Vegetated drainage ditches and constructed wetlands for removal of agricultural diffuse pollution

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Objectives

To evaluate the ability of vegetated ditch and off-stream wetland to remove pollution from water impacted by agricultural drainage.

To access the effect of plant harvesting on nutrient removal.

The non-point source pollution is a global problem affecting the safety of drinking water supply and aquatic habitats.

Eutrophication – excessive input of nutrients into surface waters

Filamentous algae in a small stream in the agricultural landscape.

Photo: Tereza Dvořáková Březinová

Water bloom in a major drinking water reservoir supplying Prague, August 2015.

Photo: Jan Vymazal

The ability of natural wetlands to retain nitrogen from freshwaters was recognized and has been reported since the 1970s (Mitsch et al., 1979; Richardson, 1990).

Constructed wetlands for treatment of diffuse pollution – design principles (Mitsch, W.J., 1992. Ecological Engineering 1, 27-47)

1. **Minimum maintenance**
2. **Use of natural energy**
3. **Design the system with landscape, not against it**
4. **Design with multiple objectives**
5. **Design the system as ecotone**
6. **Give the system time to develop**
7. **Design the system for function, not for form**
8. **Do not over-engineer the system (with rectangular basins, rigid structures and regular morphology)**

Constructed wetlands for treatment of diffuse pollution – design principles (Mitsch, 1992)

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Mitsch, W.J., 1992. Ecological Engineering 1, 27-47.

Constructed wetland for treatment af agricultural drainage near Aarhus, Denmark.

Photo Jan Vymazal

Constructed wetland for treatment af agricultural drainage near Padova, Italy.

Photo: Jan Vymazal

Constructed wetland for treatment af agricultural drainage near Huesca, Spain.

Photo: Jan Vymazal

Tile drainage treatment

Bog Burn, New Zealand, experimental pasture

Inflow: 1062 kg N/ha yr

Outflow: 221 kg N/ha yr

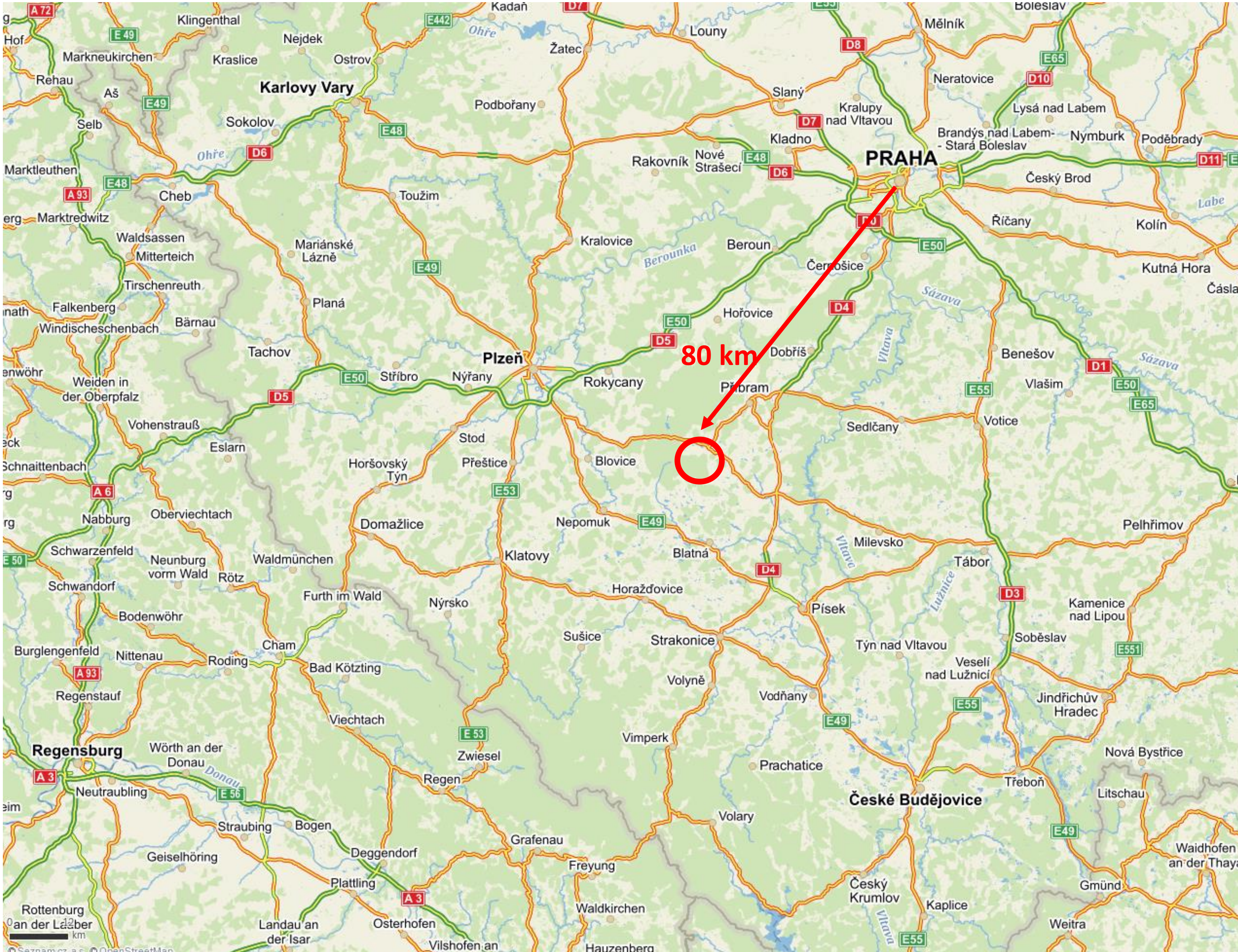
Retention: 841 kg N/ha yr (79%)

Photo: Tom Headley

Genarp, Skåne, Sweden: Phosphorus retention 140 kg P/ha yr

Bergaholm, Sweden, July 2010 & 2012

Retention:
29 660 kg TSS/ha yr


80 km
PRAHA
Plzeň
Karlovy Vary
České Budějovice
Regensburg
Kadaň
Louny
Mělník
Žatec
Klingenthal
Nejdek
Hof
Markneukirchen
Kraslice
Ostrov
Rehau
Aš
Slaný
Neratovice
Podbořany
Kralupy nad Vltavou
Lysá nad Labem
Selb
Sokolov
Kladno
Brandýs nad Labem - Stará Boleslav
Nymburk
Poděbrady
Rakovník
Nové Strašecí
Marktleuthen
Cheb
Český Brod
Toužim
Marktredwitz
Waldsassen
Mitterteich
Kralovice
Beroun
Říčany
Kolín
Mariánské Lázně
Černošice
Kutná Hora
Čáslav
Tirschenreuth
Falkenberg
Windischeschenbach
Planá
Hořovice
Bärnau
Tachov
Dobříš
Benešov
Weiden in der Oberpfalz
Stříbro
Nýřany
Rokycany
Příbram
Vlašim
Vohenstrauß
Stod
Sedlčany
Votice
Eslarn
Horšovský Týn
Přeštice
Blovice
Schnaittenbach
Oberviechtach
Nabburg
Domažlice
Nepomuk
Milevsko
Pelhřimov
Schwarzenfeld
Neunburg vorm Wald
Rötz
Waldmünchen
Klatovy
Blatná
Tábor
Schwandorf
Furth im Wald
Nýrsko
Horažďovice
Písek
Kamenice nad Lipou
Bodenwöhr
Sušice
Strakonice
Soběslav
Burglengenfeld
Nittenau
Cham
Roding
Bad Kötzting
Týn nad Vltavou
Veselí nad Lužnicí
Volyně
Vodňany
Jindřichův Hradec
Regenstauf
Viechtach
Vimperk
Zwiesel
Wörth an der Donau
Nová Bystřice
Prachatice
Neutraubling
Regen
Třeboň
Litschau
Volary
Straubing
Bogen
Grafenau
Geiselhöring
Deggendorf
Freyung
Waidhofen an der Thaya
Plattling
Český Krumlov
Gmünd
Rottenburg an der Laaber
Kaplice
Waldkirchen
Landau an der Isar
Osterhofen
Weitra
Vilshofen an der Donau
Hauzenberg
Ohře
Berounka
Sázava
Vltava
Labe
Lužnice
Donau
D4
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E48
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A 6
A 72
A 93
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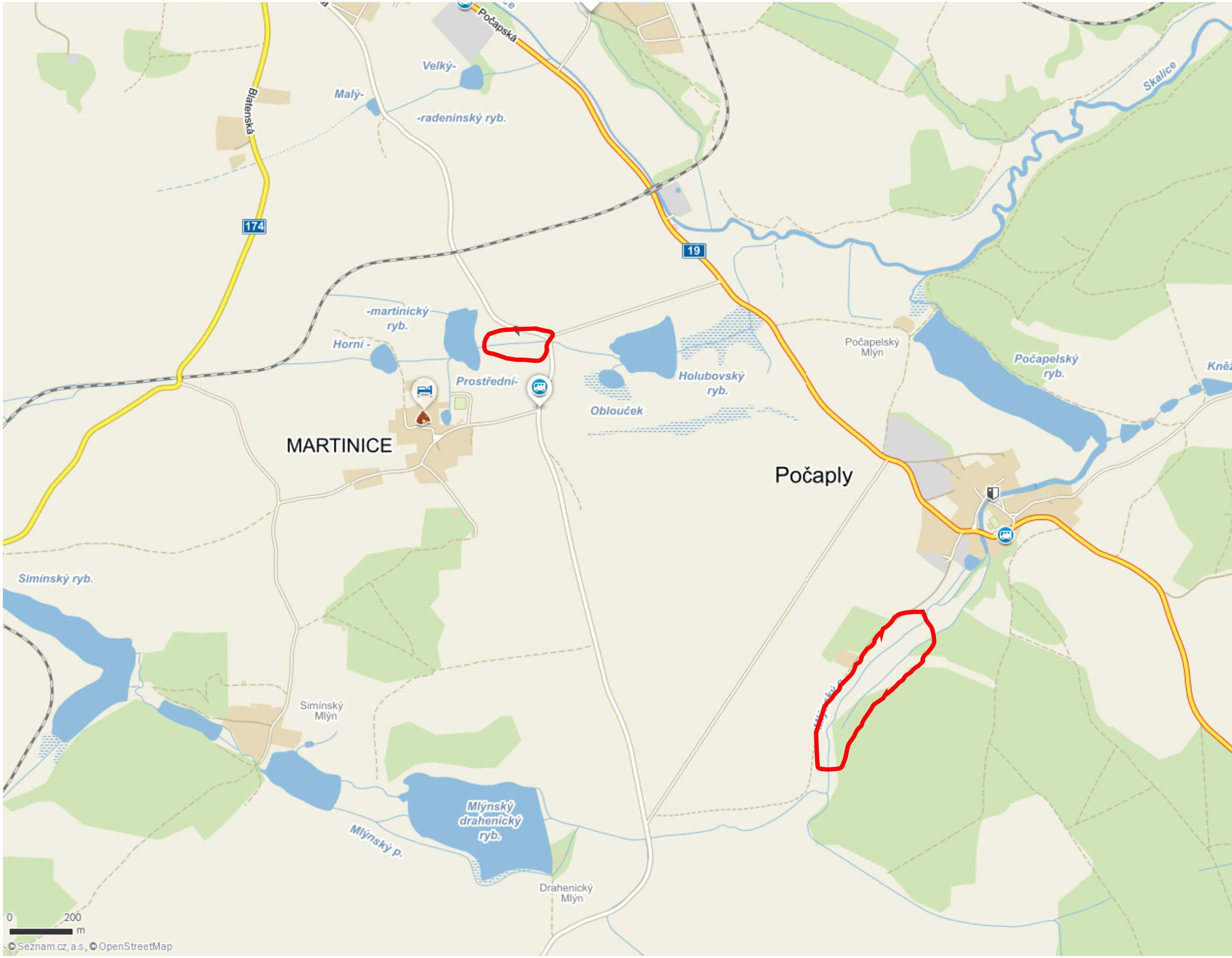

Počapská
Velký-
Malý-
-radeninský ryb.
Blatenská
174
19
Skalice
-martinický ryb.
Horní -
Prostřední-
Holubovský ryb.
Oblouček
Počapelský Mlýn
Počapelský ryb.
MARTINICE
Počaply
Simínský ryb.
Simínský Mlýn
Mlýnský drahenický ryb.
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Drahenický Mlýn
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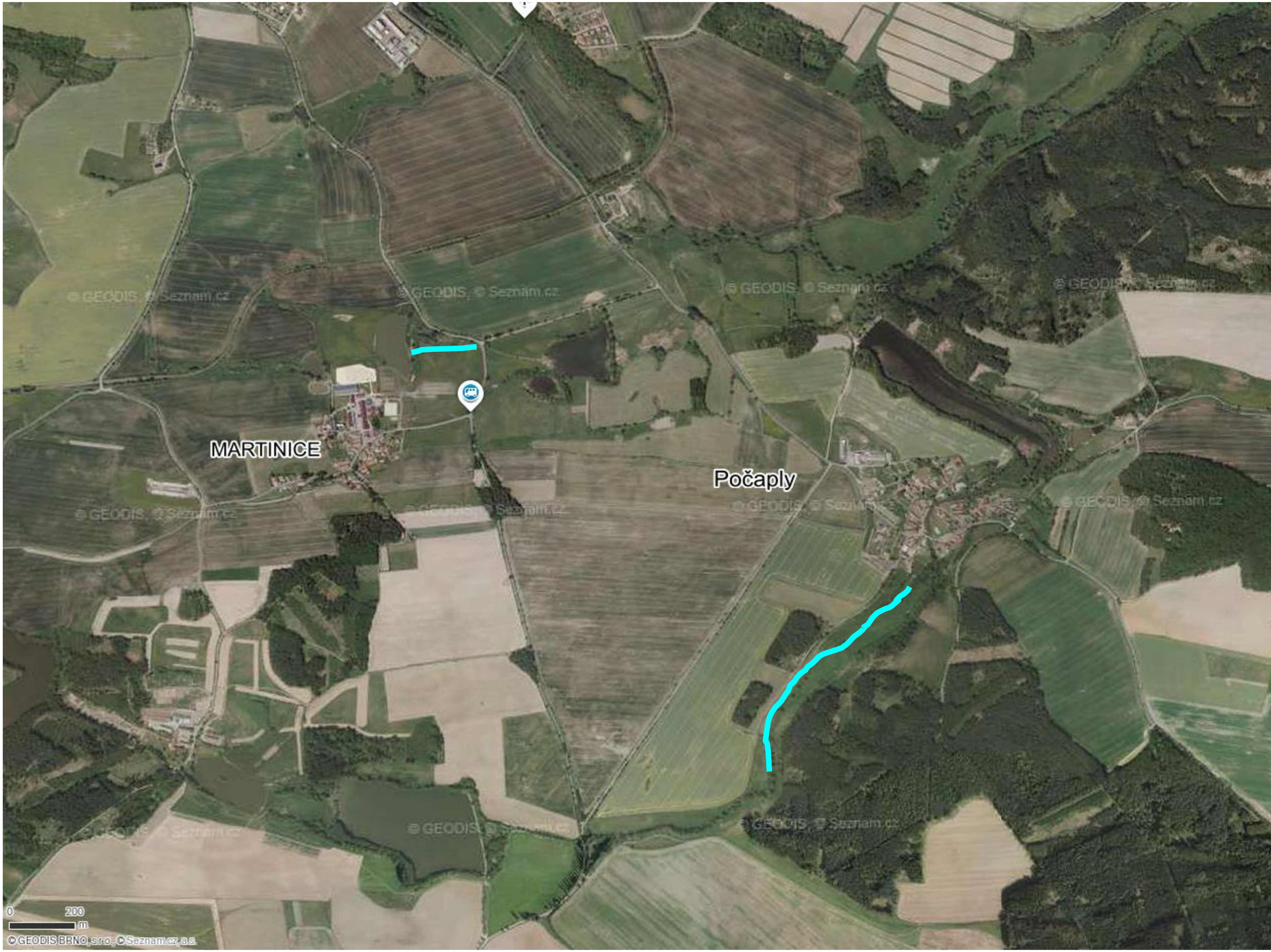
200
m
© Seznam.cz, a.s., © OpenStreetMap


MARTINICE
Počaply
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200
m
© GEODIS BRNO, s.r.o., © Seznam.cz, a.s.

Ditch 1

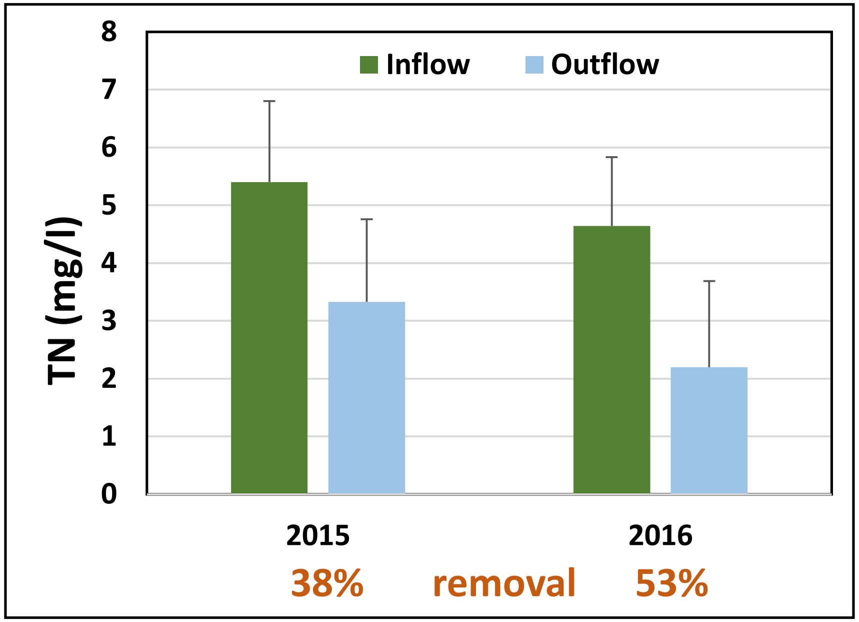
200 m long, 360 m^2 (maximum flooding area)

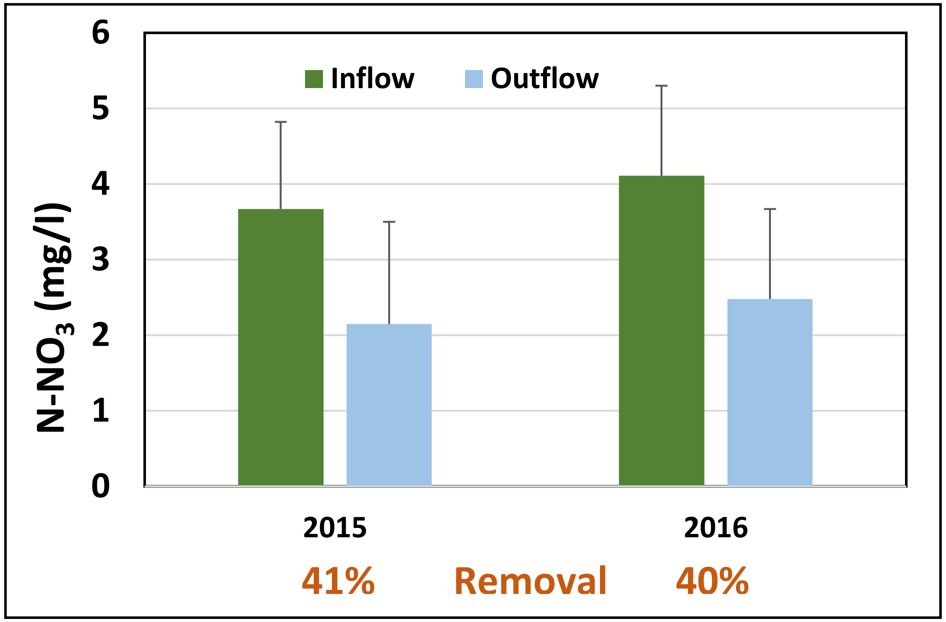
Major plant species:

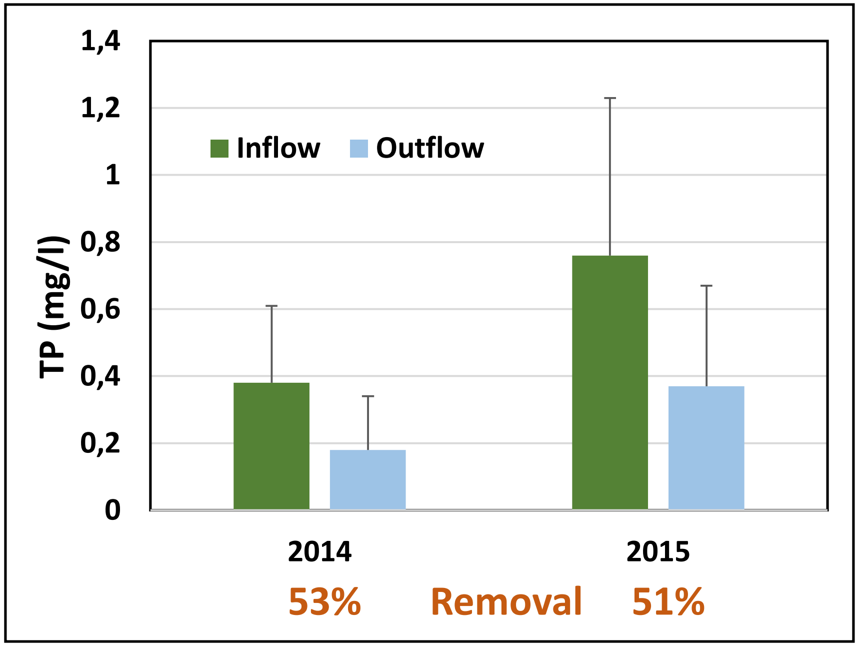
***Phragmites australis* (140 m^2), *Glyceria maxima* (64 m^2), *Typha latifolia* (20 m^2)**

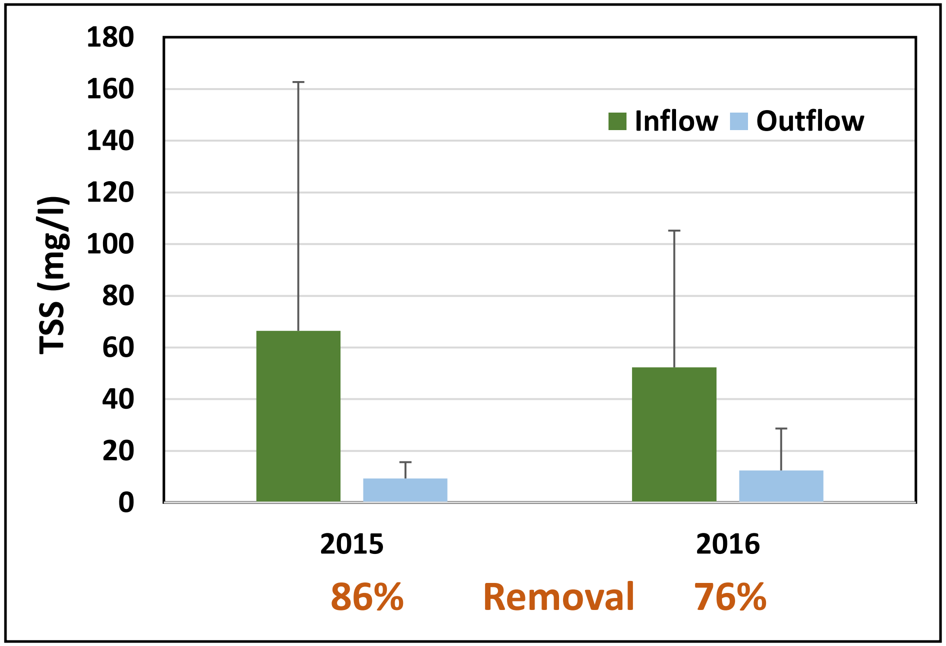

Phragmites section

Average inflow and outflow concentrations for the period 1/2015 - 12/2016

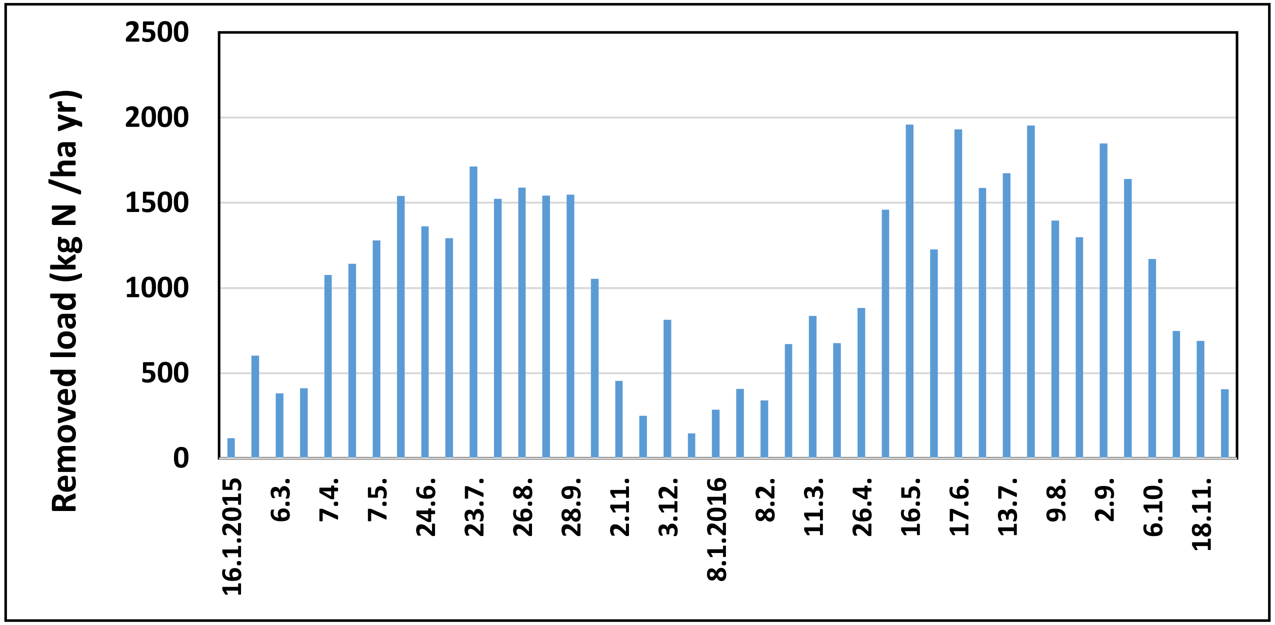


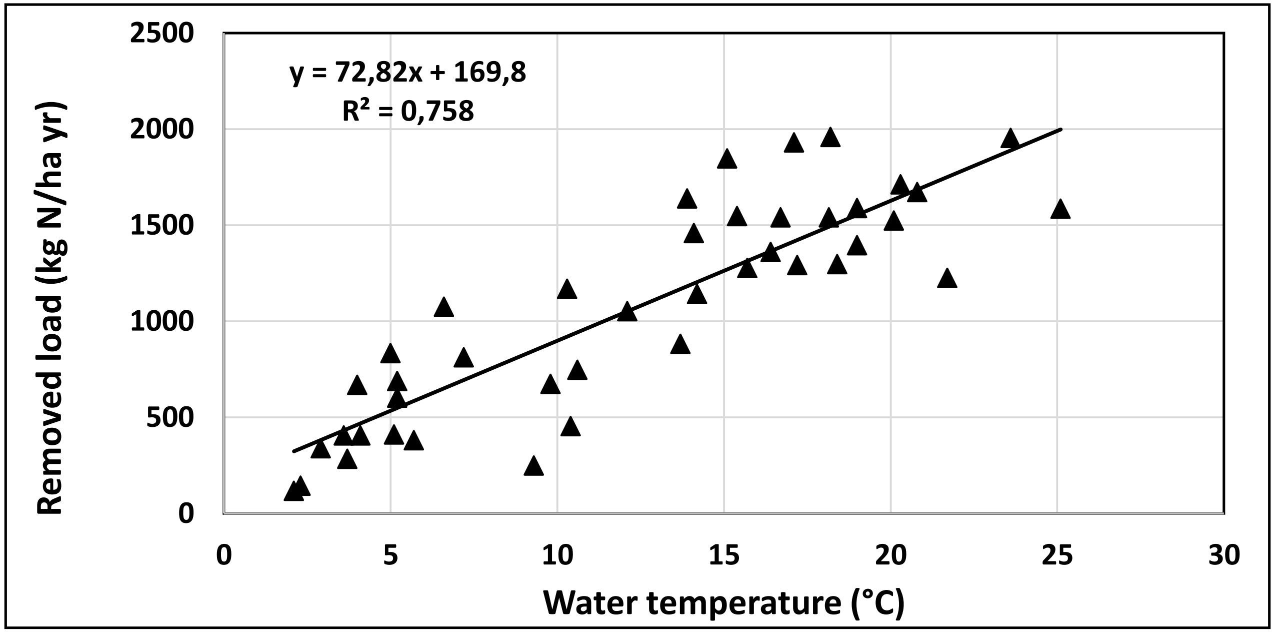






Removal of nitrogen load and dependence of removal on water temperature





TN mean removal

1157 kg N/ha yr

2015: 992 kg N/ha yr

2016: 1140 kg N/ha yr

$N\text{-}NO_3$ mean removal

804 kg $N\text{-}NO_3$/ha yr

2015: 727 kg $N\text{-}NO_3$/ha yr

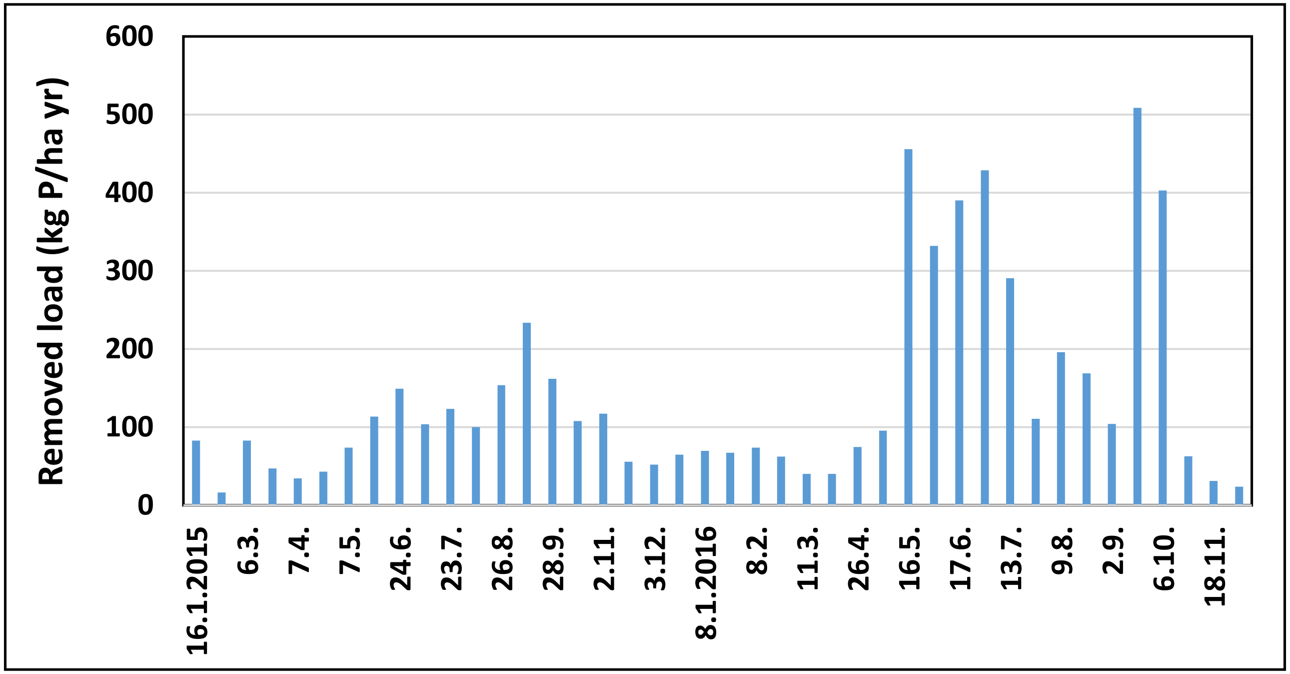
2016: 873 kg $N\text{-}NO_3$/ha yr

$N\text{-}NO_3$

$Y = 67.52x – 30,99$

$R^2 = 0.735$

Removal of phosphorus and TSS loads

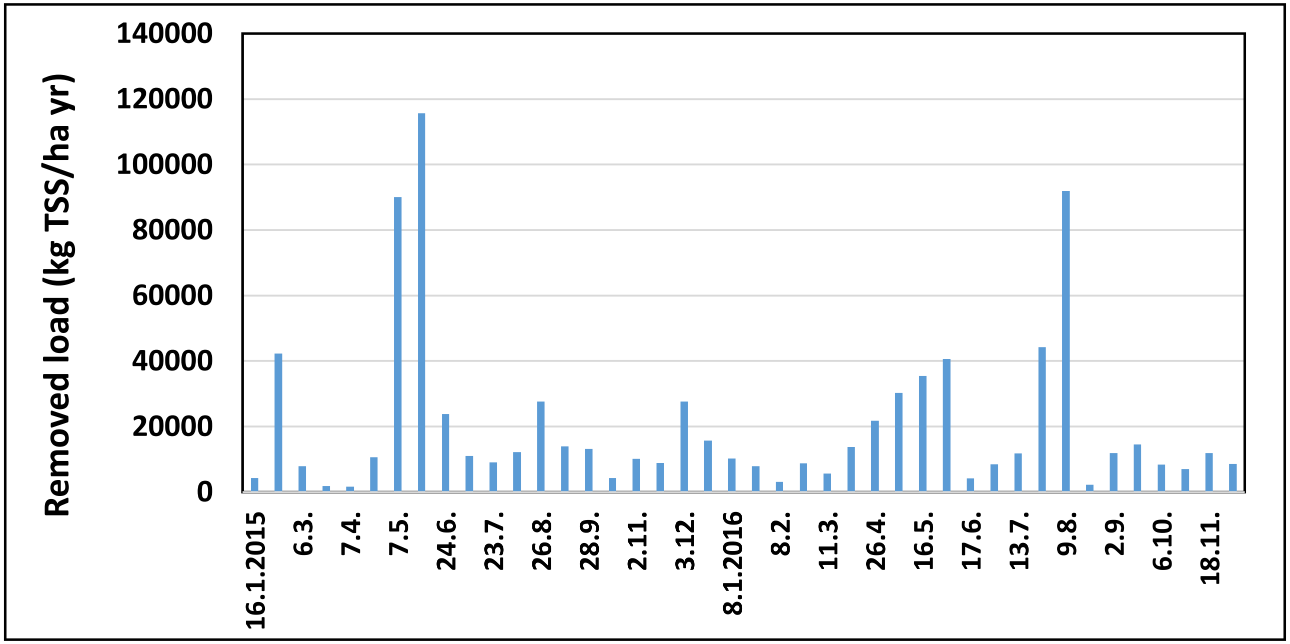


TP mean removal

142 kg P/ha yr

2015: 93 kg P/ha yr

2016: 183 kg P/ha yr



TSS mean removal

20 344 kg TSS/ha yr

2015: 22 585 kg TSS/ha yr

2016: 18 289 kg TSS/ha yr

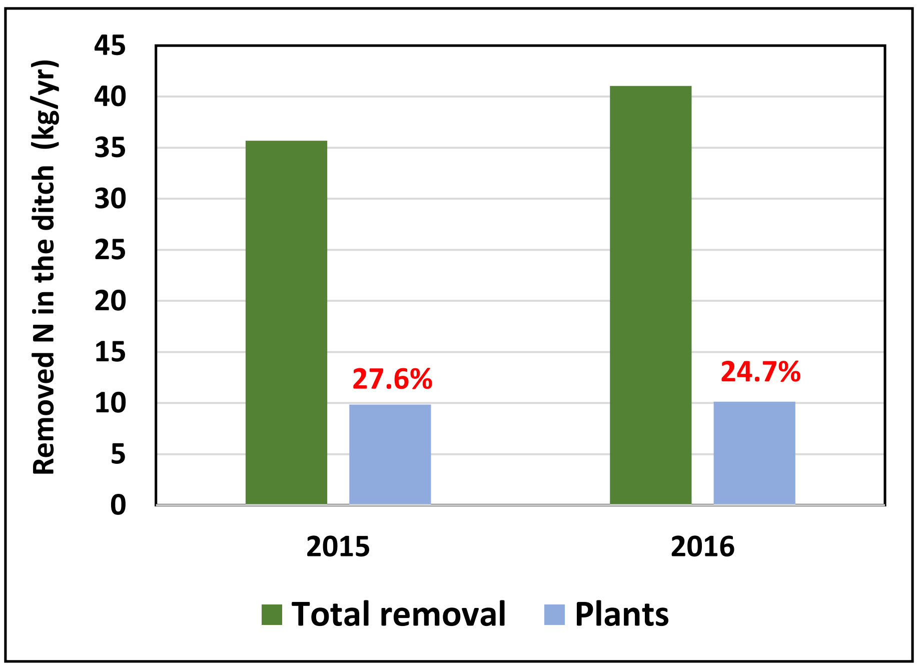
Potential of plants for nutrient removal

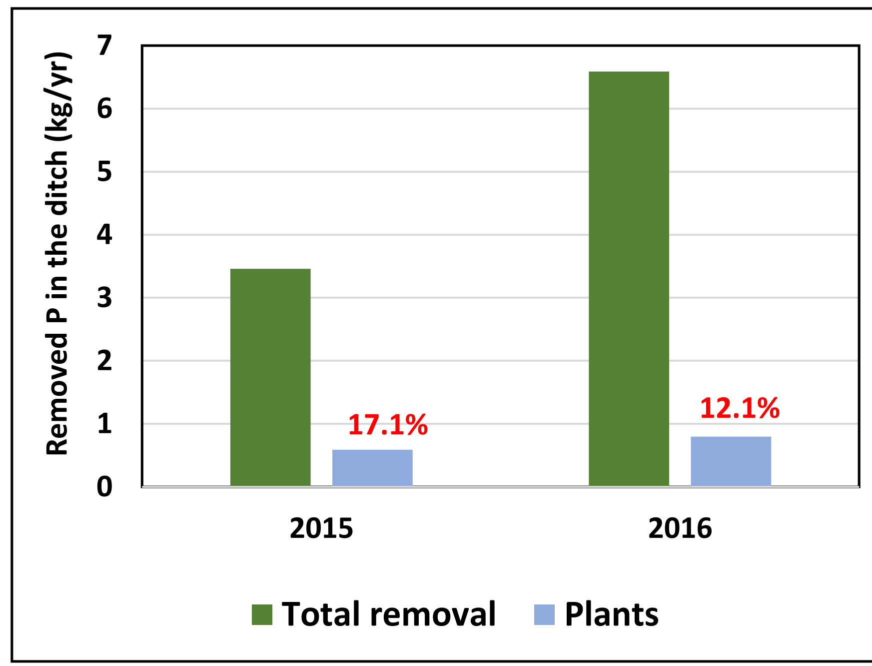
Nitrogen (g/m²)

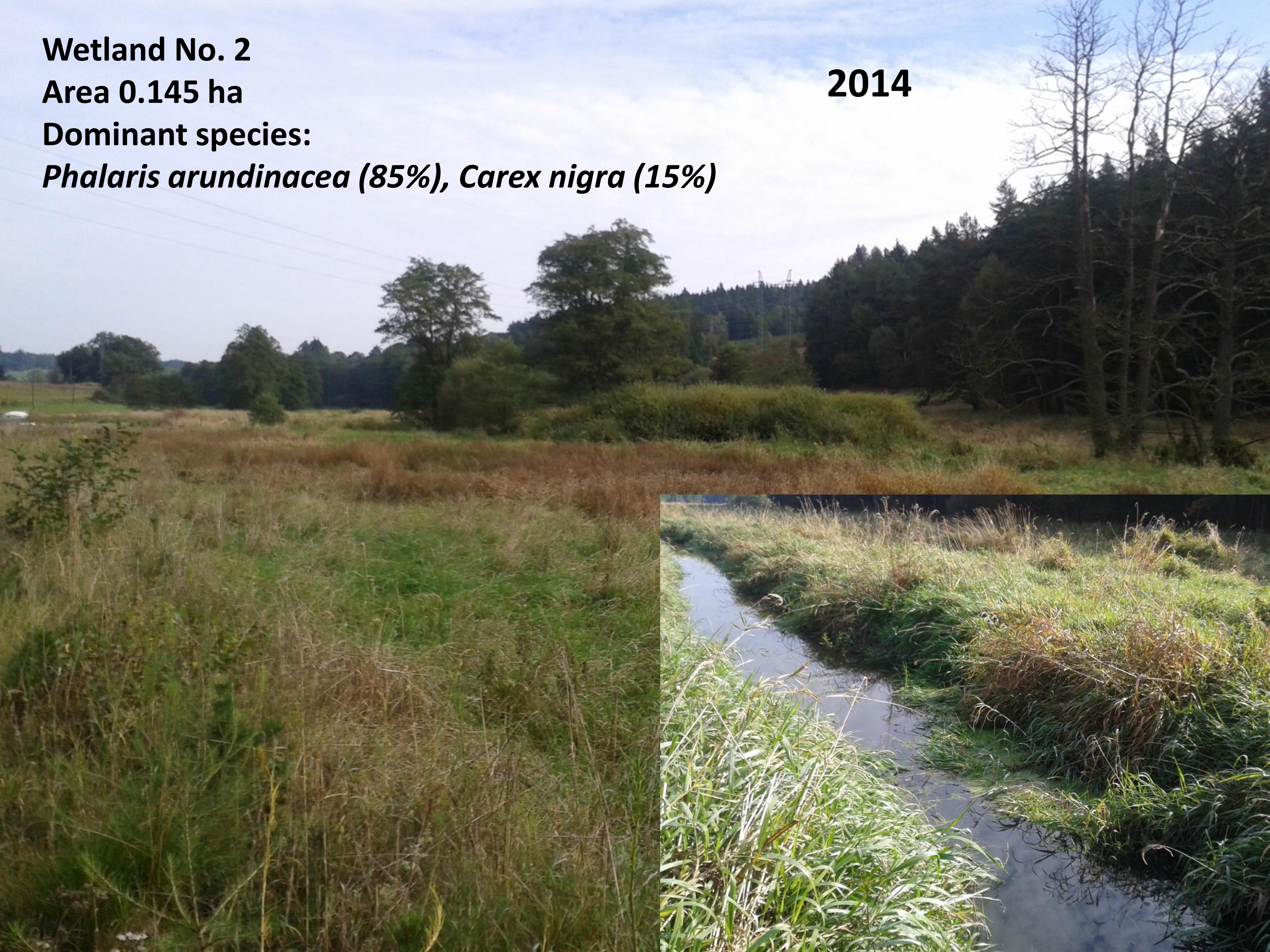
	Typha	Glyceria	Phragmites
2015	81.17	17.81	50.48
2016	66.25	25.70	51.14

Phosporus (g/m²)

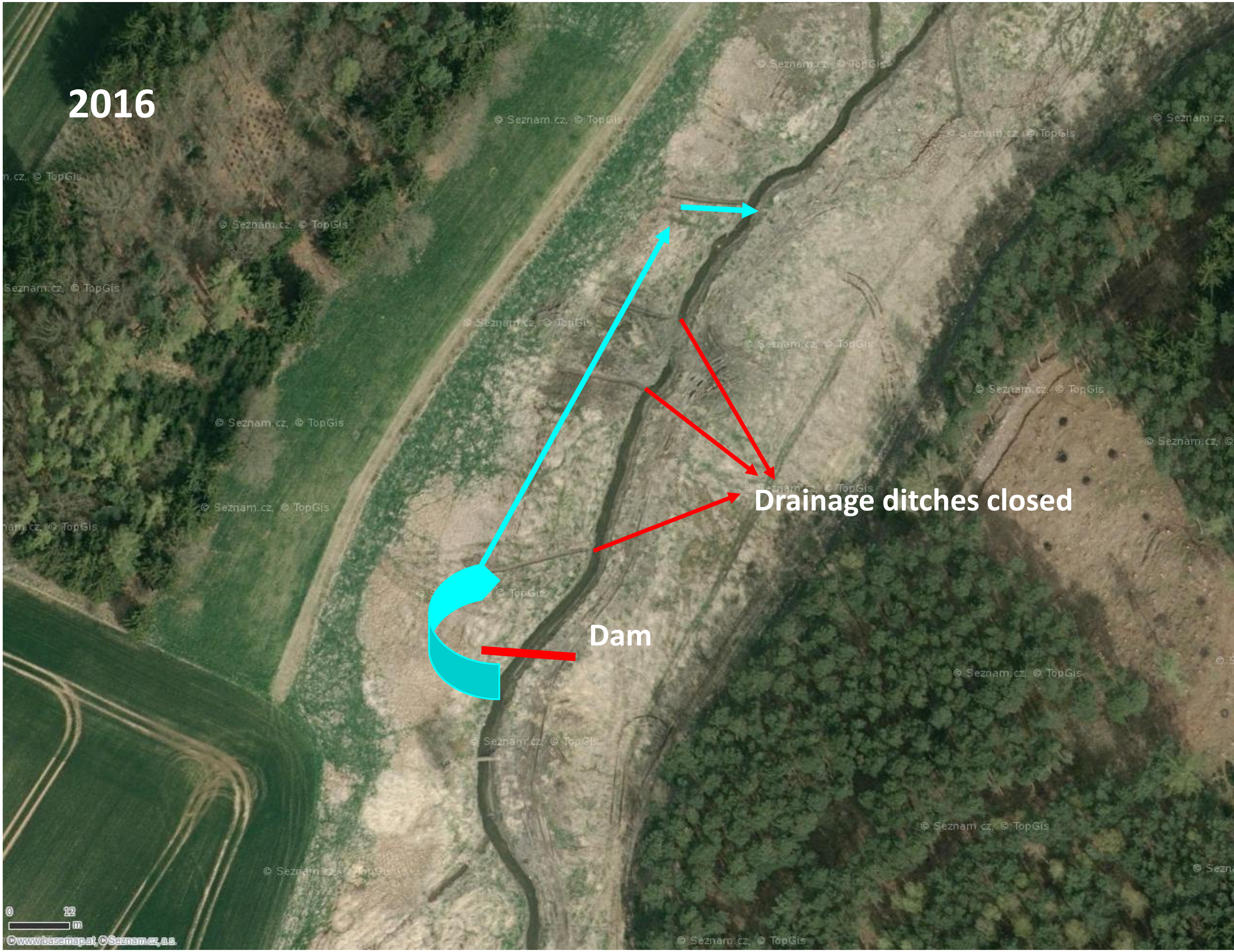
Typha	Glyceria	Phragmites
4.51	1.93	2.65
6.77	2.57	3.58



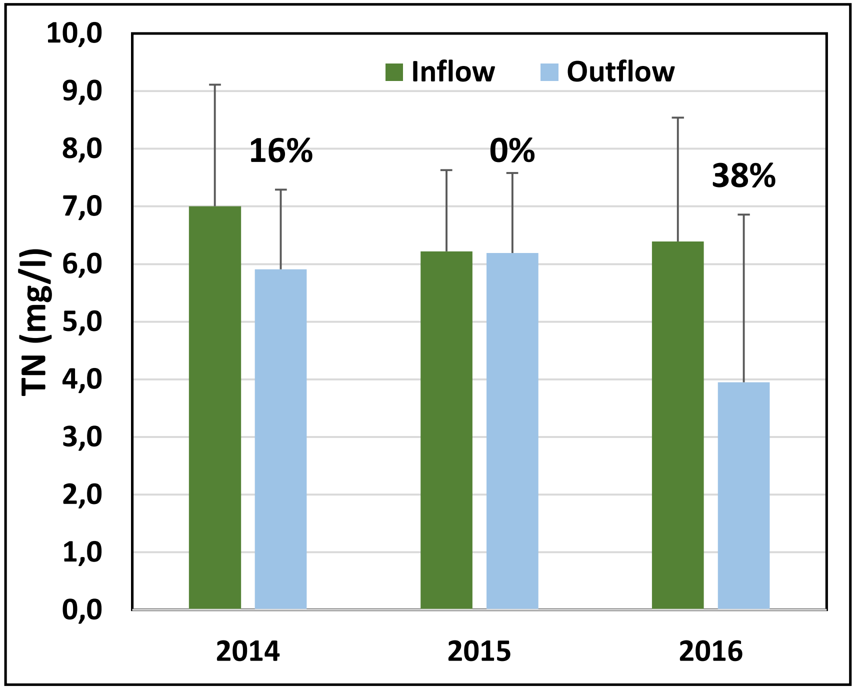


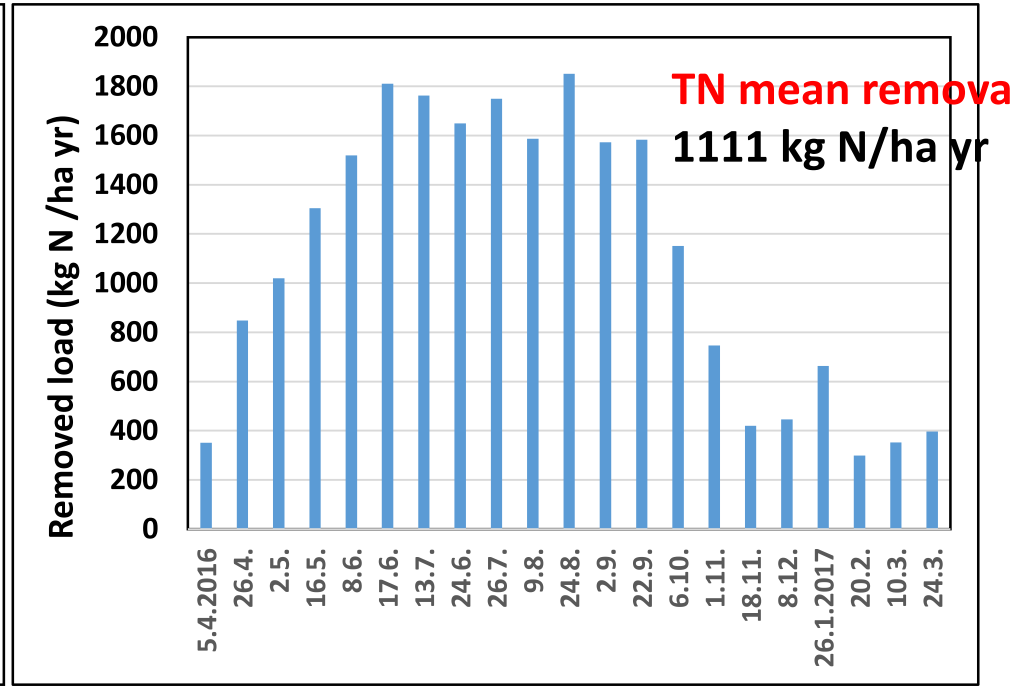

Wetland No. 2
Area 0.145 ha
Dominant species:
Phalaris arundinacea (85%), Carex nigra (15%)
2014

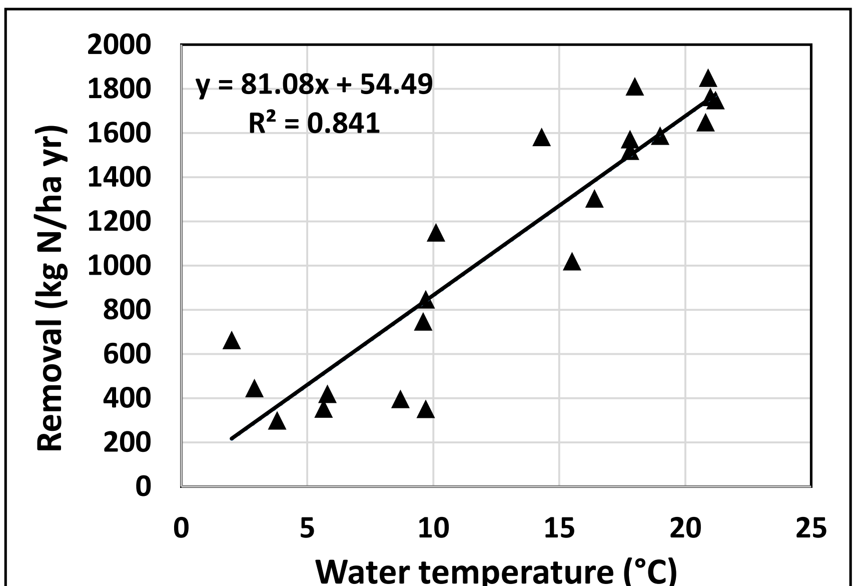

2015
CAT
317B
CAT

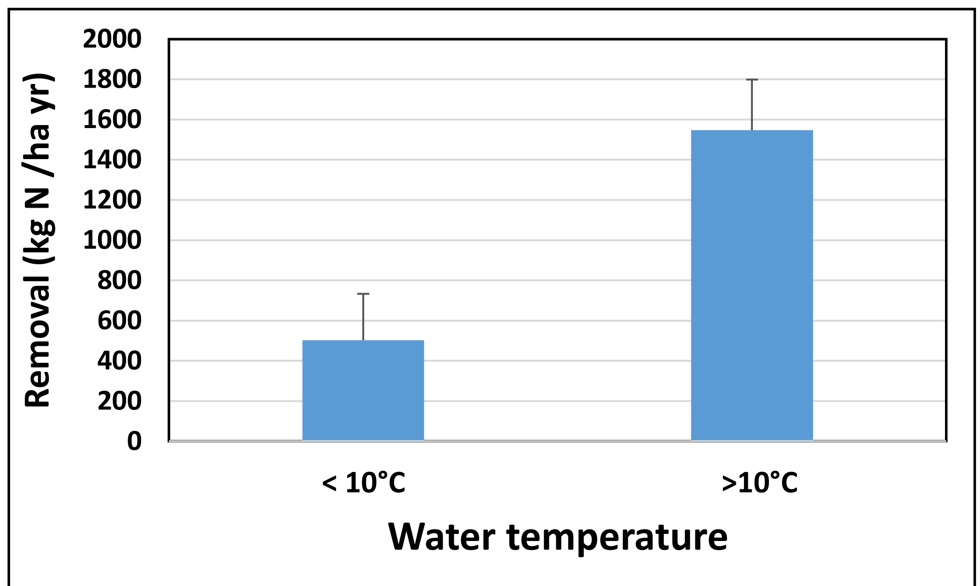

2016
Drainage ditches closed
Dam
0 12 m
©www.basemap.at, ©Seznam.cz, a.s.

Removal of nitrogen and dependence of removal on water temperature

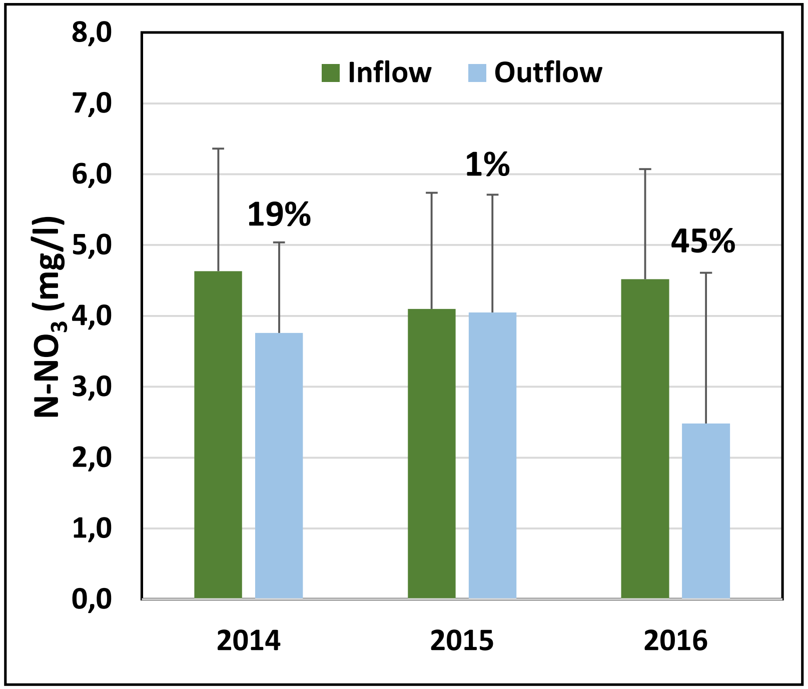


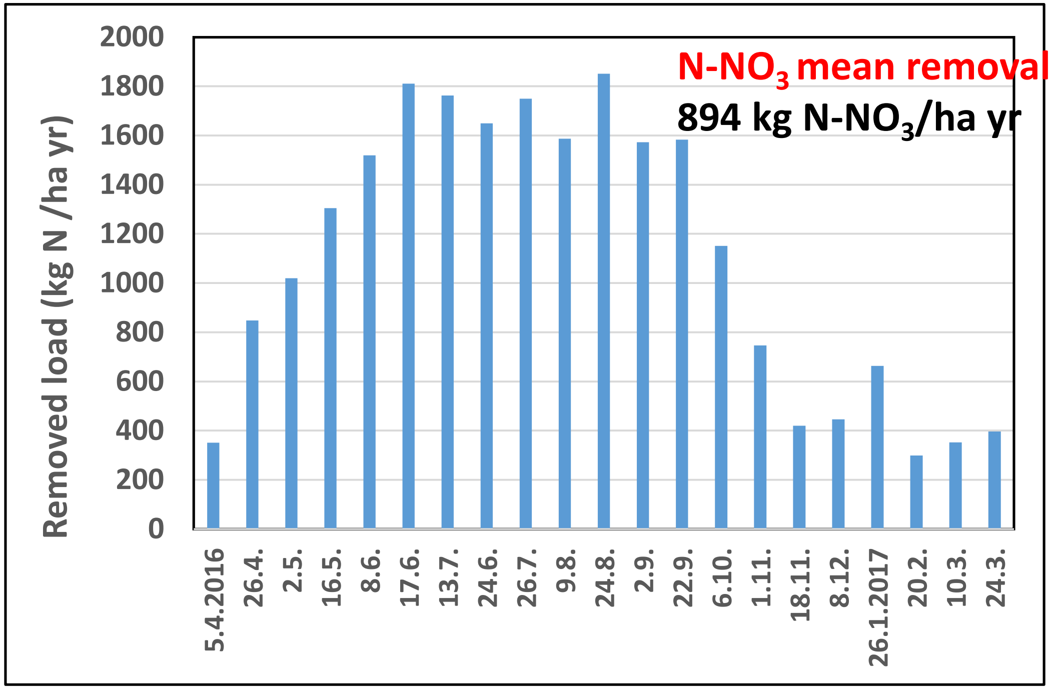


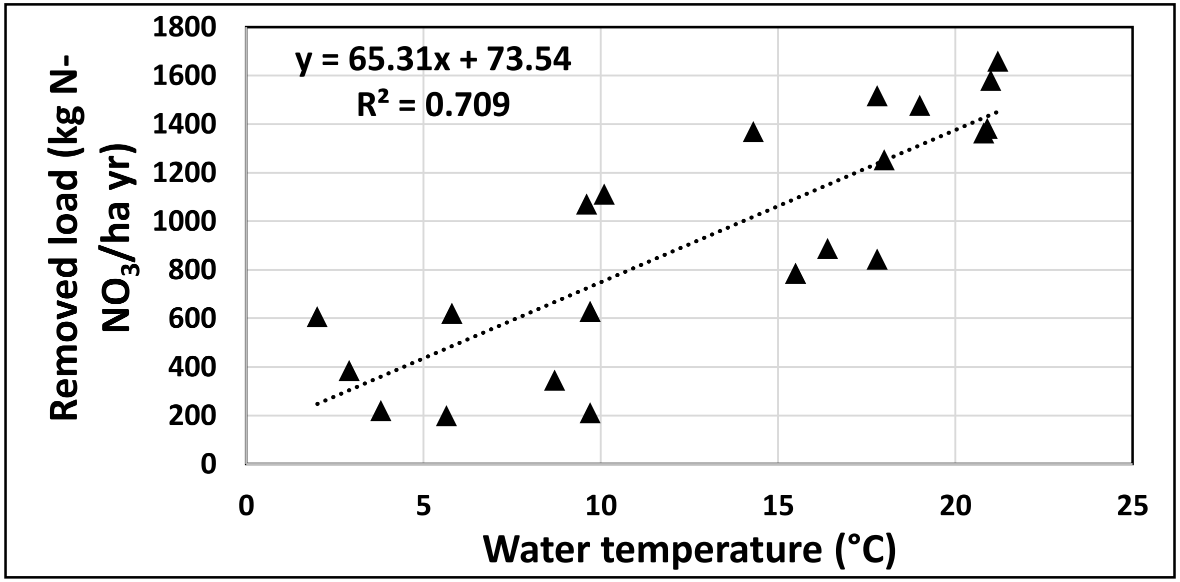




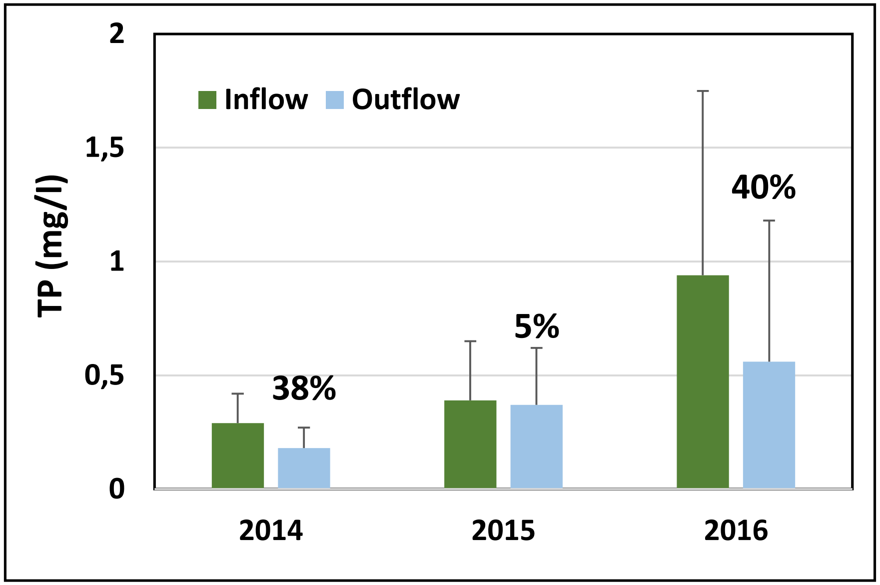
Removal of nitrate and dependence of removal on water temperature





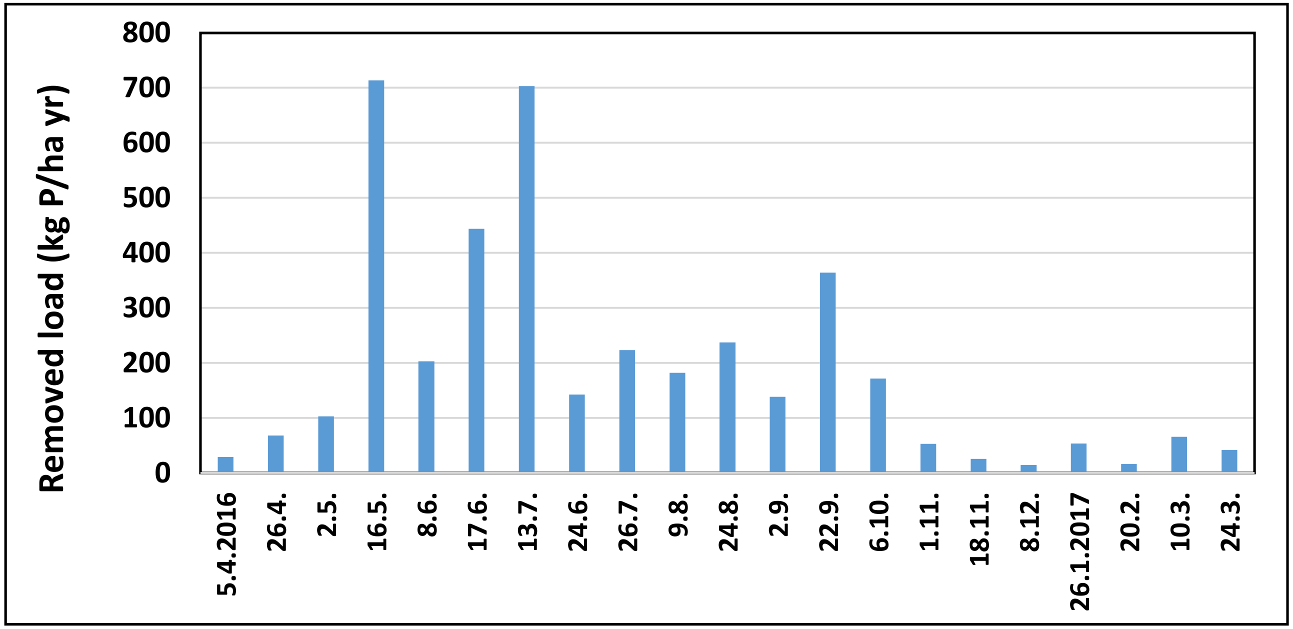


Removal of phosphorus

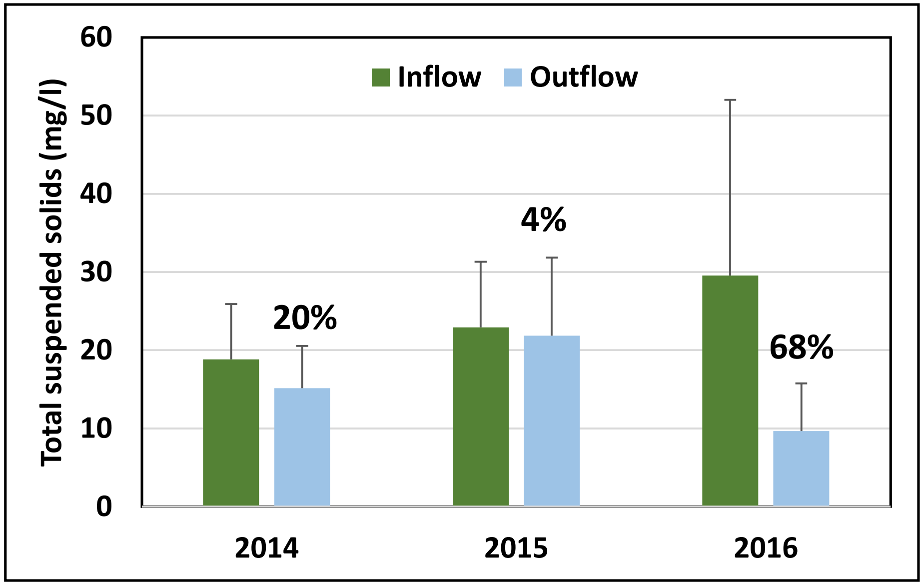


TP mean removal

153 kg P/ha yr

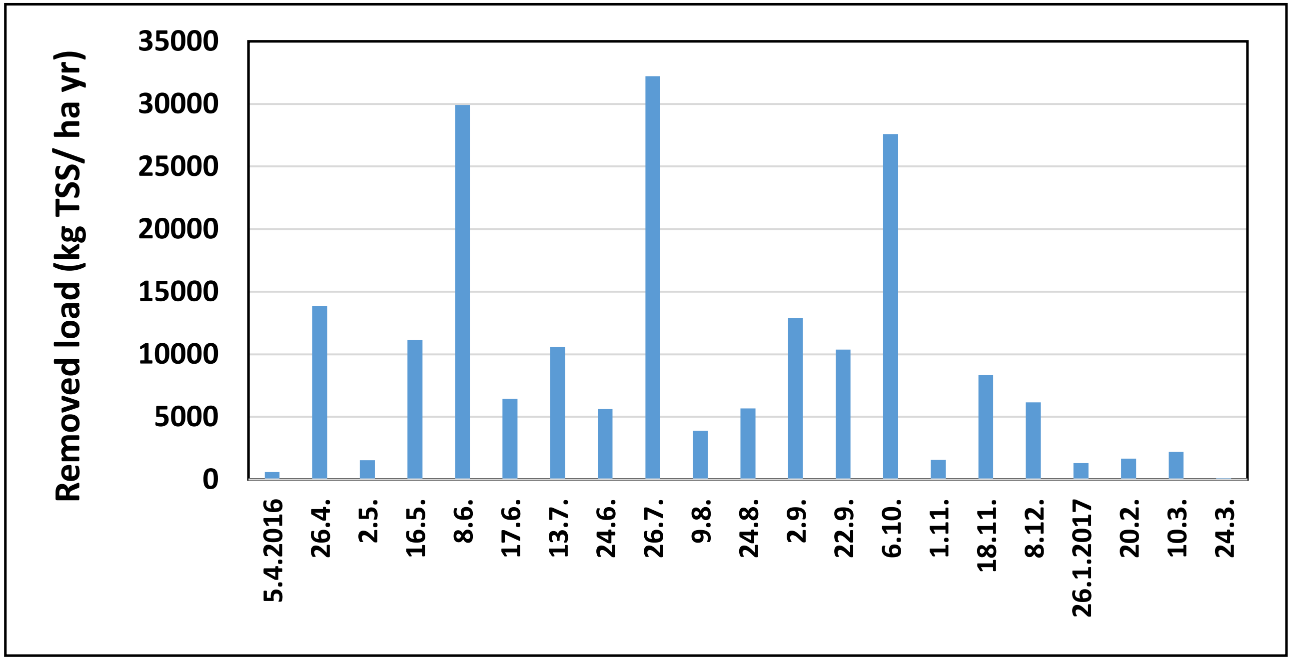


Removal of Total Suspended Solids

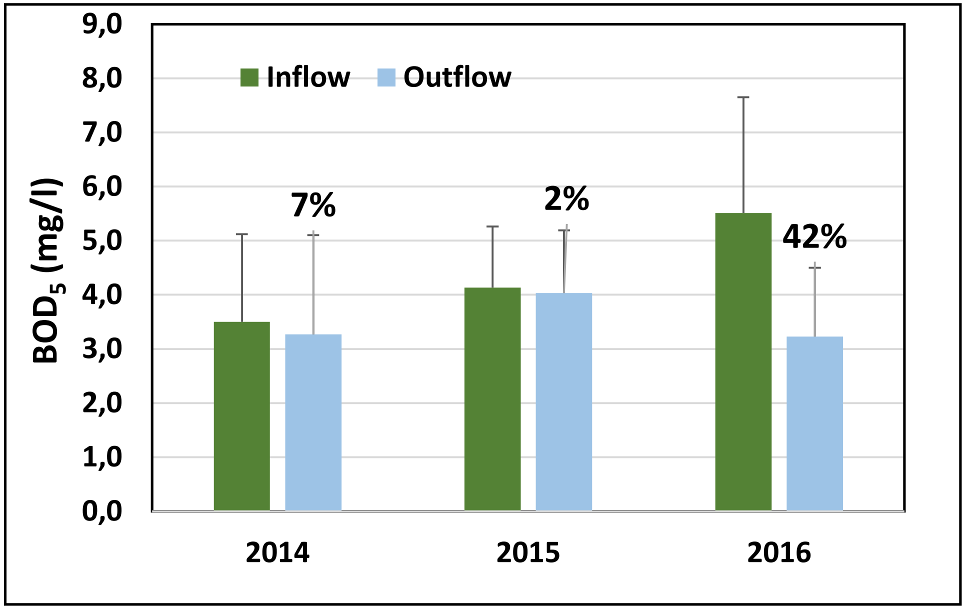


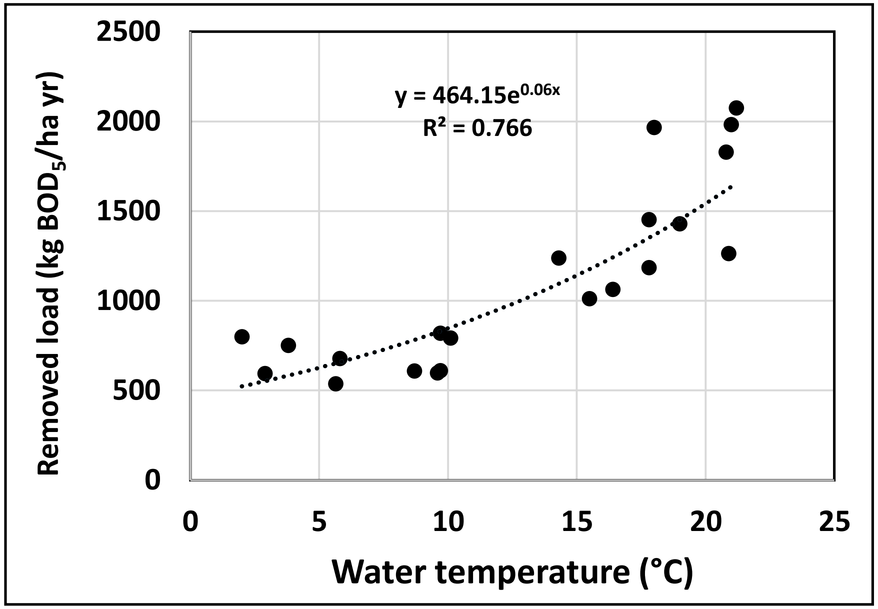
TSS mean removal

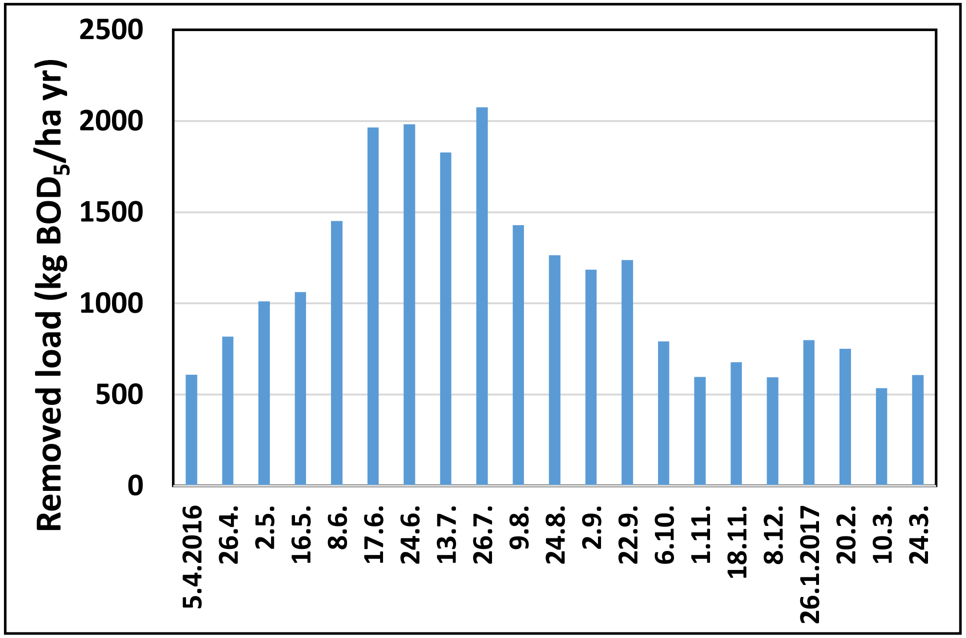
9 219 kg TSS/ha yr



Removal of BOD_5





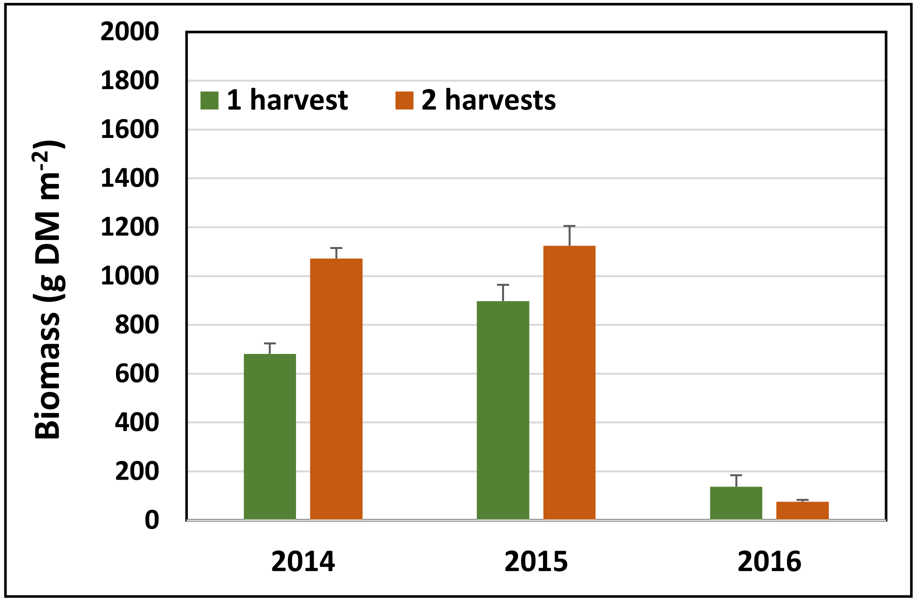


BOD_5 mean removal
1 108 kg/ha yr

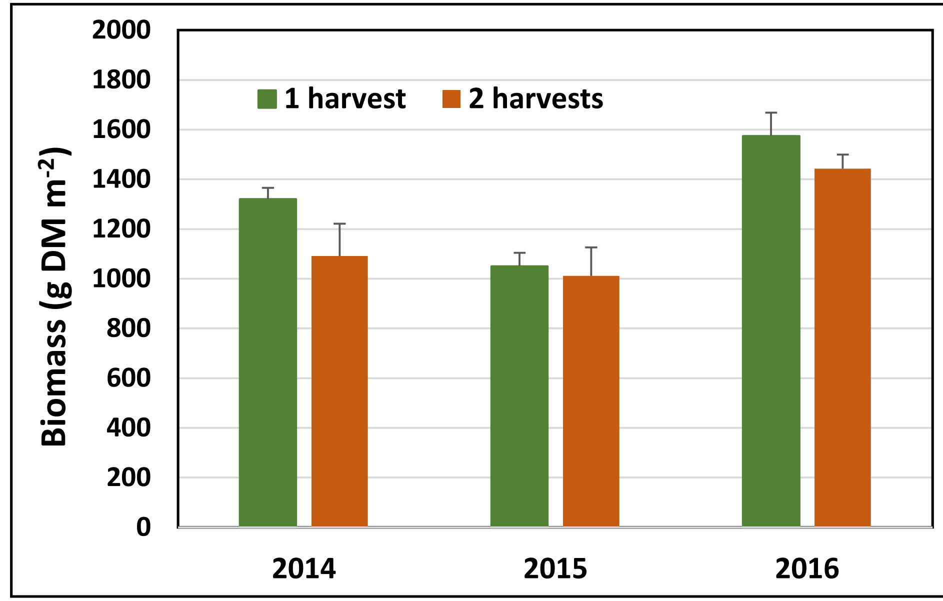
Water temperature :
> 10°C: 1 439 kg/ha yr
< 10°C: 665 kg/ha yr

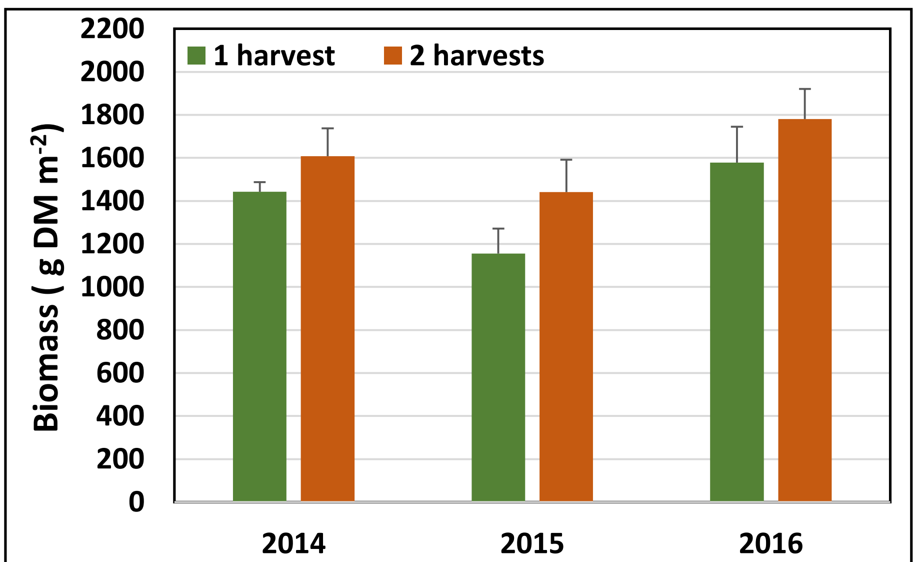
Aboveground biomass of major plant species

Scirpus sylvaticus



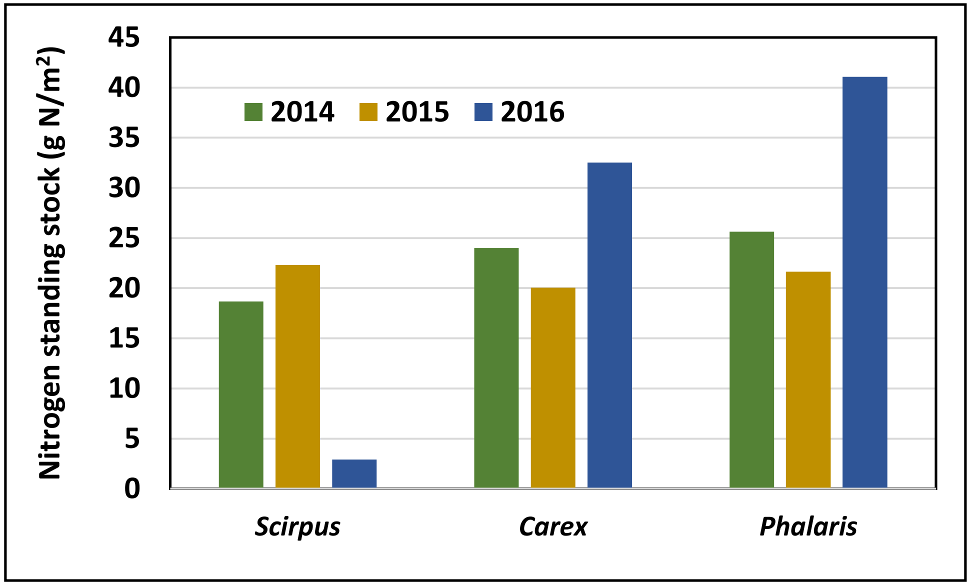
Carex nigra

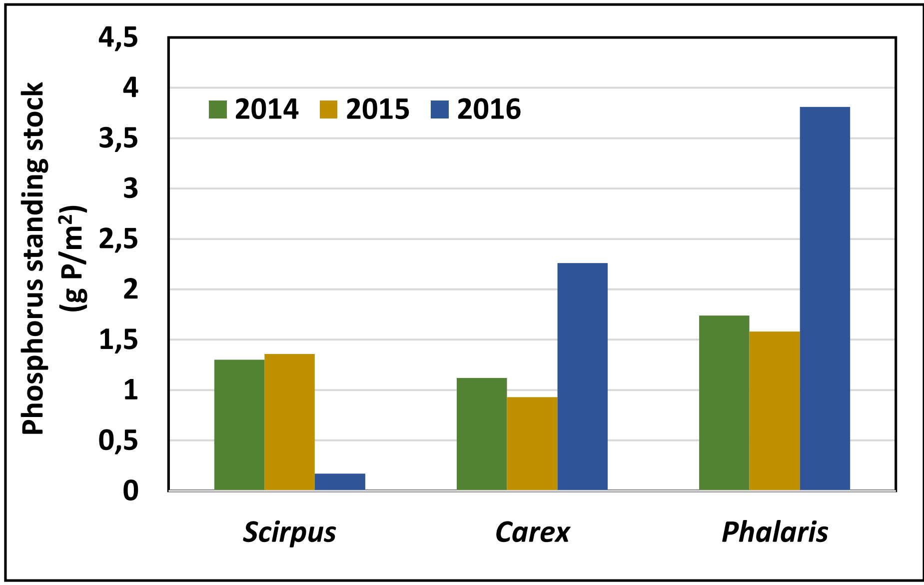




Phalaris arundinacea

Nitrogen and phosphorus standing stocks in aboveground biomass of *Scirpus sylvaticus*, *Carex nigra* and *Phalaris arundinacea* in relation to flooding conditions





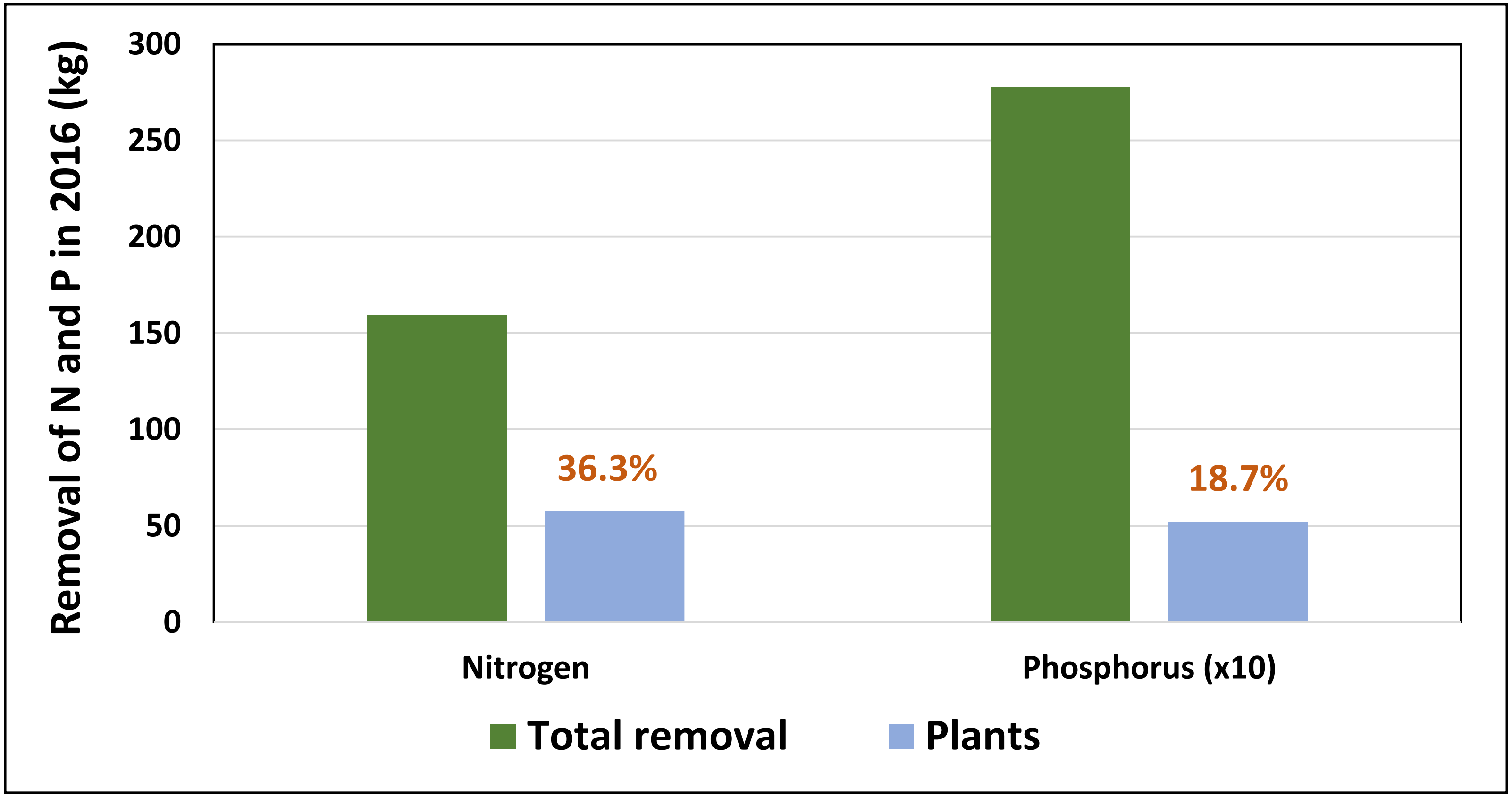
2014: naturally (intermittently) flooded

2015: no flooding

2016: permanent flooding

Potential of plants for nutrient removal

	Nitrogen (g/m^2)			Phosporus (g/m^2)		
	Scirpus	Carex	Phalaris	Scirpus	Carex	Phalaris
2016	2.90	32.52	41.07	0.17	2.26	3.81



Comparison with literature data on agricultural wetlands: Nitrogen removal

43 systems (Australia, Denmark, Finland, Italy, Korea, New Zealand, Norway, Spain, Sweden, Taiwan, USA)
Range: 11 – 13, 026 kg N/ha year
Mean: 1 373 kg N/ha year, median: 542 kg N/ha year
(Vymazal, J., 2017. The Use of Constructed Wetlands for Nitrogen Removal from Agricultural Drainage: A Review. Scientia Agriculturae Bohemica 48(2): 82-91.)

112 systems around the world
Average removal 1810 kg N/ha year (median 930 kg N/ha year)
(Land et al., 2016. How effective are created or restored freshwater wetlands for nitrogen and phosphorus removal? Summary of Systematic Review SR2, EviEM, Stockholm.)

Our study:
Average removal 1111 kg N/ha year 1157 kg N/ha year (median 1 115 kg N/ha year), for wetland and ditch and, respectively.

Comparison with literature data on agricultural wetlands: Phosphorus removal

27 systems (Australia, China, Denmark, Finland, Italy, Korea, Norway, Sweden, Switzerland, Taiwan, USA:
Mean: 152 kg P/ha year, median: 49 kg P/ha year
(Vymazal, J., 2016. The use of constructed wetlands for treatment of tile drainage from agricultural landsape. Vodní hospodářství (Water Management) 66(5), 5-7.)

146 systems around the world
Average removal 130 kg P/ha year (median 12 kg P/ha year)
Land et al., 2016. How effective are created or restored freshwater wetlands for nitrogen and phosphorus removal? Summary of Systematic Review SR2, EviEM, Stockholm.)

Our study:
Average removal of 142 and 153 kg P/ha year (median 138 kg P/ha year), for ditch and wetland, respectively.

Conclusions

The obtained values are within the range reported in the literature for constructed wetlands.

The amount of N removed via plant harvesting represented 25 -36% of the removed N.

The amount of P removed via plant harvesting represented 17-19% of the removed P.

The off stream wetlands and vegetated ditches may provide the same removal efficiency for nutrients as constructed wetlands.

Thank you for your attention