-fold to 26,500 ha. Restoration of wetlands on permanently wet soils would lead to a 6-fold increase of open and forested wetland habitats: 36,500 ha on meso-eutrophic soils and 4,500 ha on oligotrophic soils, or 72% respectively 88% of the original surface area of the 1950s. There is a huge potential for the restoration of tidal marsh along the river Schelde if embankments are moved inland. With many of these embankments already in place in the 1950s, this implies a 3-fold increase in area compared to the reference period and a 15-fold increase in area compared to the current situation. The potential for restoration of shallow waters was not calculated: in principle they can be artificially created in many sites.

Current ambition level for wetland restoration in Flanders by 2050

Table 2 also shows the official ambition level for wetland restoration in Flanders, calculated as the legally defined conservation objectives for the implementation of the Habitats and Birds Directives. We therefor translated the goals for habitat types and habitats of protected wetland species into our seven wetland categories. Comparing the 'restoration opportunity' and the objectives for wetland expansion in the Flemish Natura 2000 policy a significant discrepancy between the two figures appears. Present policy foresees a total wetland expansion of 8,900-13,000 ha (or 7,400-10,600 ha with open waters excluded) by 2050, including 1,800-3,000 ha forested wetland and 2,500 ha tidal marsh. Especially the ambitions for oligotrophic and meso-eutrophic wetlands on temporary wet soils and meso-eutrophic wetlands on permanently wet soils appear to be very modest with an increase of only 1-8 % of the restoration opportunity. With a projected increase of 19-26% of the potential restorable surface, ambition levels are significantly higher for tidal marsh and wetlands on oligotrophic permanently wet soils.

Valuation of selected ecosystem services

Absolute losses and gains in wood production, climate regulation, food production, water quality regulation and flood risk regulation under the restoration scenarios are shown in Table 3. The data used for this exercise are the best available data on ES supply at this moment. Agricultural production losses for the forested landscape scenario amount up to 185 mio € per year, which is 14 % of the total agricultural production compared to the current situation. If extensive agriculture is allowed on the temporary wet zones, this impact would be reduced with 50 mio €. Note that the real economic balance could look very different when taking into account changes in subsidies which would follow from a decrease in agricultural surface.

Benefits for water quality regulation (total nitrate release to surface water) are comparable for both scenarios, but depend on different aspects. While nitrate leaching is reduced most in the forested scenario, denitrification is decreasing significantly. In the open landscape scenario, nitrate leaching decreases less dramatically (11.3% instead of 16 % for forested), but denitrification is relatively more performant since the decrease is only 4.2 % (instead of 12% for forested). The monetary benefit ranges from 15 to 225 mio € per year. The high estimate (74 €/kg N-NO₃) is based on shadow prices of effectively implemented policy measures for nitrate in surface water (marginal cost method). Implementing a large scale restoration scenario that decreases nitrate release up to 20 %, would make a range of current technical measures dispensable.

Table 2. Decrease of the area of different wetland categories in Flanders during the past 50-60 years (in ha and %) and restoration potential still present according to a forested and open landscape scenario (in ha). In the right column current ambition levels of the Flemish Government by 2050 are mentioned (*: ambitions grouped under floodplain forests).

Wetland categories	Decrease (in ha)	Decrease (in %)	Potentials for wetland restoration (2 scenario's)		Ambition level Flanders 2050
			Open landscape	Forested landscape	Min-max (in ha)
Wetlands on temporary wet soils					
Oligotrophic - open	- 24.000	-95%	+ 20.500	+ 1.300	128
Oligotrophic - forested	- 7.000	-92 %	+ 4.100	+ 23.300	*
Meso-eutrophic - open	- 94.000	-73 %	+ 74.800	+ 13.000	1.690-3.275
Meso-eutrophic - forested	- 8.000	-56%	+ 2.800	+ 64.600	1.800-3.000
Wetlands on permanent wet soils					
Oligotrophic - open	-4.000	-94%	+ 2.800	+ 700	736-966
Oligotrophic - forested	-500	-47%	+ 1.100	+ 3.100	*
Meso-eutrophic - open	-41.500	-94%	+ 27.000	+ 9.300	571-775
Meso-eutrophic - forested	-4.500	-62%	+ 4.100	+ 21.800	*
Tidal marshes					
open	-2.300	-81%	+ 8.800	+ 3.200	2.481-2.491
forested	-50	-33%	+ 700	+ 6.200	
Open water					
Shallow water (oligo-mesotrophic & eutrophic)	+6.000	+216%	-	-	1.485-2.366
Deep water	+4.500	+293%	-	-	-

Carbon sequestration in soils is relatively insensitive compared to the total stock in the Flemish Region, but highest under the forested scenario. The nature conservation management and agricultural management imply harvest of aboveground biomass, which results in less input to the soil compartment. This however does not mean that local changes cannot be important. Especially for the permanently wet ecosystems, active peat formation could be restored. Unfortunately, the quantification methods for soil organic carbon do not incorporate carbon stocks from potential peat formation.

Water quantity regulation is an ecosystem service that is likely to become more important in the next decades. Rewetting former wetland ecosystems allows increasing water retention with 7.6 % under the forested scenario and with 4.8 % under the open landscape scenario. This volume of additionally retained water compares to a river with a steady flow of resp. 2.8 and 1.8 m³/s. Whether the retained water could all be used for consumption can be disputed, but on the other hand this will be a service that is of strategic and crucial importance in terms of climate adaptation.

While more data and discussion on the ecosystem services of the wetland restoration scenarios for Flanders can be found in Decler et al. (2016), we showed that benefits derived from the regulating services (water quantity regulation, water quality regulation and carbon storage in soils) range from 20 to 268 mio €/yr. The decrease in production services (agriculture and timber production) ranges from 137 to 186 mio €/yr. Much can be debated about the quantification and valuation methods, including the validity of the scenario. Nevertheless these estimates demonstrate that for at least three services, substantial benefits could be obtained.

Table 3. Absolute losses and gains in biophysical and monetary terms for the current situation compared to a forested and open landscape wetland restoration scenario.

Ecosystem Service	Unit Value*	Scenario		
		Current	Forest	Open landscape
Water Quantity Regulation				
Water Quantity Regulation (km ³ /yr)		1,15	1,24	1,20
Change in Water Quantity regulation (km ³ /yr)		0 (ref)	0,09 (7,6%)	0,06 (4,8%)
Low estimate water Quantity Regulation (mio €/yr)	0,075 €/m³		6,5	4,2
Mean estimate water Quantity Regulation (mio €/yr)	0,1375 €/m³		12,0	7,6
High estimate water Quantity Regulation (mio €/yr)	0,2 €/m³		17,4	11,1
Water Quality Regulation				
Total Nitrate leaching (tonne N-NO ₃ /yr)		33.764	28.375	29.933
Avoided Nitrate leaching (tonne N-NO ₃ /yr)		0 (ref)	5389 (-16%)	3831 (-11,3%)
Denitrification (tonne N-NO ₃ /yr)		19.268	16.955	18.462
Change in denitrification (tonne N-NO ₃ /yr)		0 (ref)	-2314 (-12%)	-806 (-4,2%)
Total immission to surface water (tonne N-NO ₃ /yr)		14.496	11.421	11.471
Total avoided immission to surface water (tonne N-NO ₃ /yr)		0 (ref)	3075 (-21,2%)	3024 (-20,9%)
Low estimate avoided N-immission to surface water (mio €/yr)	5 €/kg		15,4	15,1
Mean estimate avoided N-immission to surface water (mio €/yr)	39,5 €/kg		121,5	119,5
High estimate avoided N-immission to surface water (mio €/yr)	74 €/kg		227,6	223,8
Climate Regulation				
Climate Regulation (Soil organic Carbon - tonne C)		141.229.133	146.357.439	142.658.680
Change in Soil organic Carbon - tonne C)		0 (ref)	5128306 (3,6%)	1429548 (1%)
Low estimate climate Regulation (mio €) - mean annual next 50 years	20 €/ton		2,1	0,6
Mean estimate climate Regulation (mio €) - mean annual next 50 years	120 €/ton		12,3	3,4
High estimate climate Regulation (mio €) - mean annual next 50 years	220 €/ton		22,6	6,3
Agricultural production				
Agricultural production (mio €/yr)		1.300,9	1.115,9	1.165,0
Change in agricultural production (mio €/yr)	Direct*	0 (ref)	-185 (-14,2%)	-135,9 (-10,4%)
Timber production				
Timber production (mio €/yr)		12,5	10,0	10,0
Change in timber production (mio €/yr)	Direct**	0 (ref)	-1,29 (-10,3%)	-1,29 (-10,3%)
TOTAL				
Low estimate change in ES-delivery (mio €)			-162,3	-117,3
Mean estimate change in ES-delivery (mio €)			-40,6	-6,7
High estimate change in ES-delivery (mio €)			81,2	104,0

Moreover, including the obvious benefits for health, tourism and recreation could tip the balance to positive numbers (e.g. (Broekx et al. 2013b)). Also the current mean cost of 50 mio €/yr to compensate for economic damage due to flood hazards (VMM 2014) needs to be taken into account. Projected losses in food production also consider the current production model, which involves substantial financial support from public budgets, as well as issues concerning food waste and caloric efficiency of meat production. Even a slightly different production model might easily compensate projected losses in wetland areas, or provide ways of farming which can be combined with the multiple services provided in these landscapes (Jacobs et al. 2014, Van Gossum et al. 2014). Rather than retreating in the typical historical struggle for monofunctional land-service allocation and grinding on trade-offs between services and stakeholder groups, the many existing synergies on a practical and local level could offer concrete solutions for a multifunctional, biodiversity-rich wetland use.

CONCLUSIONS

Despite dramatic wetland loss in Flanders since the 1950's, our study shows there is still a large biophysical and ecological potential for wetland restoration. For a significant part, the proper spatial planning or protection status is already in place to justify action in the field.

Conversely, the official Flemish nature policy ambitions for ecological restoration or creation of lost wetlands by 2050 are restricted, especially for wetlands on temporary wet soils (both oligotrophic and meso-eutrophic subtypes) and for meso-eutrophic wetlands on permanently wet soils. Our study shows that restoring or creating wetland habitat will result in a (strongly) increased supply of several important regulating ecosystem services, and in a decrease of food production. But benefits supplied by restored or created wetlands and avoided costs of economic damage due to flood hazards might outweigh the benefits and costs involved in food production. Different policies, specific designs and local implementation examples could offer opportunities for multifunctional use, even with producing services, of restored wetlands. We believe our exhaustive area-wide approach, supported by innovative GIS modeling and ecosystem service valuation techniques, provide a great tool for assisting evidence-based policy decision making that can hopefully inspire the development of similar tools for other ecosystem types or areas.

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B8. Tidal Marsh Restoration: Tracking 50 Years of Wetland Soil Development

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ABSTRACT

We periodically followed soil formation on a tidal salt marsh created by planting smooth cordgrass, *Spartina alterniflora*, on a dredge spoil island in 1970. Surface (0-10 cm) and subsurface (10-30) soils were sampled in 1984, 1998 and 2016, and bulk density, total organic carbon (C), nitrogen (N), phosphorus (P) and particle size (sand, silt, clay, organic matter) were measured.

Trajectories of wetland soil development were clearly evident with a pronounced decrease in bulk density and an increase in percent organic matter, organic C and total N as the marsh aged. Properties characteristic of wetland soils (e.g. low bulk density, high organic C, N) developed twice as fast in surface than in subsurface soils. Properties of the mineral fraction, percent sand, silt and clay, and total P did not exhibit trajectories with marsh age. After nearly 50 years, the restored marsh soils continued to sequester C and bury N. In recent years, most of the increase occurred in subsurface soils while surface soil C and N pools reached a steady state after about 25 years.

Our findings are among the first to document long-term wetland soil development using repeated measurements rather than the chronosequence approach, and suggest that, in spite of many natural (i.e. hurricanes) and anthropogenic (i.e. channel dredging) disturbance events at the site in the past half century, the restored marsh continues to persist and provide valuable ecosystem services.

Thursday 3 May - 11.00-13.00 **Oral session C – Wetland conservation and the Ramsar Convention** -
Chair: Keith Edwards

C1. Challenges with describing the ecological character of Ramsar Sites: a case study from Myanmar

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INTRODUCTION

Contracting Parties to the Ramsar Convention are expected to manage their wetlands, including Ramsar Sites, so as to maintain their ecological character. The Ramsar Convention has defined ecological character as “*the combination of the ecosystem components, processes and benefits/services that characterise the wetland at a given point in time*”. Traditionally descriptions of the ecological character of Ramsar Sites have emphasised the ecological components, and often focussing primarily on the waterbirds, and it has been acknowledged that there is a need to improve the understanding of benefits/services (Davis and Brock, 2008).

The Republic of the Union of Myanmar acceded to the Convention on Wetlands (commonly known as the Ramsar Convention) on 17th March 2005. At the time of accession, Moeyungyi Wetland Wildlife Sanctuary (MWWS) was designated as the country’s first Wetland of International Importance (Ramsar Site). Whilst the site is internationally important for waterbirds, the site also contributes significantly to the livelihoods of more than 60,000 people living around the site (Merriman and Murata, 2016).

This presentation reports on the process of ensuring that the benefits and ecosystem services provided by MWWS were adequately assessed in order to: (a) contribute to the description of the ecological character of the site; and (b) be considered appropriately in the long-term management of the site.

METHODS

Information on the ecological character of MWWS was collected and collated through a variety of methods including reviewing reports and published documents, conducting field assessments and surveys, consultation with site staff and local communities and participatory workshops. Specific information on the livelihoods and the benefits the site provides was collected through the rapid assessment of wetland ecosystem services (*sensu* McInnes and Everard, 2017), a series of consultation workshops with sixteen communities based around the site and evaluation workshops involving site staff and Ramsar-related experts.

RESULTS and DISCUSSION

The ecological character description of a wetland must consider the combination of the ecosystem components, processes and benefits/services. The data collation and initial consultation exercise revealed that factual information was strongly skewed towards ecological components, and within that particularly faunal information. Information on ecosystem processes and services was found to be limited and primarily anecdotal.

A previous assessment of the ‘value’ of MWWS had cautiously estimated that the annual ecosystem service flows from ten services was US\$22,100,000 (Merriman and Murata, 2016). However, linkages between the flows of services, the spatial distribution of livelihoods around and within MWWS, the temporal dynamics of benefits and their relationship with the

ecological components and ecosystem processes, the understanding of threats, and the management objectives and activities were poorly understood. The work conducted through this study demonstrated that understanding the overall monetised value of a subset of services made limited contribution to the ecological character description and subsequent development of management prescriptions.

The study defined twenty different livelihoods and 49 ecosystem services for MWWS. These services and livelihoods demonstrated distinct spatial differences across the site and that the different communities interacted in different and dynamic (both spatially and temporally) ways with the wetland. This facilitated the development of a site zonation plan which compartmentalised the overall site into distinct management units each of which reflected differences in the ecological character.

CONCLUSIONS

Understanding ecosystem services and livelihoods of a wetland requires a structured and hierarchical approach that embraces participatory practices and integrates local knowledge. Understanding the spatial and temporal nature of these benefits was seen as being more pragmatic and relevant than monetising a subset of benefits. Without the comprehensive knowledge of the ecological character of the site it would not be possible to zone the site into manageable units and to set relevant management objectives.

ACKNOWLEDGEMENTS

The development of the Management Plan for MWWS was funded by the Norwegian Environment Agency through the bilateral cooperation between the governments of Myanmar and Norway established under the project *Conservation of Biodiversity and Management of Protected Areas in Myanmar*. The site staff at MWWS contributed significant amounts of time, knowledge and energy in the development of this work. Specific acknowledgement is given to Thin Thin Yu, Park Warden at MWWS and Sai Wanna Kyi, Ranger at MWWS, for their vital role in planning and conducting field work, along with the more than 400 villagers who gave up their time to partake in workshops.

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C2. The contribution of seed bank mapping to conservation programmes:

***Lythrum thesioides* case study.**

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INTRODUCTION

Mediterranean temporary ponds are characterized by an alternation of winter flooding and summer drought (Grillas et al. 2004). These environmental conditions have contributed to the presence of a specialized flora, dominated by annual species with large perennial seed banks (Médail et al. 1998). Among these *Lythrum thesioides* with a south-Eurasian distribution is currently known worldwide with only 2 populations, which occur south of Nîmes (France). One of the populations (Campuget) was discovered in 2010 in the context of an environmental impact assessment (high speed train line). This population occurs within a former shallow lake which has been drained, cultivated during about 30 years, and is now an agricultural wasteland. This plant grows only in few recent artificial ponds across the wetland. A project started in 2016 to study the distribution and the ecology of *L. thesioides* in order to provide recommendations for the management of the site and the conservation of this rare species.

In this framework, the aim of this study was to identify the optimal germination conditions for *L. thesioides* and to map the viable seed bank of the species in the wetland area of this population.

METHODS

Germination tests under controlled conditions were used to assess the optimal germination conditions of *L. thesioides*. Temperatures from 10 to 30°C, light and cold stratification effect were evaluated.

Soil core samples (diameter 5cm) were collected at 93 different stations in the Campuget site, over a 15m x 15m grid. The depth of the soil cores was 5cm except on 10 stations core depth was 30cm (then divided in 5cm slices). Indeed, seeds might be quite deep because of historical ploughing in the area. Cores were exposed to flooded conditions outdoor, after cold stratification, from July 5 to September 29 2017, with suitable conditions for germination. The seedbank was measured as the number of germinating seeds.

RESULTS and DISCUSSION

A high optimal germination temperature was found for *L. thesioides*, about 25°C (fig. 1). Light was required for germination, as often for small seeds (Fenner and Thompson 2005). Cold and wet stratification resulted in higher germination rates.

With an optimal germination temperature 10°C higher than the average temperature of germination of Mediterranean temporary ponds plants (Carta 2016), the germination behaviour of *Lythrum thesioides* seems to fit better with wet summer climate, i.e. more to the continental part of the distribution of the species.

On germination experiments of soil samples, we found a small seed bank: only 9 samples contained germinating seeds of *L. thesioides*, with a density of 509 to 7132 seeds.m⁻². Seeds were only found in the 5 first centimetres. The highest density of seeds was found outside ponds in an area where no growing plant was observed (fig. 2). This location may be used as a target for a restoration program.

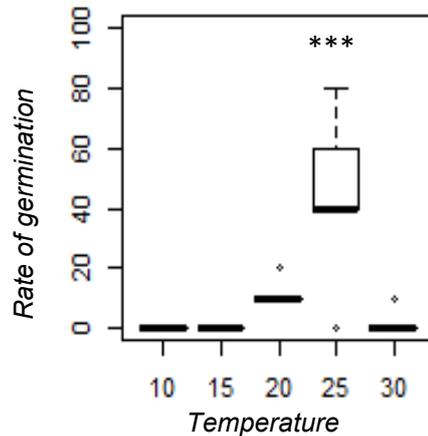


Fig. 1: rate of germination of *Lythrum thesioides* seeds, in function of temperature (Effect of temperature : p-value<10⁻¹³).

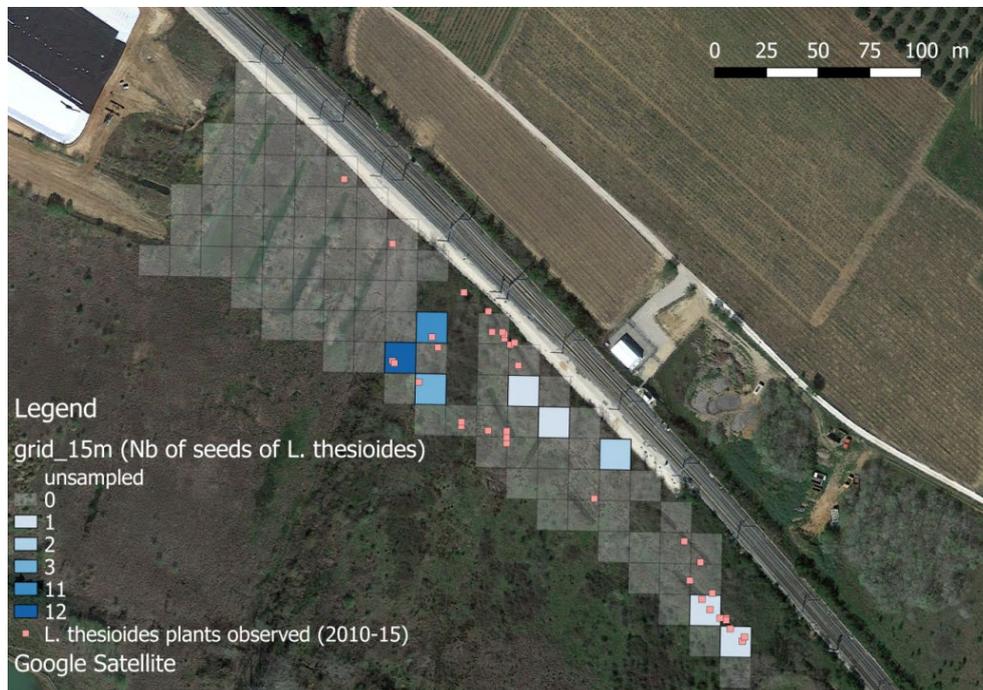


Fig. 2. Map of the Seed bank size in plots and all the observations of plants of *Lythrum thesioides* in the wetland of Campuget (Manduel, France).

CONCLUSIONS

The seed bank of *Lythrum thesioides* in Campuget is small and does not really match with the observations of adult plants in the field. Our results suggest that the creation of the

ponds favoured the establishment of *L. thesioides*. Adding ponds in locations with higher density of seeds could enhance its populations.

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C3. The challenge of wetland conservation under the intensification of agriculture

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The intensity of land use and the level of crop fertilization have been increasing worldwide since the World War II. Under such conditions wetland conservation is an ever increasing challenge. Agricultural practices favouring crop monocultures and thriving for high yields are greatly dependent on high inputs of fertilizers and pesticides. Along with the reduced diversity of cultivated crops this has resulted in severe degradation of soil fertility and reduced water retention in soils and vegetation. Furthermore, in many cases, the nutrient ratio is highly unbalanced (much higher than optimal proportion of nitrogen to phosphorus and potassium is used). This has a further negative impact on both crop health and soil fertility.

The intensification of agricultural production has led to the substantial increase of provisioning services of agro-ecosystems (for example, the cereal productivity has doubled within the last 50 years) but, at the same time, the efficiency of nutrient use by crops has decreased and the high levels of applied fertilizers may have had a severe negative impact on surface and groundwater quality and wetland sustainability.

We will review the trade-offs among ecosystem services (provisioning, supporting and regulating) that have been generated by agriculture-induced changes and will focus particularly on services such as nutrient and water cycling and climate regulation. We will present a number of measures - crop rotation, intercropping, polyculture, water conservation soil management practices – that can be used to enhance the supporting and regulating services of agro-ecosystems to renew a balance of ecosystem function and agricultural production.

This study has been done within the framework of the SCOPES (Scientific co-operation between Eastern Europe and Switzerland) international project entitled "Improving the knowledge-base and infrastructure to enhance the efficiency of nutrient use in agriculture and to reduce the negative impact of agriculture on the environment" No. IZ74Z0_160486.

C4. The SWS/WWN 2017 citizen-science survey of the state of the world's wetlands: issues and results

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INTRODUCTION AND METHODS

During 2017 the SWS Ramsar Section in association with the World Wetland Network (WWN) and Wildfowl & Wetlands Trust (WWT) organised an online survey of the state of the world's wetlands. Anyone knowing about a wetland was asked to report on their perceptions of the current and recent ecological character state of, and trends in, the wetland and what are the drivers (both positive and negative) of the current state and trends in the state of the wetland. Over 500 valid reports were received for wetlands of different sizes, covering all regions of the world. This presentation will provide a summary of the main findings of this first-ever global citizen-science wetland assessment, and will speak to the challenges and issues we have identified for running any future such surveys.

RESULTS AND DISCUSSION

Preliminary results of the survey indicate that whilst many wetlands were reported as being still in a good state of ecological character, deterioration in this character is widespread, with more wetlands deteriorating in ecological character than improving. Such deterioration is particularly widespread in Latin America & the Caribbean and in Africa. These results are similar to other recent ecological-science based assessments of wetlands, and confirm the value of 'citizen-science' assessments to add value to, and complement, such assessments. Full results are being prepared as a paper for submission to *Wetlands* journal, and so are not provided in this abstract

C5. Proposed measures for restoration of Studenchishte wetland (Ohrid, Macedonia)

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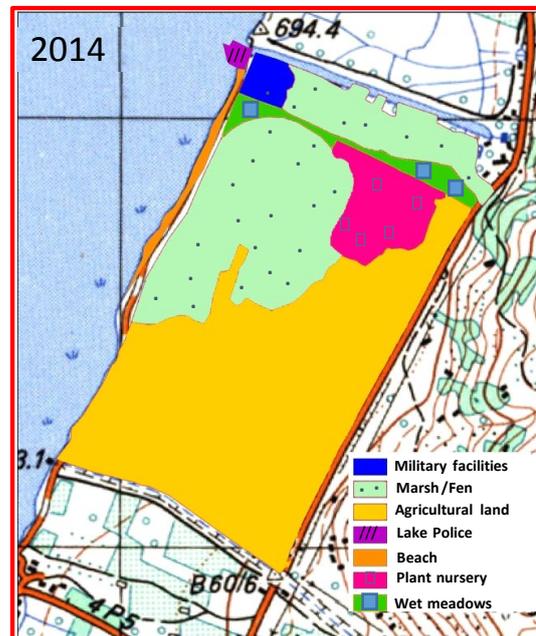
INTRODUCTION

Studenchishte, a wetland area with natural marshes, fens and semi-natural wet meadows is the very last wetland of a previously extensive riparian fringe located on the shore of ancient Lake Ohrid, a UNESCO World Heritage Site, in the Ohrid-Prespa region of the FYRepublic of Macedonia. This wetland has undergone man-caused gradual drying and degradation as other wetlands in Macedonia and all Europe in the last century. At present, only about 50 ha of wetland remain and they are facing total destruction for the purpose of tourism development and urbanization (Apostolova *et al.*, 2016). Moreover, satellite imaging has shown a progressive reduction of the size of the wetland (Apostolova *et al.*, 2017) which proves its vulnerability, and urges its protection and revitalization.

METHODS

We consider that the area of protection of the marsh is about 65 ha and 3440 m perimeter, delimited in the north by Studenchishte canal, in the east and south by a road, and to the west by the Ohrid Lake shoreline. Main impacts inside the protected area are the presence of agricultural land, a plant nursery, and military and police facilities. The buildings at the beach for tourist use (club, bar and sports area) also negatively impact the site. The recovery of the wetland requires the following actions:

- Closing of the road near the beach to the transit and enabling the connection south of the marsh between the P501 and the beach road.
- Acquisition by the state of the agricultural land located inside the protection zone.
- Acquisition of the current Club and Beach Bar and its transformation to wetland visitor and management center.
- Location of the plant nursery out of the marshland area, in the south road.
- Creation of a buffer zone of 50 m wide along the P501 and the south road that will protect the marsh from road traffic with autochthonous vegetation.
- Restoration of the agricultural land to wetlands, extracting the materials to create the ponds following the old existing trace. Accumulation of the materials extracted in the buffer zone of the P501 forming a longitudinal mound that will be covered with wild vegetation of the area.



Other materials will be accumulated in three small hills where observatories will be located for wildlife and flora viewing by visitors. One of them next to the management center (current Bar), another next to the visitor's center (current Club), and a third one a little further south near the current Ambrosia center, where the visitor's tour will end.

- Creation of a path or boardwalk for visitors, where the evolutionary process of the wetland is exposed, the current situation and the protection and restoration measures planned and carried out.

Finally, the restoration of the current wetland would proceed once the areas of agricultural land have been consolidated and recovered to ponds and wetlands, so that the flora and fauna have dispersed and colonized the new spaces and can serve as a refuge in the current marsh and fen area.

CONCLUSIONS

The implementation of the proposed measures is required in order to conserve the Studenchishte Marsh and recover a significant part of the wetland area. The land reclamation work should be carried out firstly (e. g. closure of the road to traffic and acquisition of agricultural land) and secondly environmental restoration work. It is essential to prohibit any new occupations first, eliminate the current ones and recover the area to protect. Also is necessary to establish a control program to verify the evolution of measures and do new ones to accomplish the restoration.

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C6. Macrophyte community structure affects the presence and abundance of the Dytiscidae aquatic beetles in waterbodies along the river

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INTRODUCTION

Macrophytes are important structural and functional elements of many aquatic habitats. They are involved in the energy flow and nutrient cycling. They also affect sedimentation processes and provide habitats, food, breeding locations, and refugia for aquatic invertebrates, fish, and a range of other organisms. Several investigations revealed that the composition of macroinvertebrate communities dwelling macrophyte beds is determined by water quality and by the structure, density, and condition of the vegetation. Aquatic beetles present one of the dominant macroinvertebrate groups of inland waters. Dytiscid water beetles (Dytiscidae) belong to macrobenthos and colonise both temporary and permanent water bodies (Foster 2010). Predaceous diving beetles Dytiscidae are abundant in isolated water bodies, such as small water bodies along rivers (Bilton 2014). The presence of aquatic vegetation in water bodies is very important since species presence and abundance is higher in vegetated sites in comparison to sites without vegetation. Roots, leaves, and stems provide visual and physical barriers which serve as shelters from predation. In the present study we examined the presence and abundance of macrophytes, as well as beetle and fish communities in 39 natural and man-made water bodies along the rivers Drava and Mura (Slovenia). We were especially interested in the beetle family Dytiscidae due to limited information on this group regarding their habitat demands (Foster 2010) and since some species from this family depend on macrophytes for oviposition and pupation.

METHODS

The macrophyte surveys were carried out in the years 2014–2017. In the case of small water bodies (less than 100 m in length), we examined entire areas, for oxbows or channels we examined at least 100 m long sections, and in the case of ponds we used the transect method that is used for lakes. Relative abundance was evaluated using a 5-degree estimation scale. Water samples for analyses of inorganic phosphorus, nitrogen, and some cations were sampled and analysed in the laboratory. Oxygen concentration, pH, and electrical conductivity were measured *in situ*. Beetle fauna was sampled using traps.

Redundancy analysis (RDA) was used to assess the relationships between the composition and abundance of macrophytes, aquatic beetles, fish, and water chemistry.

RESULTS and DISCUSSION

The examined water bodies differed in macrophyte community structure and in the presence and abundance of organisms of higher trophic levels. The presence and abundance of macrophytes in water bodies were best explained by electrical conductivity of water (6%), sulphate concentration (7%), sodium ion (8%), and additional 9% by oxygen concentration and saturation level. RDA analysis that aimed to explain the variability of Dytiscidae beetles by macrophyte presence and abundance showed that the majority of larger beetles (Dytiscinae) are related to short growth forms of macrophytes (*Potamogeton trichoides*) or to the representatives

of free floating Lemnaceae, while smaller beetles were found in waters with dense stands of submerged species.

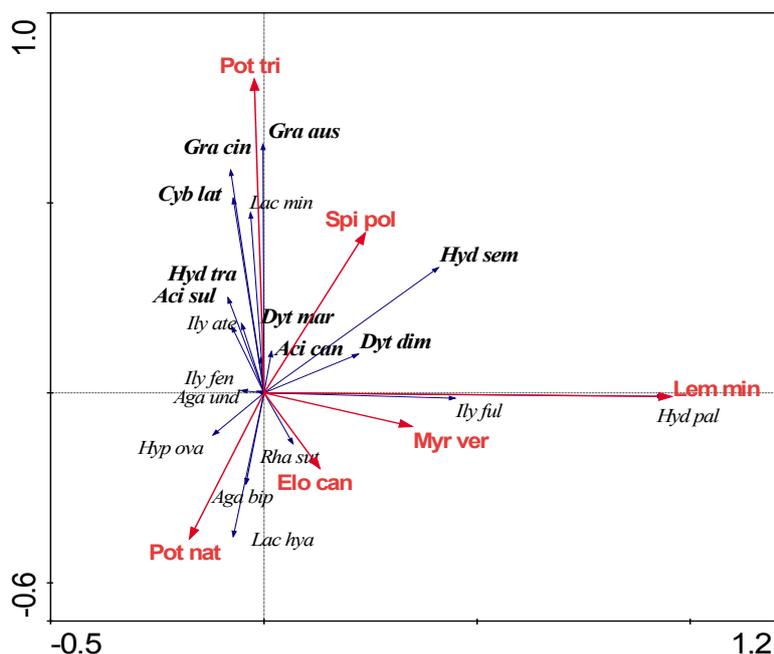


Fig. 1. RDA plot showing the relation between macrophytes and the presence and abundance of beetles from the family Dytiscidae.

CONCLUSIONS

Macrophytes are the first target for management of water bodies therefore the knowledge on their relations with other trophic levels provide the basis for actions aimed at biodiversity protection.

ACKNOWLEDGEMENTS

The authors gratefully acknowledge the financial support from the project LIVEDRAVA, LIFE 11 NAT/SI/882.

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C7. Invasive alien vines alter characteristics of riparian vegetation habitats

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INTRODUCTION

Riparian zones play a significant role in the structure and function of aquatic ecosystems. It is usually the most fertile and productive part of the landscape. Vegetation type and riparian zone width are closely related to the ecological status of the aquatic ecosystems and indicate its vulnerability (Petersen 1996). Partition of riparian zones increases their vulnerability as well as the vulnerability of the water bodies.

Invasive alien plants exert negative impacts on native plants and ecosystems. They affect ecosystems *via* flow of energy and cycling of matter, by changing habitat characteristics, excessive use of resources, accumulation of litter, and by changes in erosion dynamics. They mainly colonise riparian zones in places, where original vegetation was removed or failed to establish (Hejda and Pyšek 2008). However, this is not the case with invasive vines that are able to infect undisturbed riparian zones and spread on top of the existing vegetation (Zelnik et al. 2015). These vines can significantly alter riparian vegetation habitats and affect their vitality. In Slovenia two invasive vines occur in abundance in riparian zones, namely annual vine *Echinocytis lobata*, and perennial vine *Parthenocissus quinquefolia*.

The present study aimed to examine the effect of these two vines on habitat characteristics of their host plants *Salix fragilis* and *Salix caprea*. We also wanted to examine the differences in leaf optical properties between vines and their hosts. Leaf light reflectance and transmittance reveal plant energy balance. Leaf reflectance is also known as “a spectral signature of plants” that can serve as a highly valuable tool in assessing plant vitality. In some cases, it also enables the distinction among species (Klančnik et al. 2012). Spectral signatures of the examined species could serve as a basis for detection of invasive vines in riparian zones by remote sensing.

METHODS

Our experimental plants were alien invasive vines *Echinocytis lobata* and *Parthenocissus quinquefolia*, which spread over their host plants *Salix fragilis* and *Salix caprea*. Both alien species originate in North America.

The experiment was performed in the riparian zone of the river Krka. The alien/host species relations were studied on ten locations for each pair. Physical parameters, namely radiation quality and quantity, air and plant temperatures, and relative humidity were measured *in situ*. Three micro-locations with respect to host plant species were monitored, namely close to the leaf surface of the host plant with and without vine, and outside the stand. In laboratory we performed biochemical analyses and measured optical properties of both vines and their host plants. The chlorophyll *a*, chlorophyll *b*, carotenoid, anthocyanin, and UV-absorbing compounds contents were determined, and the reflectance and transmittance spectra were measured in the range from 290 nm to 880 nm.

RESULTS and DISCUSSION

The two vines altered the physical environment of both willows significantly. Relatively modest light intensity was reduced for more than 50%. *P. quinquefolia* was somewhat more efficient than *E. lobata*. Both vines showed similar influence on the quality of light. Relative humidity as well as air and soil temperatures were less affected by vines. Optical properties

significantly differed among both vines and willows in the selected wavelengths according to functional traits of the four studied species.

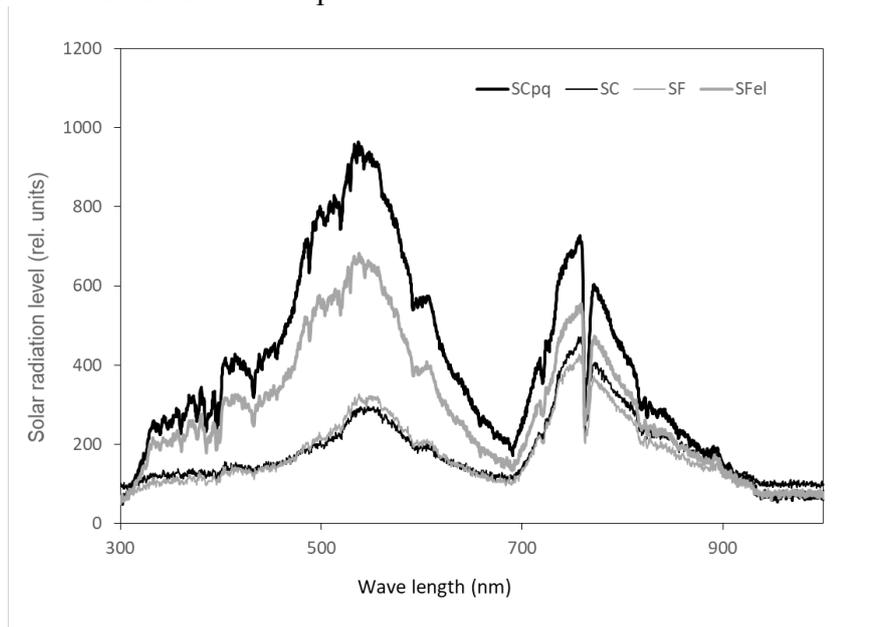


Fig. 1. Relative solar radiation level for different wavelengths in the willow stands at the leaf level of *S. caprea* without (SC) and with *P. quinquefolia* (SCpq), and *S. fragilis* without (SF) and with *E. lobata* (SFel). Ambient relative solar radiation at peak values (530 nm) was 50.000.

CONCLUSIONS

Vines significantly altered light environment of both willows. “Spectral signatures” of vines and willows differ significantly and therefore enable the detection of invasive species by remote sensing.

ACKNOWLEDGEMENTS

The authors acknowledge financial support from the Slovenian Research Agency through the core research funding for the programme Plant biology (P1-0212).

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C8. Diversity of diatom communities in different habitats of the pool spring Zelenci (Slovenia)

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INTRODUCTION

Diversity of diatom communities and selected environmental factors in pool spring Zelenci were investigated. This spring is a part of complex wetland consisting of marshes, fens and pools. The characteristic of this pool are its numerous underwater micro-springs scattered on the bottom, generating vertical currents, which transport benthic diatoms into the water column. The aims of our research were to investigate a) diversity of diatom communities in different habitats of the pool and b) the influence of selected factors on diversity and composition of diatom communities.

METHODS

Samples were taken at four sites in two-month intervals between August 2014 and August 2015. Tychoplankton samples were gained with plankton-net, while epipelon was sampled on sediments in shallow parts. Water temperature, pH, conductivity, O₂ concentration and saturation were measured at each sampling occasion, as well as concentrations of NH₄⁺, NO₃⁻ and PO₄³⁻. Diatoms were identified at magnification of 1000×, taxonomy followed Hofmann et al. (2013).

RESULTS and DISCUSSION

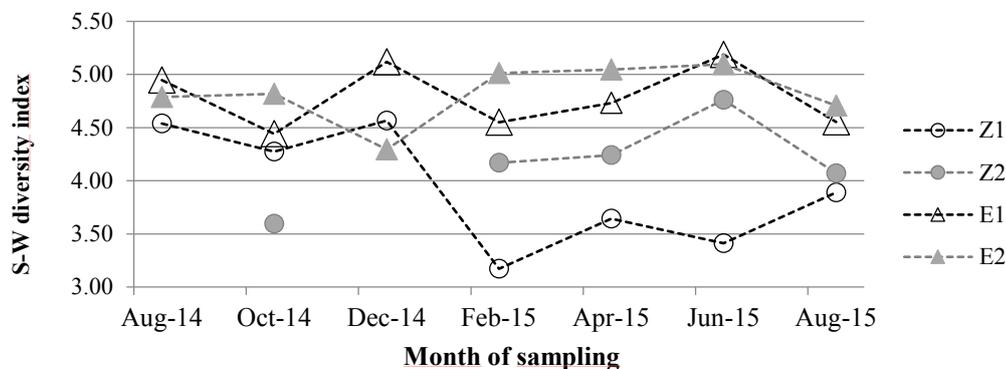


Fig. 1. Values of Shannon-Wiener diversity index calculated on the base of composition of tycho planktonic communities (Z1, Z2) and epipelonic communities (E1, E2).

In total, 120 diatom species were found. The most abundant was *Achnantheidium minutissimum* which is the most characteristic species of springs (Cantonati et al. 2006). Other abundant species were also *Denticula tenuis*, *Navicula cryptotenella*, *Cocconeis placentula* and *Fragilaria pinnata*. Water temperature and oxygen saturation had the biggest impact on tycho plankton species composition.

Sun exposure, relatively stable conditions resulted in high diatom species diversity. Shannon-Wiener diversity index was high in all samples and ranged between 3.2 and 5.2 (Fig.1). Epipelon showed greater diversity than tycho plankton, because of stable conditions in the litoral, while disturbances generated by underwater springs lowered diversity of tycho plankton.

Planktonic species were found in tychoplankton, but low-profile species dominated the tychoplankton community, since they are more tolerant to disturbances (Rimet and Bouchez 2012) caused by underwater springs on the bottom, where these species come from with vertical currents. Epipelon communities were dominated by motile species (Tab. 1) which can migrate through the silty substrate.

Values of TI indicated that spring is loaded with nutrients, since values showed oligo-mesotrophic to meso-eutrophic conditions.

Table 1. Number of species occurring in tychoplankton (left column) and in epipelon communities (right), as well as most characteristic species for specific community.

tychoplankton		epipelon	
94 species		26 species	
16 species		+ 78	104 species
<i>Cocconeis placentula</i>	Most	<i>Navicula cryptotenella</i>	
<i>Achnanthydium pyrenaicum</i>	characteristic	<i>Nitzschia dissipata</i>	
	species:	<i>Navicula oblonga</i>	
51%, 51%	low profile	33%, 37%	
20%, 22%	high profile	14%, 16%	
23%, 23%	motile	52%, 47%	
6%, 3%	planktonic	1%, -	
Z1: 1.26-1.83; Z2: 1.33-1.79	Trophic Index	E1: 1.72-2.03; E2: 1.81-2.02	

CONCLUSIONS

Pool spring Zelenci hosts a high diatom species richness, which is a result of specific environmental conditions. All measures in the spring and in its catchment area that could impact the hydrology, nutrient status or habitats should be prevented if we want to preserve the diversity of diatoms as well as the aesthetic value of the pool spring.

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15.30-17.00 Oral session D – Biogeochemical aspects of wetlands – Chair: Jos Verhoeven

D1. Distribution of mineral nutrients in littoral vegetation of an ancient shallow reservoir

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INTRODUCTION

In littoral vegetation growing along the shores of a 16th century reservoir, differences were assessed between peak-season (summer, July) and off-season (fall, November) live and dead aboveground plant biomass (dry mass). Investigated were also differences in organic matter mass and both concentrations and pools (standing stocks) of ash, N, P, K, Ca, Mg and Na in the rhizosphere soil and live or dead vegetation at 14 sites hosting 4 plant community types dominated by (numbers of sites in brackets): *Phragmites australis* (3), *Carex acuta* (5), *Calamagrostis canescens* (3) and *Glyceria maxima* (3). These sites were selected to represent the ranges of habitats colonized by each of these plant community types. All sites were situated in different parts and sub-zones of the littoral zone of the Rožmberk fishpond (S. Bohemia, CZ, constructed in 1592). The Rožmberk is, in fact, a eutrophic shallow (average depth 1.5 m) reservoir of about 5 km² area, designed primarily for fish rearing and flood control. It also receives treated municipal wastewater; until about 2008 mixed with treated piggery sewage containing large amounts of suspended solids, settling down as nutrient-rich saprobic mud on the Rožmberk bottom. Nutrients leached out from the mud, a dense fish stock, partly fed with grain, and nutrient input from the catchment are responsible for a strong eutrophy of the reservoir water.

For more detailed soil and vegetation characteristics of the 14 sites selected for our investigations see Hroudová et al. (1988). That paper also gives the summer and fall plant biomass data for each site. Our present aim is to test the following hypotheses:

- (a) Habitat sets of the four community types studied differ in nutrient supply to the vegetation and in the size of organic matter pools in the rhizosphere.
- (b) Aboveground biomass of the four community types contains different pools (standing stocks) of mineral nutrients; differences also exist in the efficiency of late-season nutrient resorption from above- to belowground plant parts (estimated from differences between the summer and fall nutrient standing stocks in aboveground live or dead biomass).
- (c) Moisture content in the rhizosphere soil of each community type affects nutrient standing stocks in both the summer (live) and fall (predominantly dead) plant biomass.

METHODS

Hroudová et al. (1988) described the methods used in the above investigations. In brief, rhizosphere soil was sampled 6x within a year at each site. The resulting average data obtained for each soil characteristic were used in our further calculations. The sampling depth was equal to the rooting depth (of about 90 % of the roots) of the vegetation (between -10 and -20 cm). The harvest method was employed to estimate the aboveground biomass of

each community at each site, both in summer and fall. At each site, either live summer or dead fall biomass was harvested from 4 quadrats of 0.25 m² each, in communities dominated by *Phragmites* or *Glyceria* or *Calamagrostis*, and from 0.5 m² rectangular plots in *Carex* – dominated communities. Only the plant litter lying on the snow-covered ground surface had to be harvested in next year's early spring. In summer, the live-plant samples were divided into species and then dried at 85 °C. Chemical analyses of plant material corresponded with methods recommended by the Czechoslovak Ministry of Agriculture.

RESULTS and DISCUSSION

Below is a summary of the results evaluated in accordance with their PCA (Principal Component Analysis) and ANOVA. These analyses, separated by season (summer and fall), seem to explain either existing or lacking significant differences among the data.

- 1) Regression of plant biomass on rhizosphere nutrients:
 - a. Summer: significant relation only to Ca (+ relation)
 - b. Fall: significant relations to NO₃, Ca (+ relations), Mg and organic matter (OM), (- relations)
- 2) Relating soil moisture to plant biomass and stoichiometry, only for summer:
 - a. No significant relationships.
- 3) Relating plant biomass to plant stoichiometry (N:P, N:K, Ca:P, K:P), only for summer:
 - a. N:P negative trend (p = 0.063)
- 4) N and P resorption efficiencies - no significant differences between communities or between different soil moisture contents - great variation of data from the same community types, reflecting wide habitat ranges of each of them.
- 5) Regressions of soil moisture on rhizosphere nutrients, by season:
 - a. Summer: significant relations to PO₄ (- relation) and Ca (+ relation)
weakly significant relations to K and Na (both – relations)
 - b. Fall: significant negative relations to NH₄, NO₃, K and Na
positive relations to total N and Ca
weakly significant (0.1 > x > 0.05) relations to PO₄ (- relation) and OM (+ relation).

Most of the results for each of the four community types studied show great variation, reflecting the diversity of nutrient availability in habitats favoring each dominant species. The scatter of most PCA results for individual plant community types is evident in the figures 1a and b and thus illustrates this variation.

Comparisons between the summer and fall data on nutrient standing stocks and stoichiometric relations calculated from them, together with data on nutrient resorption (fig. 2), though variable, still provide an insight into the mineral nutrient economy of littoral vegetation rooted in relatively nutrient-poor sandy soil, but differently supplied with nutrients in water percolating from the eutrophic reservoir, or originating from local springs or, also, from adjacent manured areas.

CONCLUSIONS

Significant probability of validity of the hypotheses put forward initially can be confirmed either only partly or not at all in the following way:

- (a) Different nutrient supply to different vegetation types from different rhizosphere nutrient pools: confirmed only partly (for *Glyceria maxima* dominated communities).
- (b) Different efficiency of nutrient uptake and use, manifested in different nutrient standing stocks in aboveground biomass of the four community types: not confirmed. Different efficiencies of late-season nutrient resorption: weakly significantly confirmed.
- (c) Water availability affecting nutrient use, as manifested in nutrient standing stocks in both live (summer) and dead (fall) plant biomass: not confirmed.

These results document a great adaptability of the efficiency of nutrient uptake and use in plant species dominant in wetland vegetation. This complex trait enables them to become dominant in a wide range of wetland habitats experiencing similar hydrological regimes.

ACKNOWLEDGEMENTS:

The authors appreciate the skillful assistance of Ms. Ivana Nedbalová (field work) and their colleagues from the chemical laboratory of the Institute of Botany at Průhonice. Plant material was analyzed at the Regional Agricultural Laboratory at České Budějovice.

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FIGURES

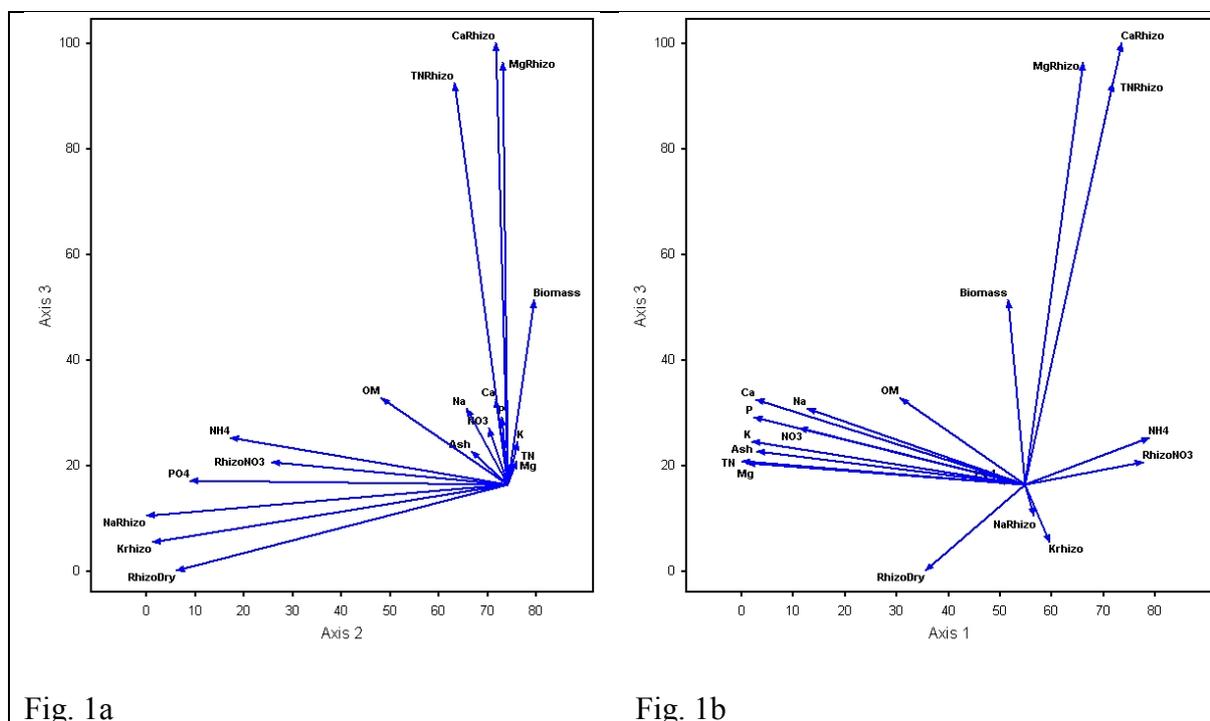


Fig. 1a

Fig. 1b

Fig. 1a, b – Principal Component Analysis (PCA) for all (plant and rhizosphere) nutrient data. Axes 1 and 3 – plant nutrients are highly correlated to axis 1, *Glyceria maxima* (Glymax) is separated on axis 3 (positively related to rhizosphere soil Ca and Mg). Per cent. explained variance: Axis 1 = 40.11%; 2 = 21.60%; 3 = 14.10 %, total = 75.81%

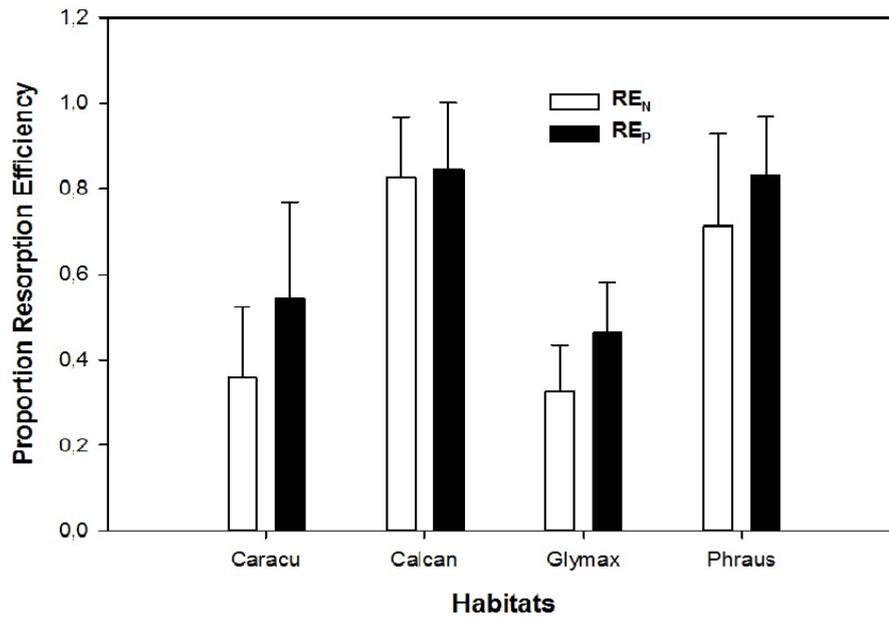


Fig. 2 – Relative efficiencies (RE) of nitrogen (N) and phosphorus (P) resorption (= translocation from aboveground to belowground plant parts) in habitats colonized by the plant community types dominated by: Caracu - *Carex acuta*; Cacan - *Calamagrostis canescens*; Glymax - *Glyceria maxima*; Phraus - *Phragmites australis*.

D2. Oxygen prevents eutrophication and can make turbid waters clear again

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INTRODUCTION

Internal phosphorus (P) mobilisation from aquatic sediments is an important process adding to eutrophication problems in wetlands. To tackle eutrophication, a clear understanding of the interacting effects of sediment characteristics and surface water quality is vital.

According to the classic theoretical framework sufficiently high oxygen (O₂) concentrations in the surface water will prevent P release from the sediment (Mortimer, 1941; 1942). According to this, the oxidation of dissolved ferrous iron in the sediment (Fe²⁺) will result in the formation of ferric iron (hydr)oxides hydroxides at the sediment surface, which will bind P and prevent its release to the surface water. Under anaerobic conditions, Fe-reducing bacteria will reduce ferric compounds and part of the P is released to the surface water. However, according to Geurts et al. (2010) at pore water iron/phosphate (Fe:P) ratios below 1 mol mol⁻¹, phosphate mobilization from the sediment to the water layer was considerable and linearly related to the pore water P concentration, independent of the oxygen concentration of the water layer.

In this study we analysed the release of P from sediment columns under anaerobic and aerobic conditions and related this release to iron and phosphorus concentrations in the sediment pore water.

RESULTS and DISCUSSION

In many columns P mobilisation was absent under aerobic conditions although the Fe:P ratio of the sediment pore water was low and phosphate concentrations high. This unexpected result can most likely be explained by the oxidation of the sediment-water interface where ferric Fe immobilises P, even though it is commonly assumed that free Fe²⁺ concentrations need to be higher for this. Therefore, a controlling mechanism is suggested in which the partial oxidation of iron-sulphides in the sediment plays a key role, releasing extra Fe²⁺ near the sediment-water interface (figure 1).

Forced oxidation of the water layer above the sediment water interface can be used to prevent phosphate release from phosphate rich sediments. This has been applied in lake Ouderkerk in the Netherlands. In this lake deeper water layers became anoxic due to oxygen consumption resulting from the oxidation of organic matter (dead algae) during the growing season. In this lake oxygenation of the hypolimnion (this is not the same as aeration) was applied to stimulate phosphate binding by the sediment. The effects of hypolimnetic oxygenation on the water quality and the development of phytoplankton were studied during a 6 years monitoring program. The results reveal that oxygenation strongly decreases the release of phosphate into the hypolimnion which together with the epilimnic fixation of phosphate by pelagic micro-algae, has resulted in a strong decrease of the total-P concentrations in the lake water. As a consequence, growth of algae was strongly reduced and Secchi depth (water transparency) has strongly increased.

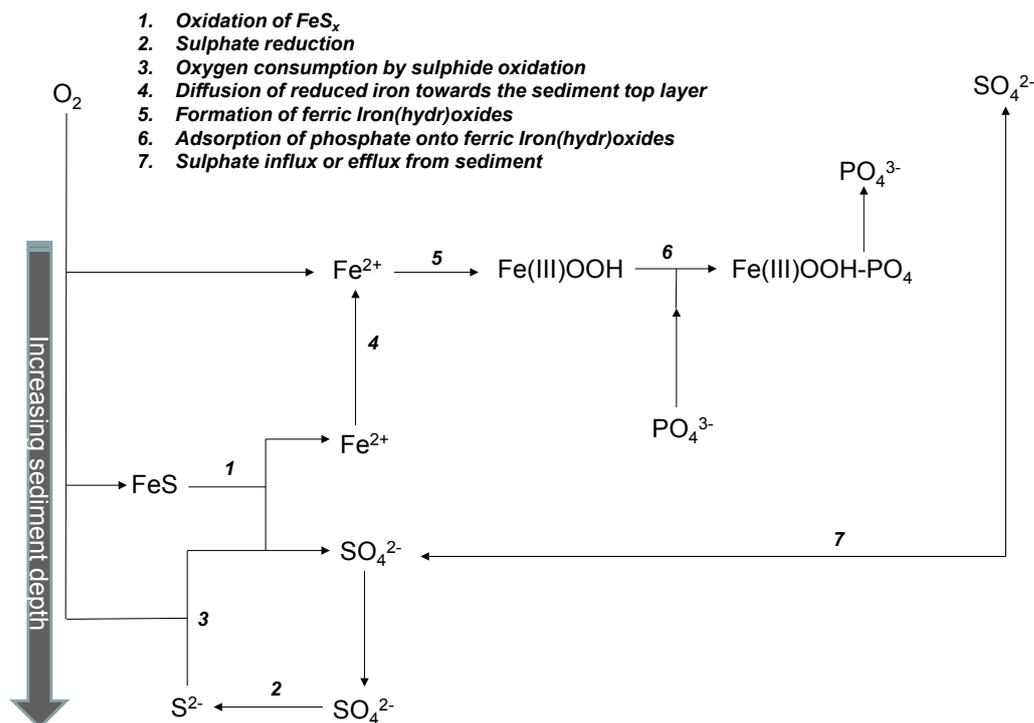


Fig. 1. Schematic overview of the proposed mechanism, showing key processes in the upper millimetres of the S-rich, peat sediments involved in P mobilisation.

CONCLUSIONS

Oxygenated conditions can prevent the release of phosphate from sediments even from many sediments with an unfavourable dissolved Fe: dissolved P ratio. In shallow surface waters and wetlands temporary oxidation of the sediment can prevent eutrophication by improving the binding of phosphorus in the sediment and by enhancing the aerobic oxidation of reactive organic matter. Oxygenation of deeper water bodies has the same effect and can strongly improve the water quality.

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D3. Silicon accumulation in the wet meadow species *Deschampsia cespitosa* from different habitats

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INTRODUCTION

Biominingerals, namely silicon (Si) and calcium (Ca), have multiple functions in plants as they affect water and energy balance, and increase plant resistance to pathogens and herbivores (He et al. 2014). The representatives of the families Poaceae and Cyperaceae accumulate large amounts of different biominingerals in their organs (Bauer et al. 2011). The rate of mineral uptake is usually positively related to leaf transpiration rate, therefore it may be more pronounced in plants thriving in wetlands. Biominingerals mainly accumulate in the epidermal layer, which may consequently significantly alter leaf optical properties (Epstein 1999, Klančnik et al. 2014). *Deschampsia cespitosa* L. is a perennial grass belonging to the Poaceae family. It colonises a variety of grasslands, but it favours poorly-drained soils. In this study we aimed to examine leaf structural traits in *D. cespitosa* plants from different habitats and the contents of Si, Ca, and some other elements in *D. cespitosa* leaves. In addition, we also measured leaf optical properties.

METHODS

Experimental plants were sampled in four different locations, namely in the floodplain of the river Rak in Rakov Škocjan, in the intermittent Lake Cerknica, where plants grow on carbonate rocks, in a raised bog under the top of the mountain Komen, and at the foothills of the mountain Komen, at a forest edge with prevailing calc-alkaline volcanic rocks. Ten plants were sampled randomly per location. For each sampled plant, rhizospheric soil at the micro-location of sampling was also sampled for further analysis. The analysis of the leaf morphology was conducted on transverse sections of the leaves and by taking replicas of the leaf surface. The chlorophyll *a*, chlorophyll *b*, carotenoid, anthocyanin, and UV-absorbing compounds contents were determined. The optical properties were determined in the laboratory on vital, fully developed leaves. The reflectance and transmittance spectra were measured in the range from 290 nm to 880 nm. The concentrations of silicon (Si), phosphorus (P), sulphur (S), chlorine (Cl), potassium (K), and calcium (Ca) in leaves and soil were determined using X-ray fluorescence spectrometry.

RESULTS and DISCUSSION

The locations differed significantly according to the soil properties, including element composition. Differences in habitat characteristics resulted in different morphological, optical, and elemental properties of the examined plant groups. The majority of differences were obtained among plants colonising habitats that developed on two contrasting rock types. Prickle hair density was highest at Lake Cerknica and lowest at Komen, top. The differences were also evident according to element analysis of the leaves, where plants from Komen, top differed the most. The most pronounced differences were obtained in leaf K content, which ranged from 1% to 2.87% of plant dry mass. Significant differences were also found in leaf Si and Ca contents (Fig. 1). Differences in leaf structure reflected in altered optical properties.

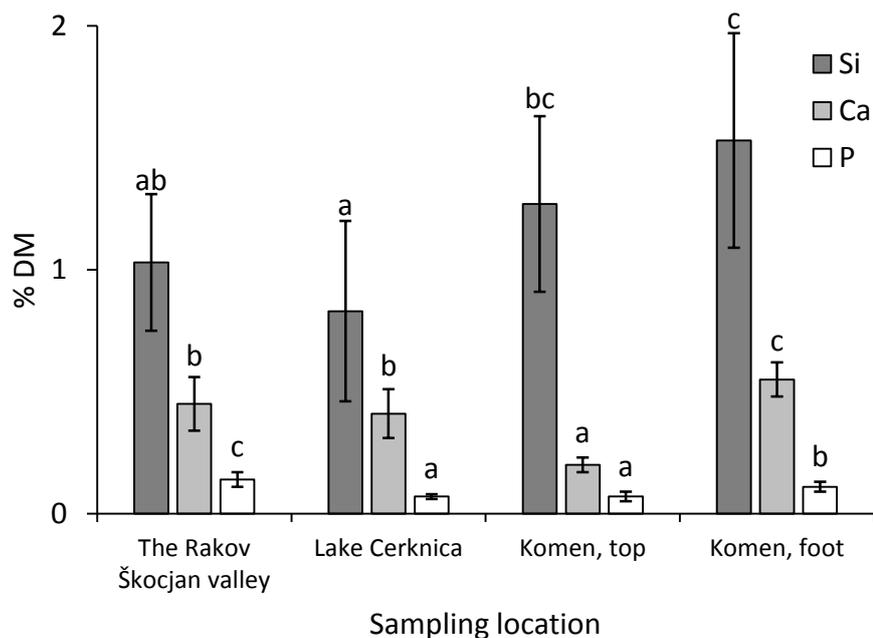


Fig. 1. Leaf silicon (Si), calcium (Ca), and phosphorus (P) contents of *Deschampsia cespitosa* from four different locations. Data are means \pm SD. Different letters above columns indicate significant differences for each element ($p \leq 0.05$; Duncan tests).

CONCLUSIONS

The present study revealed that habitat characteristics significantly affect leaf traits of plants colonising different habitats, including the amount of biominerals. Due to a substantial role of Si in grasses, this could affect plant fitness in specific environments.

ACKNOWLEDGEMENTS

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D4. Updating the hydrogeological model of the Gallocanta Lake (Spain): a contemporary approach

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INTRODUCTION

Wetlands have been recognized as highly sensitive ecosystems in recent years, for this reason more and more of them have been continuously protected by authorities. However, due to their fragility, many of them suffer from the pressure of human activities such as agricultural activity or change of land use. Those factors can lead to an alteration in how they function.

Hydrological studies are especially relevant in this context, both in terms of the supply of drinking water to the population and for the understanding of how certain contaminants and materials behave (i.e. their mobility, dispersion or effect on the environment). Therefore, those studies have become a very useful tool to evaluate complex ecosystems from an environmental perspective.

Based on this principle, Ebro Hydrographic Confederation carried out an in depth study during the early 2000s. The objective was to compile all the previous studies that took place in the area and establish a regulation for water use in the surrounding area of Gallocanta Lake. The main part of the study was to develop a flux numerical model simulating the hydrogeological functioning of the Gallocanta Basin.

The objective of this project is to use FREEWAT platform to update that study, with the goal of evaluating the vulnerability of the ecosystem, in the face of present and future scenarios of climate change and water management.

STUDY AREA

The Gallocanta Basin is located in a large endorheic basin in the central sector of the Iberian Range (Luzón et al. 2007), in the NE Iberian Peninsula. Its total area is about 540 km² and it has a lengthened morphology N-S. It is more than 40 km in length and about 25 km in width at its widest point. Elevation varies from 990 m at the lowest, where Gallocanta Lake is located, and 1400 m above the average sea level in the NW boundary. Gallocanta Lake is the largest saline wetland in Western Europe. It has a maximum length and width of 7.5 km and 2.5 km, respectively. The lake is included in the Gallocanta Lake Nature Reserve. It also is a Special Protection Area for the conservation of bird species and a wetland included in the RAMSAR Convention since 1994. Gallocanta has a bird sanctuary in NE Spain frequented by grey cranes on their annual migration from Scandinavia to northern Africa (Kuhn et al. 2011).

The middle of the catchment is filled with Tertiary and Quaternary sediments and forms a flat upland at 1000 m a.s.l. The catchment is bounded on its north and northeast sides by Palaeozoic rocks of Sierra de Santa Cruz, and to the south and southwest sides by carbonate and calcareous Mesozoic rocks of the Jurassic and Cretaceous. The marly and gypsum facies of the Upper Triassic (Keuper facies) are, together with the carbonate facies of the Middle Triassic (Muschelkalk facies), the underlying bedrock (Luzón et al. 2007). Those impermeable materials not only prevent water flow out of the basin and hinder interactions between surface and deep aquifers, but also contribute to the increase of the salinity of the lake, which is higher

when water levels are low (Castañeda et al. 2015). Salinity ranges between 0.5 and 49.4 dS m⁻¹ (García Vera et al. 2009).

The climate of the Gallocanta basin is Mediterranean semiarid, with a strong continental and altitudinal influence. Summer is hot and dry and winter is cold with little rainfall. Average annual rainfall is 442 mm, with peak rainfall in spring and fall but a strong inter-annual variation (i.e. max. 1958-1959: 732 mm and min. 1993-1994: 265 mm). Average annual temperature is 11.6 °C but the aforementioned altitudinal and continental influence lead to a great temperature variation (i.e. min. of around -20 °C and a max. above 35 °C).

The main characteristic of the water volume in the lake is its inter-annual and inner-annual variability. Recording started in 1974, since then, the lake's water level dropped continuously until 1985, when the lake dried. After a recovery during the late 1980s, since the mid-1990s until 2010 extremely dry years alternated with years of open water.

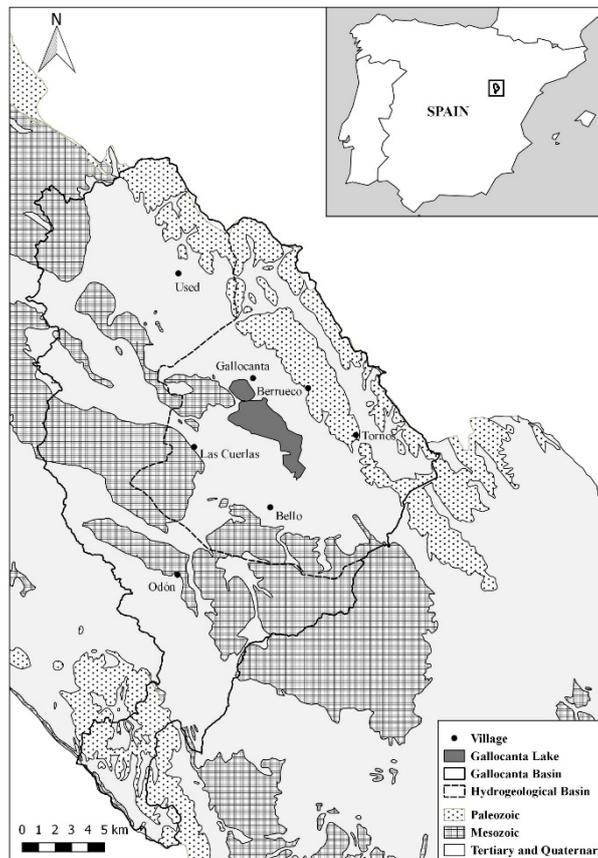


Fig. 1. Location and geology of Gallocanta Basin.

METHODS

FREEWAT platform was used as the main tool for modelling and processing data. FREEWAT is an open source and public domain GIS integrated modelling environment for the simulation of water quantity and quality in surface water and groundwater with an integrated water management and planning module (Rossetto et al. 2015). FREEWAT is installed as a plugin in QGIS and includes geoprocessing, post-processing tools and modelling settings. It uses SpatialLite as a geodatabase manager, and MODFLOW-2005 as the main modelling code. MODFLOW and its relating modelling codes are used since they are widely recognized as international standard for simulating groundwater conditions and their interaction with surface water (Cannata et al. 2017).

Conceptual Model

Gallocanta Basin is located within the Gallocanta Hydrogeologic Unit (GHU) (San Román, 2003). It is characterized by its hydraulically open boundaries in part of the basin and the different extensions of the groundwater basin and the surface basin. GHU is comprised of several aquifers: Jurassic and Cretaceous carbonated rocks (carbonated aquifers) and quaternary rocks (quaternary aquifer).

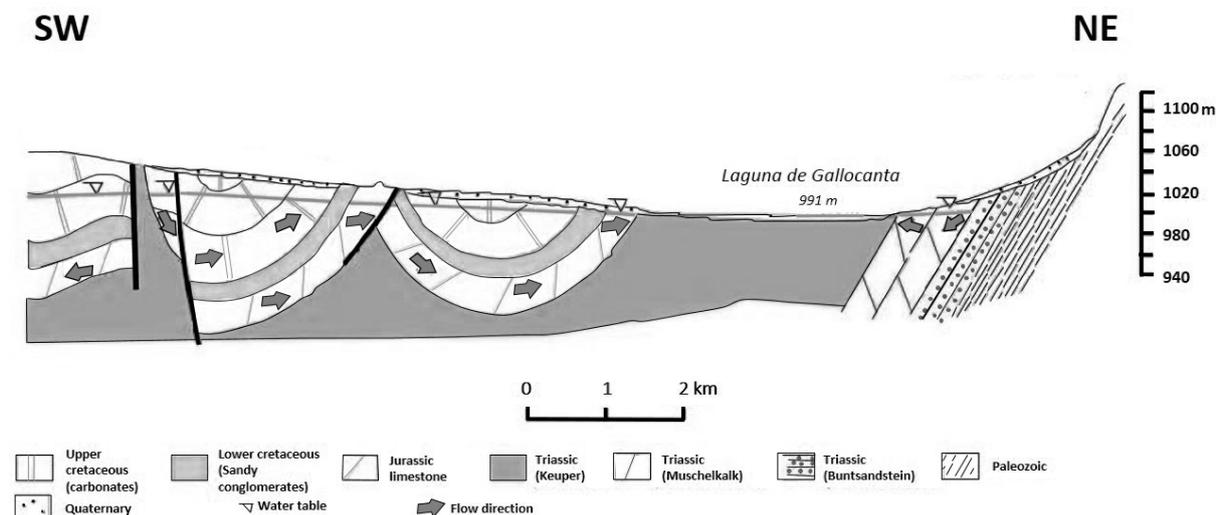


Fig. 2. Cross-section of the hydrogeological system.

In the model, inflows and outflows were simulated. Inflows are through rainfall (areally-distributed recharge), groundwater leakage and sporadic surface runoff whereas outflows are through evapotranspiration and groundwater extractions.

In accordance with the geology of the basin, different hydrogeological parameters were set. The study area has been divided into nine hydrostratigraphic units with specific hydrogeological characteristics, and variable thickness and outcropping surface. Due to the complex geology of the basin, vertical discretization has been divided into 43 layers. Hydrogeological parameters are based on the nine hydrostratigraphic units.

Table 1. Hydrostratigraphic units.

Hydrostratigraphic Unit	Thickness (m)	Hydraulic conductivity (m/d)			Specific storage (l/m)		Porosity (%)
		Horizontal KX	Horizontal KY	Vertical KZ	SS	SY	
Buntsandstein	130-150	0.001	0.001	0.00005	0.000001	0.001	0.1
Muschelkalk	140-200	1	1	0.005	0.00005	0.005	0.5
Keuper	140-500	0.0001	0.0001	0.00000005	0.0000001	0.001	0.1
Jurassic	200-260	25	25	0.125	0.00005	0.015	1.5
Utrillas- Ceno	100-250	0.02	0.02	0.0001	0.0001	0.001	0.1
Carbonated Cretaceous	200-300	2.5	2.5	0.0125	0.005	0.005	0.5
Loam-dolomitic cretaceous	150-200	0.5	0.5	0.0025	0.0002	0.002	0.2
Tertiary	50-350	0.01	0.01	0.00005	0.0001	0.001	0.1
Quaternary	5	50	50	0.5	0.25	0.6	20

Model implementation

As a test of the conceptual model and the software, the model was run under steady-state conditions. The modelling area is defined by a grid of 208 km² surrounding the lake with a resolution of 250 m by 250 m, 48 columns by 72 rows (3456 cells). Model vertical discretization consisted of forty three layers from 1150 m a.s.l. (layer 1) to 0 m a.s.l. (layer 43) with uniform thickness. From 0 m to 500 m, the thickness of each layer is 50 m. From 500 m to 980 m each layer is 20 m thick. Four layers (5 m, 10 m, 10 m and 20 m) span 980 m to 1020 m. From 1020 m to 1100 m there are 20 m layers again and from 1100 to 1150 is one layer of 50 m.

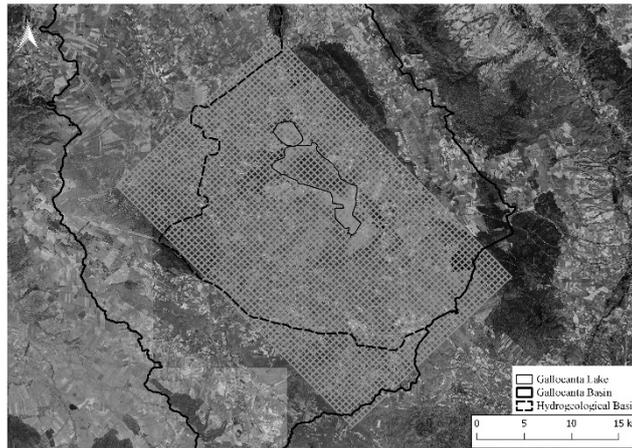


Fig. 4. Horizontal discretization of the model grid.

Since Gallocanta is an endorheic basin, one of the relevant updates to the model is the implementation of the Lake Package (LAK) for the Gallocanta Lake as a boundary condition. This package allows the simulation of hydraulic interaction between the lake and groundwater in the surrounding aquifers so that the effects of the changes in the conditions of one of the bodies of water are calculated on the other (Cannata et al. 2017).

The water budget was done by including the WEL Package, which was implemented to simulate the recharge by surface runoff, and the RHC package, used to recharge the aquifers based on areal distribution. In addition to that, a layer of heads observations was used for the calibration of the model. Rainfall, runoff, infiltration, evapotranspiration and extractions data from the previous CHE model were used for the water budget.

RESULTS and DISCUSSION

The model estimates inflows of 12724 m³ by rainfall and infiltration and 5612 m³ by surface runoff whereas outflows are estimated at 17723 m³ by evaporation through the lake and its surrounding area and 614 m³ by extractions.

The model calibration was done by including 20 heads observation across the study area while running the model. Correlation between estimated and observed heads is 0.58. However, the model tends to overestimate the observed heads (Fig. 4).

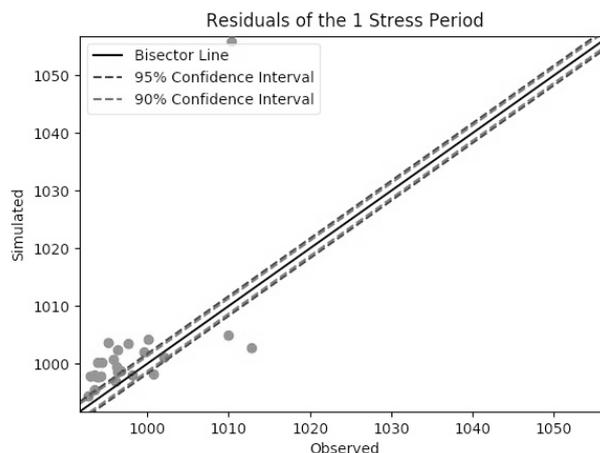


Fig. 4. Observed and estimated heads

The overestimation could be an indication of the presence of another outflow apart from the lake. This could be related to the hydraulically open boundaries of the system across the NW and SE limits. This hypothesis has to be verified.

CONCLUSIONS

Recovery and update of an old hydrogeological model of the Gallocanta Basin has been done. FREEWAT platform has proved to be an efficient and powerful tool in a complex basin like Gallocanta. However, according to the results, estimated heads are higher than observed heads, which means that another outflow apart from the lake should be considered in the basin. This overestimation could confirm that Gallocanta Basin is connected to the adjacent Jiloca river basin or Piedra River basin through groundwater interactions in the SE and NW boundaries of the Gallocanta Basin. This theory would lead us to rethink the current conceptual model of the basin, which would influence the protection of the Gallocanta Lake and its water management regulation. The extension and update of the model is necessary to confirm the change in the conceptual model and will provide information for facing future and present climate change and modifications in water management in the basin in the short and long term in Gallocanta wetland.

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D5. Sediment quality investigations in Lake Lesser Prespa (Greece): tracking the impact of eutrophication through new knowledge

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INTRODUCTION

The shallow lake Lesser Prespa (aka Mikri Prespa) in NW Greece (40°46'N, 21°06'E) is a vital habitat for migratory waterbirds such as the Dalmatian Pelican (*Pelecanus crispus*) and the Great White Pelicans (*Pelecanus onocrotalus*) which breed there in large and increasing populations (Catsadorakis and Crivelli 2001, Catsadorakis et al. 2015). The area has received numerous national and international designations as a protected area due to the spectacular avifauna as well as the important populations of other endemic and rare species (Crivelli and Catsadorakis 1997). Apart from habitat and regulating services (water, climate) this iconic lake and its surroundings provide other goods and services such as water provision for agriculture use, fishing, opportunities for recreation and tourism (i.e birdwatching, aesthetic enjoyment), cultural values, information for cognitive educational development and scientific exploration.

Despite being a protected area, the lake shows clear signs of eutrophication and has a history of cyanobacterial blooms (Koussouris and Diapoulis 1989, Papadimitriou et al. 2010, Tryfon et al. 1997). A regular water quality monitoring during 2013-2015¹ shows that elevated levels of chlorophyll occur in the lake during late summer and autumn while in the meantime dissolved oxygen concentration tend to decrease or even deplete near bottom-water (Maliaka V. et al. unpublished data). Furthermore, harmful concentrations of microcystins (up to 862 µg/L) have been detected in sporadic cyanobacteria blooms especially near the lakeshore during the warm periods (Maliaka V et al. in preparation) which may pose a serious health hazard to wildlife and humans. Average phosphorus (P) levels in the water reflected mainly a mesotrophic and a periodically eutrophic state of the lake according to Carlson TSI (1977) and OECD criteria (1982) (Maliaka V. unpublished data). Bioassays performed in 2013 and 2015 by using seston from Lake Lesser Prespa show that phytoplankton growth and microcystin concentrations were strongly promoted by adding nitrogen (N) or both N and P (Maliaka V. et al. submitted). These results indicate that the water of the lake water is vulnerable to further N enrichment while co-limitation of N and P is expected to be critical too.

Understanding and addressing the sources of the nutrients to the lake Lesser Prespa is critical before selecting any preventive or restoration measure to mitigate eutrophication. Current

¹ Research Project 'Eutrophication Assessment of Prespa Lakes with the Use of Biogeochemical Indicators (2013-2017)'. More information at <http://bit.ly/1GNq2M5>.

research¹ on the nutrient inputs in the lake shows that nutrient-rich water is draining from the agricultural fields towards the lake (Maliaka V. et al. unpublished data) whereas the presence of the abundant breeding waterbirds can contribute locally to the eutrophication of the lake via their nutrient-rich excrements (Verstijnen Y.J.M. et al., in preparation). Internal nutrient loading from the lake sediments may also contribute significantly to the eutrophication processes of this shallow lake similarly to other shallow lakes worldwide which receive increased external nutrient inputs (Scheffer 2001). Especially nutrient-rich sediments may act as a source of nutrients under favourable environmental conditions and processes such as the prevalence of anaerobic (lack of oxygen) and turbid conditions, low redox potential, high pH, high primary production or enhanced breakdown of organic matter influenced by alkalinity (Boers 1991, Hosper 1997, Smolders et al. 2006). Less availability of soil complexes which have strong P-binding capacity i.e. iron (Fe) can lead in increasing P-mobilisation in the sediments and successive P- release towards the lake water. Particularly the release of P to the water layer seems to depend on the Fe/P ratio in sediment pore water (Smolders et al. 2001). In some cases, the internal nutrient loading is the major nutrient source in lake systems. For this reason, even after many years of external nutrient input elimination, no satisfactory reduction of nutrients at the water layer is achieved and thus a delay or no improvement of the water quality is observed (Boers 1991, Istvánovics et al. 2002, Kagalou et al. 2008).

Scarce information is available about the nutrient content of the sediments of Lake Lesser Prespa. Therefore, the physicochemical properties of the sediments which are associated with the trophic status of the lake are rather unknown. The objective of this study is to assess the amount and the spatial distribution of the nutrients which are currently accumulated in the surface sediment of the lake. Sediment sampling was performed in 10-12 lake sites during 2012, 2013 and 2015, while a more intensive sediment sampling took place in 2014 (58 sites).

METHODS

Surface sediment samples were taken from 10 sites in Lake Lesser Prespa during March and August 2012 (Fig. 1), from 12 sites during June and October 2013 (Fig. 1), 58 sites during September 2014 (Fig. 2) and from 10 sites during October 2015 (Fig. 1). The samples were collected with a Van Veen grab sampler. Sediment pore-water was collected anaerobically from each sediment sample with vacuum syringes (60 ml) connected to soil moisture samplers (Rhizons SMS, Eijkelkamp Agrisearch Equipment, The Netherlands).

Sediment pore-water analysis

The concentrations of phosphate (PO_4^{3-}), nitrate (NO_3^-) and ammonium (NH_4^+) were measured colorimetrically with an Auto Analyzer 3 system (Bran+Luebbe, Germany). Dissolved P was additionally analysed by using inductively coupled plasma spectrophotometry (ICP-Optical emission spectrometer, Thermo Scientific iCAP 6000 Series ICP) was used.

Sediment analysis

From each sediment sample approximately 50 g was dried (48 hrs at 60°C) in duplicate for the determination of the moisture content. Hereafter, a homogenized portion of 200 mg dried sediment of one replicate was digested with 4 ml HNO_3 (65%) and 1 ml H_2O_2 (30%), using a microwave oven (mls 1200Mega, Milestone Inc., Italy). Digestates were diluted and analysed by ICP as described above. The other replicate of dried sediment was incinerated (4h at 550°C) for the determination of the organic matter content. Moreover, soluble (or exchangeable) P and N content of the sediments was determined via water-extraction (mixing 17.5 g of fresh sediment sample with 50 ml milliQ water) and NaCl (salt)-extraction method (mixing 17.5 g of fresh sediment sample with 50 ml NaCl) method. The supernatant was collected via soil

moisture samplers and analysed colorimetrically with an Auto Analyzer 3 system (Bran+Luebbe, Germany).

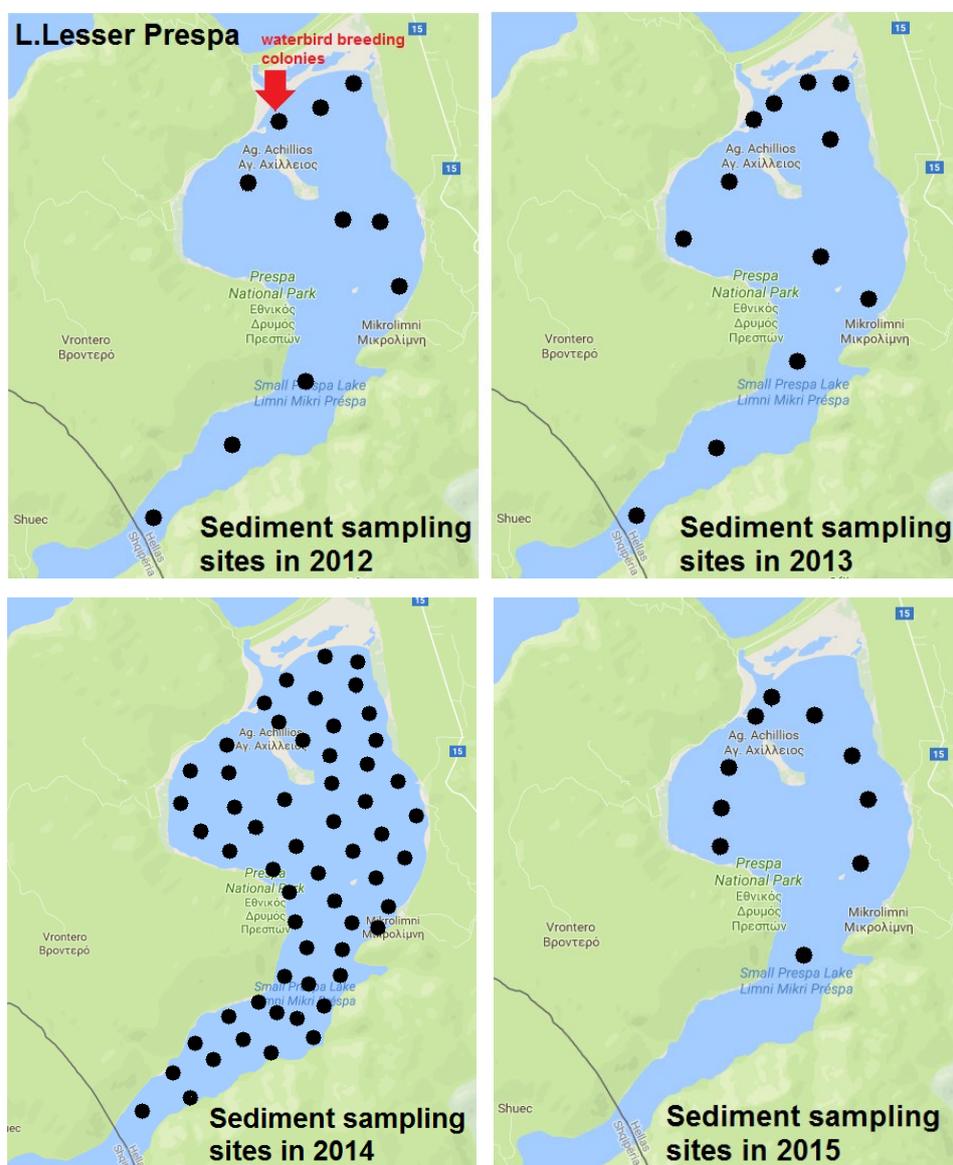


Fig. 1: Illustration of sediment sampling sites in 2012 (n=10), 2013 (n=12), 2014 (n=58) and 2015 (n=10). The red arrow ↓ (on the upper panel on the left) indicates the location of the major waterbird breeding colonies at Lesser Prespa.

RESULTS and DISCUSSION

Phosphorus concentration in lake sediments

The proportional amounts of total-P and total-Ca (mmol/kg) among the collected sediments during 2012 – 2015 at Lake Lesser Prespa do not confirm strongly the presence of Ca-P complexes in the lakebed (Fig. 2). These complexes can show a very low solubility in the soils/sediments and the contained P is considered rather inert and immobile (Burley et al. 2001, Driscoll et al. 1993). Therefore, ‘inert’ P in apatite-like forms does not seem to be dominant at

the surface sediments of the lake. On the contrary, measurements of Total-P and Total-Ca at the surrounding reedbeds and the agricultural soils at the catchment of the lake show a higher abundance of Ca – P complexes (Maliaka et al. 2012, unpublished data).

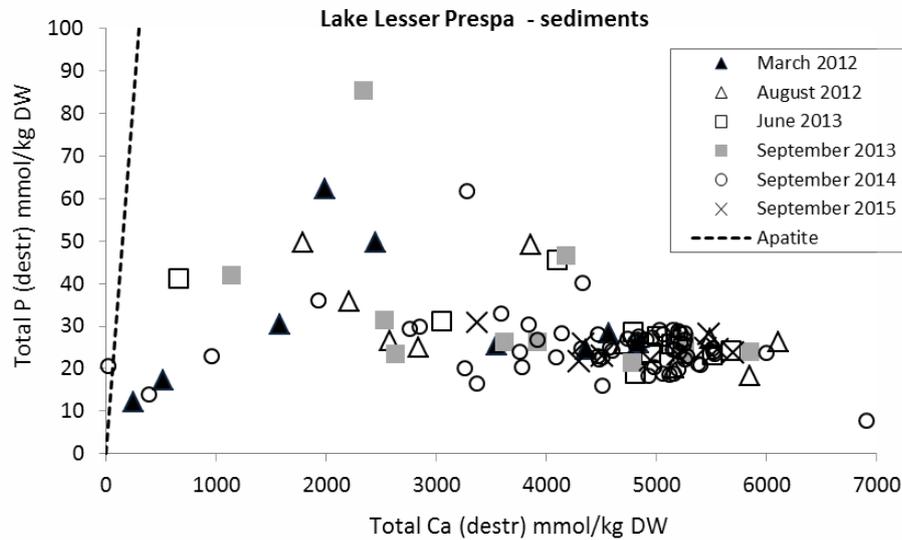


Fig. 2: Illustration of total-P and total-Ca concentration in sediments of Lesser Prespa Lake measured in collected samples during 2012-2015 and their correlation with the mineral apatite.

In this study, the Fe:P ratio of the sediment pore water is used to detect the potential of P-release from sediments since it can reflect the capacity of the sediments to release P (Geurts et al. 2008, Smolders et al. 2001). The pore-water Fe:P ratio calculated for all sediment pore-water samples collected during 2012, 2013 and 2015 from lake Lesser Prespa show that the majority of the sites are not susceptible to P-release (Fig.3). However, sediment sites particularly near the breeding colonies of the Dalmatian and Great White Pelican (Fig. 1) had Fe:P <1 (Fig. 3), which indicates a high risk of P-diffusion across the sediment-water interface (Geurts et al. 2008). Eight other sites at the lake indicate a moderately high P-release potential as well (Fe:P < 3.5, Fig. 3). Based on these data, one could argue that the potential P-release from sediments in Lesser Prespa will be low. However, temporary and localized depletion of oxygen in the bottom water layer might result in pulse wise releases of P from the sediment. Once this amount of P is free in the water column, it can be available to phytoplankton and stimulate their growth. Periodic oxygen depletion has been already detected at the lake during regular monitoring measurements 2012 – 2015 (Maliaka V. et al. unpublished data 2012, 2013-2015). Comparable results of Fe:P were obtained in September 2014, where 34.5% of the sites show moderate P-release risk (pore-water Fe:P <3,5) and only 3.4% of the sites show high P-release risk (pore-water Fe:P <1).

Nitrogen concentrations in the lake sediments

Total Inorganic Nitrogen (TIN, which is the sum of NH_4^+ and NO_3^-) ($\mu\text{mol/kg DW}$) extracted from sediment show increasing concentrations in organically-rich sediments (%) of Lesser Prespa (Fig. 4). In September 2014, the average TIN (NaCl-extr) range was between 67 – 5445 $\mu\text{mol/kg DW}$ (median 487.5) while Organic matter content between 5 – 41.3% (median 20.9). Increasing TIN concentrations were detected in sites with higher accumulation of organic matter content too.

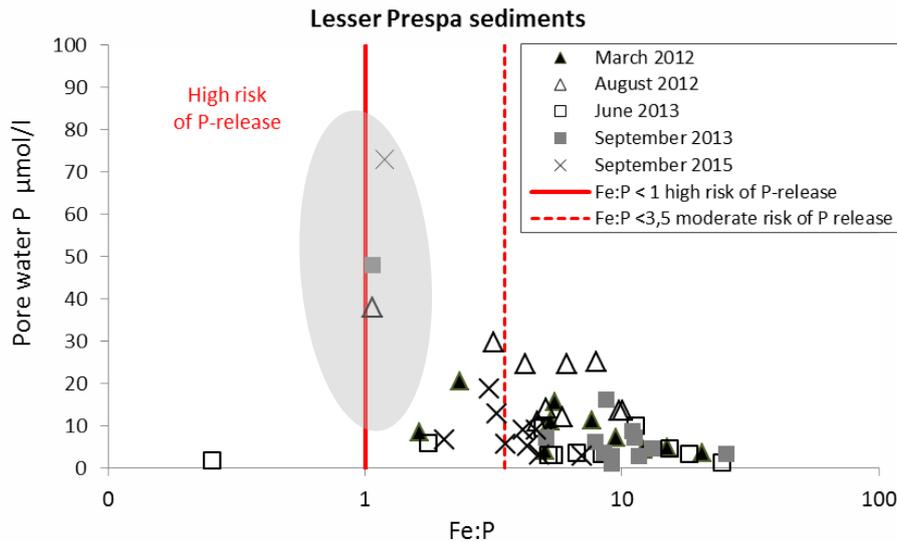


Fig. 3: Overview of pore-water-P and pore water Fe:P ratio measured in the sediments which were collected during 2012, 2013 and 2015 at Lake Lesser Prespa. Grey circle indicates the sediment sites near the largest waterbird-colonies which lie at the north part of the lake (see Fig.1)

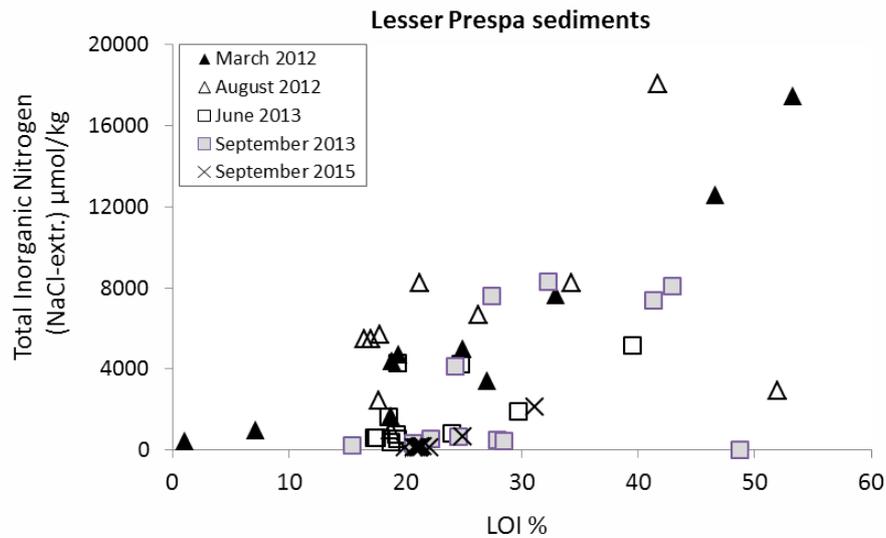


Fig. 4 Overview of the concentrations of Total Inorganic Nitrogen (NaCl extr.)(µmol/kg) and organic matter content (%) in sediments of Lake Lesser Prespa during 2012, 2013, 2015.

Lake sediments can more or less function as a sponge, which retains nitrogen entering the system via external sources, but will also function as a source of nitrogen when inorganic nitrogen concentrations in the water layer become low. This study shows that the sediments of lake Lesser Prespa contain rather high amounts of inorganic nitrogen which can be strongly correlated with organic matter. The increasing temperatures (20 – 26 °C) that occur near the sediment surface in summertime (Maliaka V. et al. unpublished data 2013 - 2015) may stimulate the decomposition processes of the organic matter and therefore mobilize inorganic -N from the sediments towards the water body (Smolders et al. 2006). Meanwhile, algal bioassays and low N/P ratios in Lesser Prespa indicate that nitrogen rather than phosphorus is the main nutrient limiting phytoplankton growth. (Maliaka V. et al, subm., Petaloti C. et al. 2004).

Spatial distribution of nutrients in the sediments

The distribution of pore-water nutrient (N, P) concentrations at the lake sediments of Lesser Prespa show a distinct accumulation of soluble nutrients at the north part of the lake where the largest breeding colonies of pelicans and cormorants occur nowadays (Fig. 1)(Society for the Protection of Prespa, Waterbird conservation activities reports 2009- 2013). Annual nutrient input by both pelicans and cormorant species to the lake is estimated to be at least 1200 kg N year⁻¹ and 1614 kg P per year⁻¹ (Verstijnen et al. in prep.). Such a loading could be of minor importance for the whole lake, however, on a local scale (i.e. near breeding colonies, roosting places) the frequent deposition of waterbird excrements can strongly contribute to the formation of nutrient-rich sediments. Fe:P ratios indicate moderate and high risk of P-release near this location too (Fig. 3). The variation of pore-water P in the sediments of the lake (Fig. 5b) show a local accumulation of soluble P near the middle part of the lake, which is mostly surrounded by mountainous area, and near the east part of the lake where an agriculture area with bean fields lies nearby (Crivelli and Catsadorakis 1997). Extremely low levels of pore-water P (< 5 $\mu\text{mol/l}$) are observed at the southernmost part of the lake and also sporadically at the north-eastern part of the lake where an extent reed bed zone lies in between the lake the agricultural land (Crivelli and Catsadorakis 1997). The overall levels of P in the pore-water at the lake are not considered too high (< 30.4 $\mu\text{mol/l}$) compared to other eutrophic freshwater systems (Geurts et al. 2010, Geurts et al. 2008, Smolders et al. 2001, Zak et al. 2004).

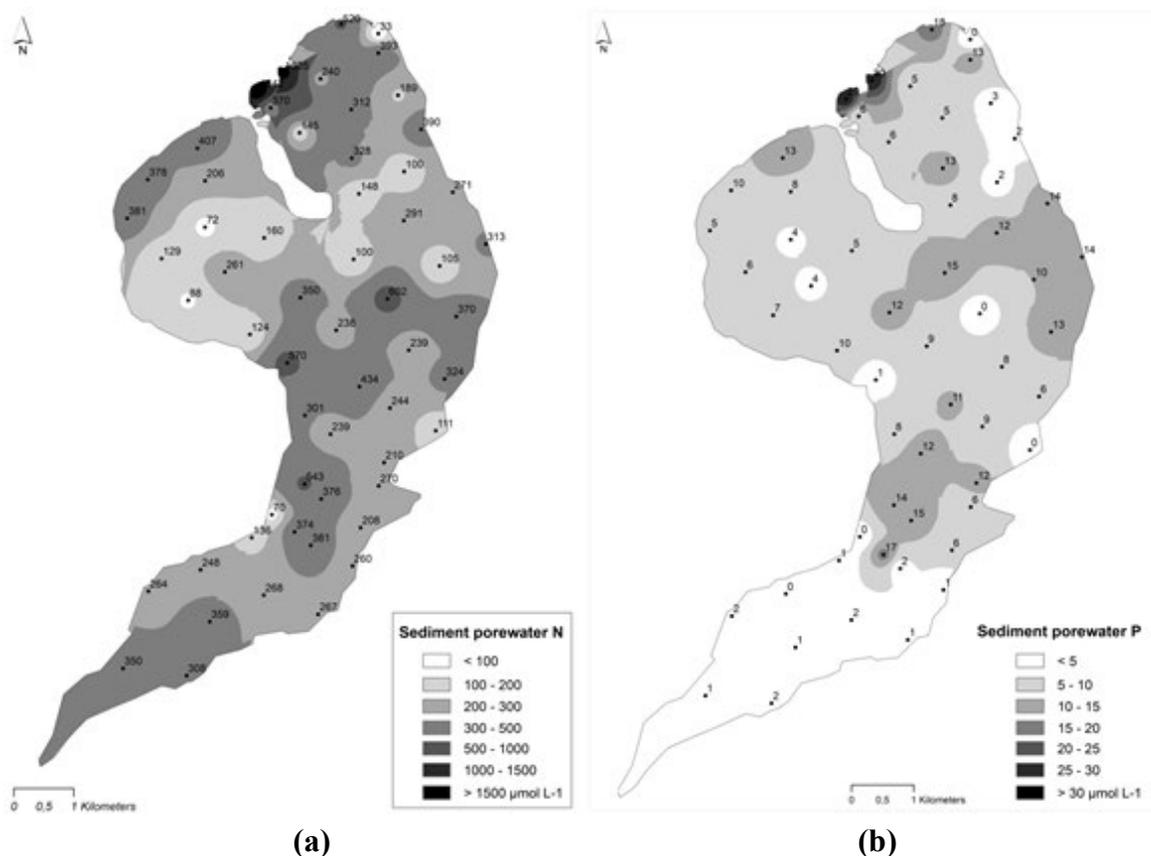


Fig. 5: Illustration of the spatial distribution of pore water N (panel a) and pore water P (panel b) at the sediments of Lake Lesser Prespa in September 2014. The dots (•) on the maps indicate the sampling locations (n=58) and the local concentrations of P and N accordingly.

Similar to pore water P, pore-water N reached the highest levels near the waterbird-breeding colonies (Fig.5). Increased concentrations are also observed locally near the deepest lake sites (> 7m) and range between 570 – 602 $\mu\text{mol/l}$. In contrast with pore water P, the south part of the lake contains relatively high concentrations of pore water N (> 300 $\mu\text{mol/l}$) while comparable levels are distributed at the middle and north part of the lake. Organic matter content (%) is also more abundant at the south and the north part of the lake (data not shown here).

CONCLUSIONS

Nutrient cycling, and particularly the retention of nutrients, is considered an important ecosystem service which is largely linked to biogeochemical cycles of the sediments in lake systems. However, increased loading of nutrients and organic matter may cause a significant pressure to these functions and as a result lake sediment may have gradually less capacity to store nutrients and act as an internal diffuse source of nutrients. Usually sediments show a slow response to pressures, which are difficult to detect without specific measurements. The lack of knowledge on these processes can partly explain failures in combating eutrophication problems especially in shallow lakes.

The long-term sediment quality study which was conducted in Lake Lesser Prespa in Greece during 2012 – 2015 shows that:

- The sediments of the lake are probably not an important direct source of phosphorus yet. Based on Fe:P ratio, most sites show low risk of phosphorus diffusion towards the lake water while the sites with high-risk of phosphorus diffusion lie near the breeding-waterbird colonies. The detected concentrations of highly soluble P forms (pore-water P) in the lake sediments are not considered high except for a few sites. Increasing accumulation of soluble P is likely to occur from agricultural sites at the east site of the lake.
- Apart from low concentrations of readily available phosphorus in the porewater, low amounts of immobile or 'inert' P forms (such as Ca-P complexes) are present in the sediments too.
- Increased Total Inorganic Nitrogen concentrations are present in organically-rich sediments in the lake. Such sites occur especially near the breeding-waterbird colonies. Increased mineralization rates in warm periods may therefore result in cumulative diffusion of Total Inorganic Nitrogen towards the lake water. Such processes may strongly boost the outbreaks of cyanobacterial blooms and the increase of harmful Microcystins which have been found to be N-limited.

An experimental incubation of surface sediments under aerobic and anaerobic conditions which has been conducted within the framework of the current Research Project¹ can provide valuable insights about the internal Phosphorus and Nitrogen loading towards the lake. Further comparison of these internal loads from the sediment with the external P, N loads from the watershed (streams inflows) and the breeding waterbirds (pelican, cormorants) is required in order to assess further the role of sediments at the eutrophication of the lake. Such knowledge can contribute in setting priorities in a future lake management plan where the mitigation of eutrophication is intended.

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D6. Nitrous oxide emission from nitrogen-rich organic soils

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INTRODUCTION

Human activity has increased the atmospheric concentration of nitrous oxide (N₂O; IPCC, 2013), a powerful greenhouse gas and the main stratospheric ozone depleting agent (Ravishankara et al., 2009). Organic soils are likely to be an increasingly important global source of N₂O due to human activities, particularly drainage and fertilisation for agriculture (Syakila and Kroeze, 2011; Butterbach-Bahl et al., 2013; He et al., 2016; Paustian et al., 2016). However, predicting global N₂O emissions is a challenge owing to high temporal and spatial variability (Reay et al., 2012; Batjes, 2014), and because of the paucity of data from the tropics (Reay et al., 2012; Butterbach-Bahl et al., 2013).

METHODS

We conducted a global soil and gas sampling campaign between August 2011 and December 2017, following a standard protocol. We sampled 66 organic soil sites in 29 regions across the tropical, temperate and boreal climates. Within each region, at least one site was established in a natural peatland and another one in an adjacent drained area. The hydrology and trophic status of the natural peatlands ranged from groundwater-fed swamps and fens to ombrotrophic peat bogs. Land use varied between natural (fen, bog, swamp or bog forest) and agricultural (pasture, hay field or arable). Within the sites, locations followed a groundwater-depth gradient. Gas fluxes were determined using the static chamber method at least three times within three days per location. Soil pH, NO₃-N, NH₄-N, P, K, Ca and Mg, TN and organic matter content were determined from the collected samples. In French Guiana fen samples, the bacterial and archaeal 16S rRNA genes and functional genes involved in nitrogen cycling (*nirS*, *nirK*, *nosZI*, *nosZII*, bacterial and archaeal *amoA*, *nifH*, *nrfA*, ANAMMOX bacteria genes) in soil were quantified by using quantitative PCR method.

RESULTS and DISCUSSION

In all areas N₂O emissions were significantly higher in the affected sites than in the natural sites. Statistical analyses showed a strong positive correlation between the N₂O emissions and soil NO₃-N content ($p < 0.05$), while soil moisture and water table level showed a negative correlation with N₂O emission ($p < 0.05$) in all sites.

We found that the emissions can be predicted by models incorporating soil nitrate concentration (NO₃⁻), water content (WC) and temperature. N₂O emission increases asymptotically with NO₃⁻, and follows a bell-shaped distribution with WC. Combining the two functions explains 70% of log N₂O emission from all organic soils. Accordingly excess soil NO₃⁻ provided, either through draining wet soils or irrigating well-drained soils can increase N₂O emission by orders of magnitude. Combining soil NO₃⁻ with temperature explains 69% of log N₂O emission. Across the global sites, tropical organic soils exhibited the highest N₂O emission and thus should be a research and conservation priority for reducing N₂O emissions.

Drainage had a clear impact on the communities of *nirS*, *nirK*, *nosZ*, archaeal *amoA* and *nifH* gene possessing microorganisms. The structure of the communities was mainly related to different N forms. The bacterial community was more abundant ($p < 0.001$) in the natural site while the N₂O production potential (abundance of the *nir* genes) was not different between the drained and non-drained sites. N₂O reduction potential (abundance of *nosZ* genes) was higher

($p < 0.01$) in the natural area where significantly lower mineral N content and high groundwater level were detected.

CONCLUSIONS

Our findings provide a single predictive model of the drivers of N₂O emissions from organic soils across the global range of environmental factors. This highlights the importance of drainage and reactive N addition to organic soils as a significant global contributor to climate change and stratospheric ozone depletion. As the temperature effect on N₂O emissions is of minor importance compared to drainage, our results are applicable to all major climate zones.

The anticipated large increases in atmospheric N₂O from N-rich drained organic soils can be mitigated through wetland conservation and restoration, and through appropriate soil management, such as reduced tillage, nutrient management and improved crop rotations. These have been implemented to some extent in developed countries but need to be expanded in these countries, and urgently implemented in tropical regions.

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