Greenhouse gas emissions from restored and natural wetlands, northwestern Indiana.

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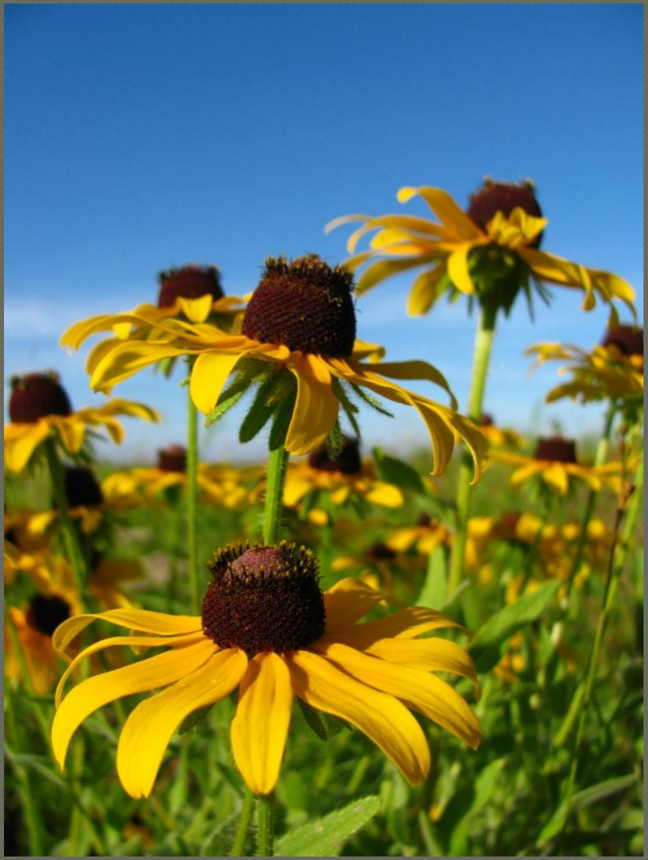
Background

- Wetland ecosystem services
  - Flood abatement and water storage
  - Nutrient Removal
  - Biodiversity
  - Habitat
  - C sequestration



Background

- Wetland Losses
  - Conversion to ag
  - Example: Great Kankakee Marsh (over 400,000 ha)

- Restoration
  - WRP and CRP (1990)
  - 110,000 ha restored in glaciated interior plains

Background

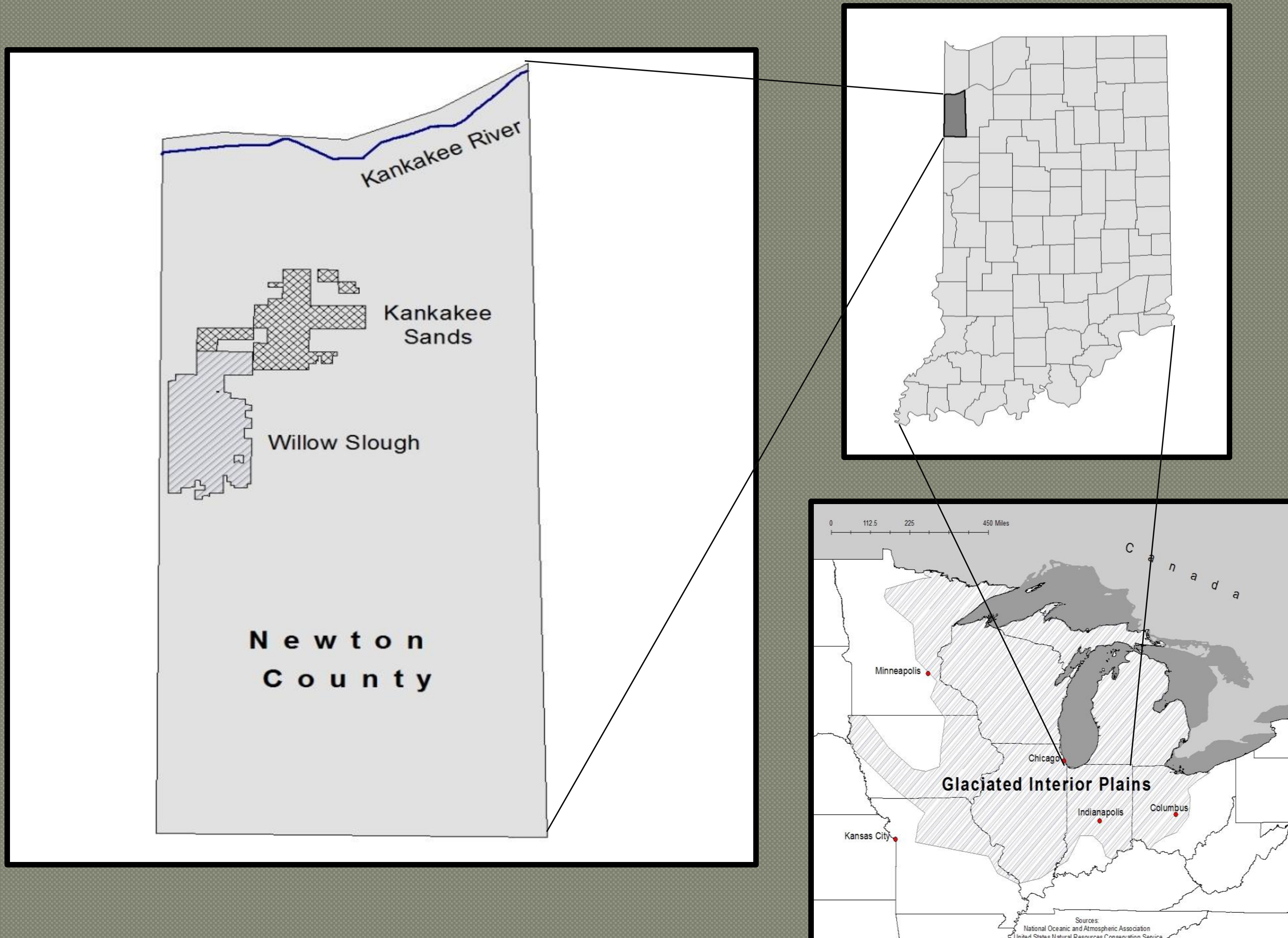
- Wetlands emit greenhouse gases (GHG)
  - CO_2, CH_4, and N_2O
  - Contribute 23% - 40% of global CH_4 (Ehhalt 2001)
- GHG contribution is poorly quantified in
  - Fresh water mineral soil wetlands (FWMS)
  - Restored wetlands
- Provide data to assist modelers and land managers

GHG Production

- CO_2 $CH_2O + O_2 \rightarrow CO_2 + H_2O + energy$
  - Production: aerobic respiration, methane oxidation, various redox reactions
  - Consumption: C fixation
  - Aerobic, Anaerobic
- CH_4 $CH_3OH + CO_2 + 12e^- + 10H^+ \rightarrow 2CH_4 + 3H_2O$
  - Production: methanogenesis
  - Consumption: methane oxidation
  - Anaerobic
- N_2O $CH_2O + 2NO_3^- + 6e^- + 8H^+ \rightarrow CO_2 + N_2 + 5H_2O + N_2O$
  - Production: denitrification
  - Consumption: denitrification
  - Anaerobic

Research Questions

- Do emissions of CO_2, CH_4, and N_2O differ between natural and restored wetlands in northwestern Indiana?
  - What are the controlling factors?
- How do GHG emissions in northwestern Indiana marshes compare to other wetlands?
  - Particularly FWMS
- What is the regional contribution of restored wetlands to GHG emissions?



Kankakee River
Kankakee Sands
Willow Slough
Newton County
0
112.5
225
450 Miles
Canada
Minneapolis
Chicago
Glaciated Interior Plains
Indianapolis
Columbus
Kansas City
Sources:
National Oceanic and Atmospheric Association
United States Natural Resources Conservation Service

Kankakee Sands Timeline

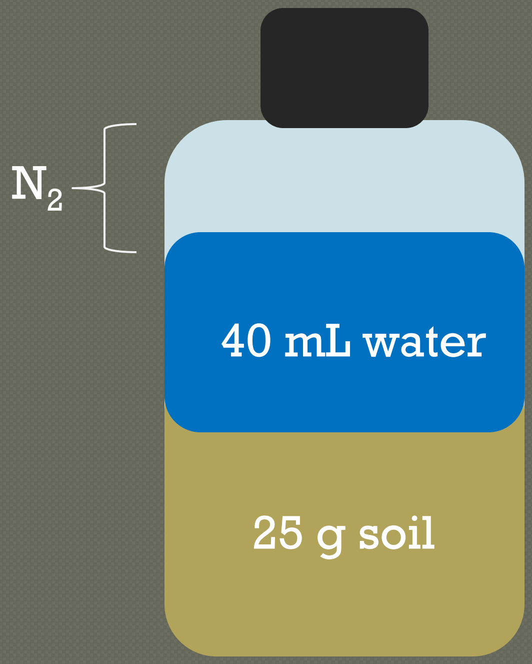
- 1853-1918: the Great Kankakee Marsh is ditched, drained, and converted to agriculture (over 1 million acres)
- 1996: TNC purchases agricultural land
- 1999-2001: TNC restores 7,800 acres of prairie with embedded depressional wetlands


Kankakee Sands
(Restored Sites)


Willow Slough
(Natural Sites)

Anaerobic Incubation Measurements

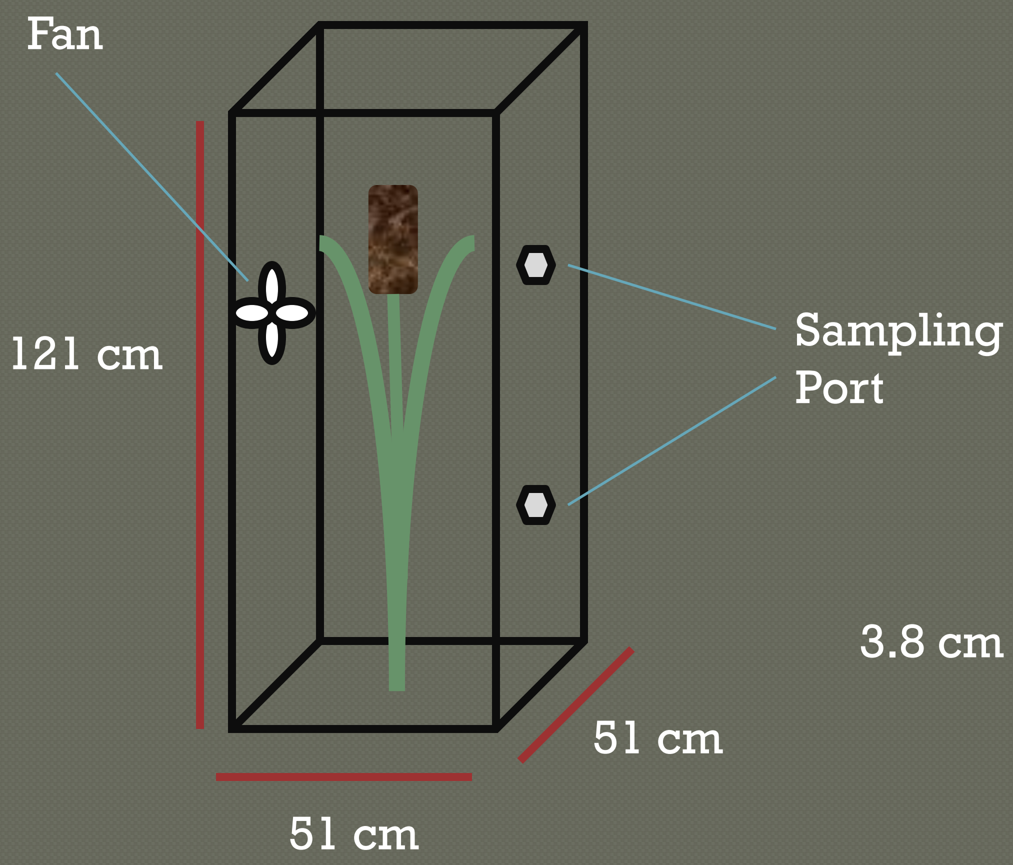
- 8 wetlands
  - 4 natural, 4 restored
- 5 months of data
  - May-September
- 5 cores per wetland
- 5 gas samples
  - 0.25, 1, 2, 3, and 4 hrs

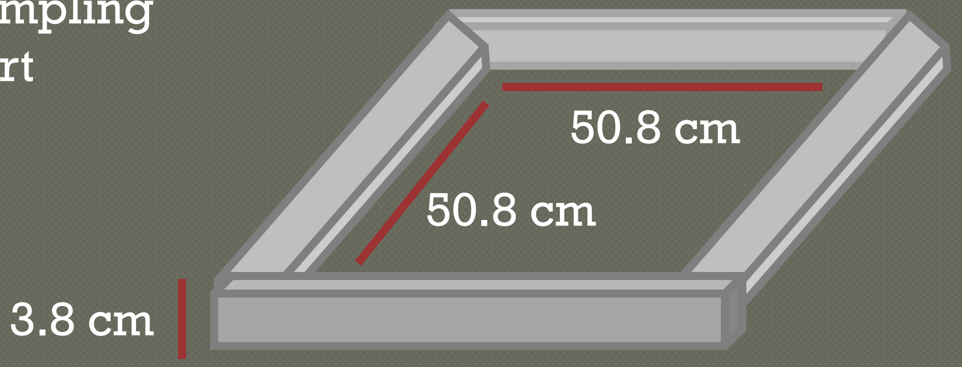


Static Flux Chamber Measurements

- 4 wetlands
  - 2 natural, 2 restored
- 4 months of data
  - June-September
- 4 permanent sampling locations per wetland
- 4 gas samples
  - 0, 10, 20, 30 min

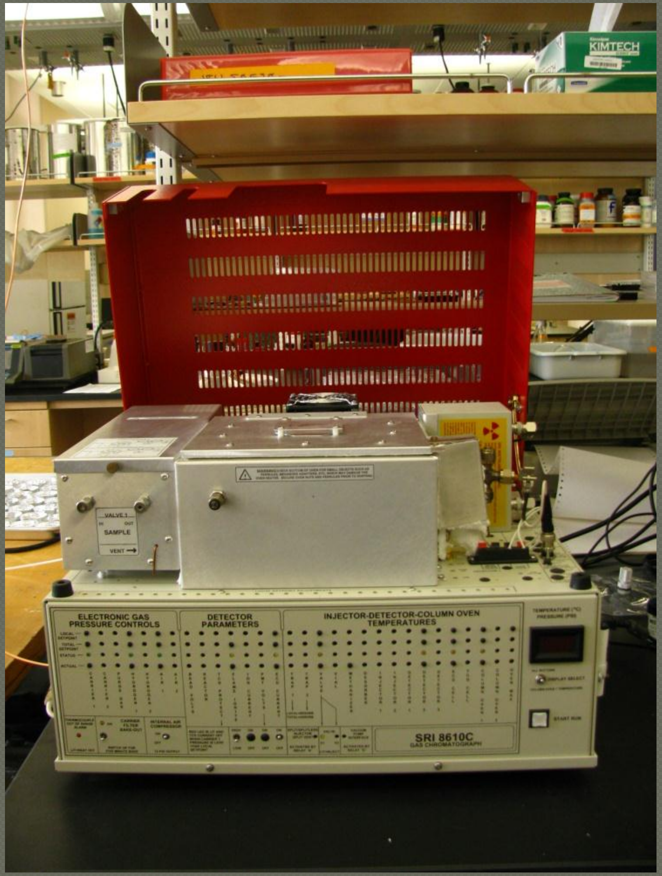
Static Flux Chamber Design





Gas Analysis

- SRI 8610C Gas chromatograph
  - CO_2
    - FID equipped with methanizer
  - CH_4
    - FID
  - N_2O
    - ECD
- Quality checks
  - 4 point standard curve
  - Standard and blank every 10 samples
  - Gases stored with standards



Supporting Soil Data

- Soil collected once a month
- Perkin-Elmer CHN Analyzer
  - Soil organic carbon (SOC)
  - Total nitrogen
- Gravimetric Measurements
  - Bulk density
  - Moisture content
  - Porosity
  - Water filled pore space

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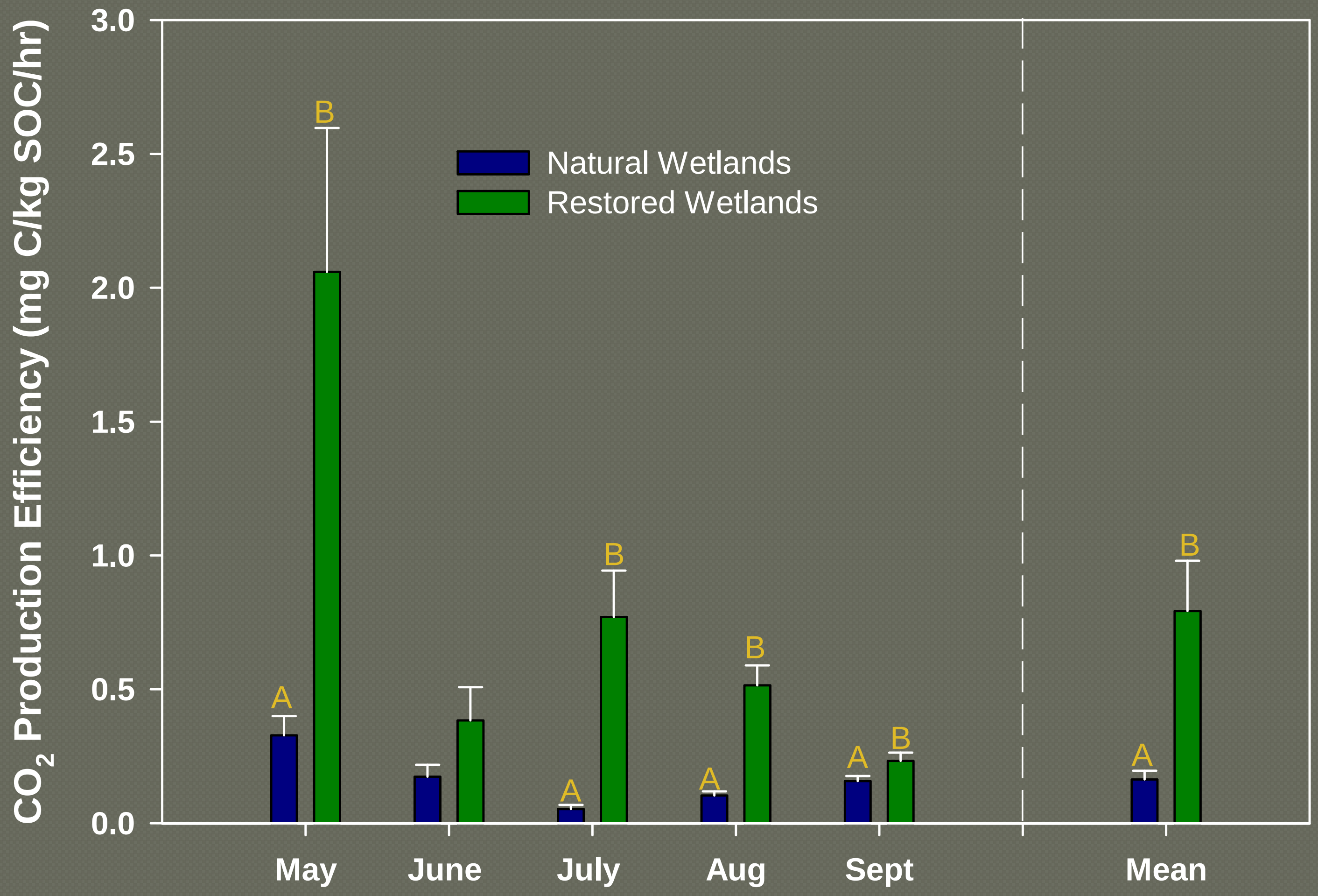
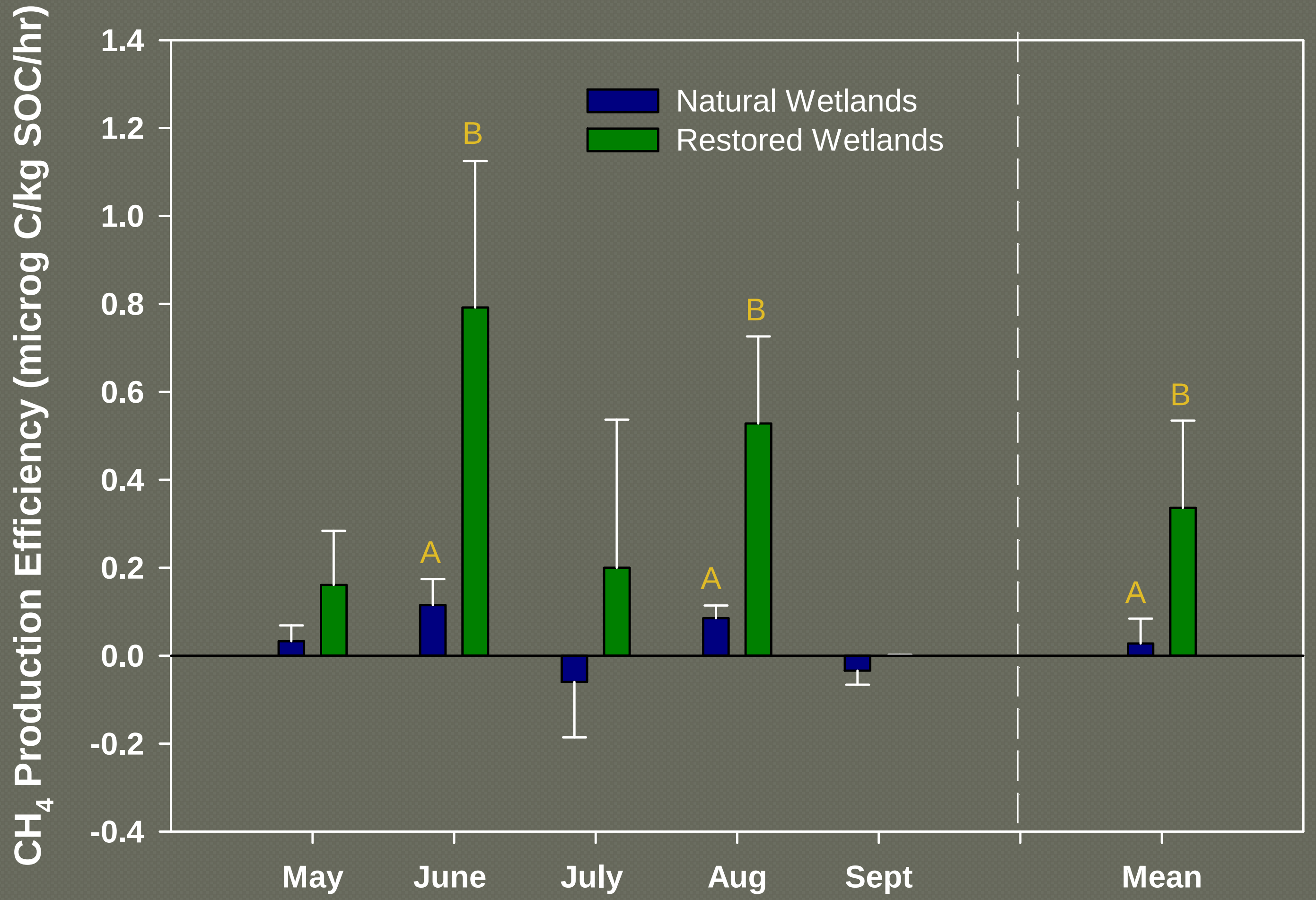
- What is the regional contribution of restored wetlands to GHG emissions?

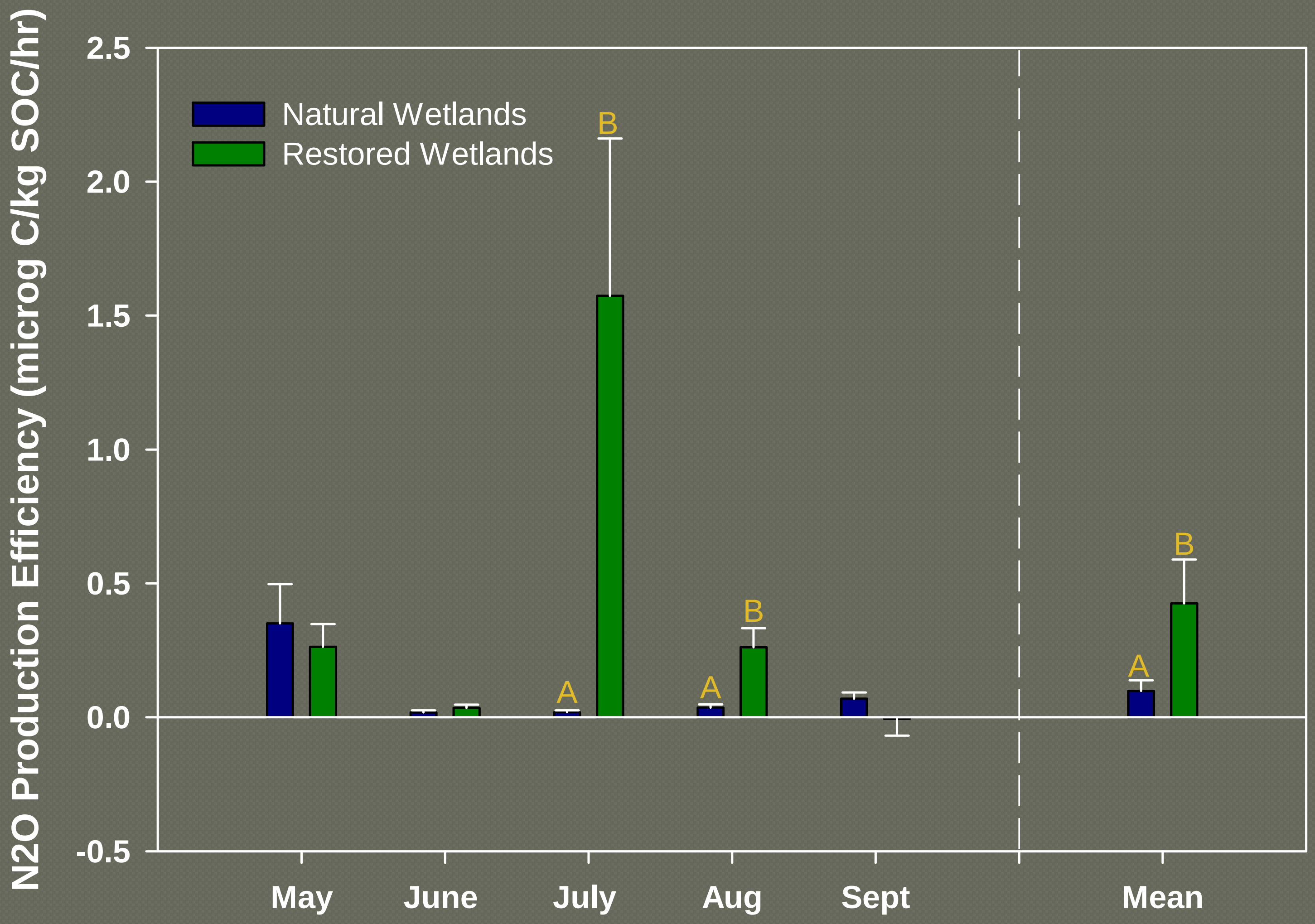
Anaerobic Incubations- CO_2



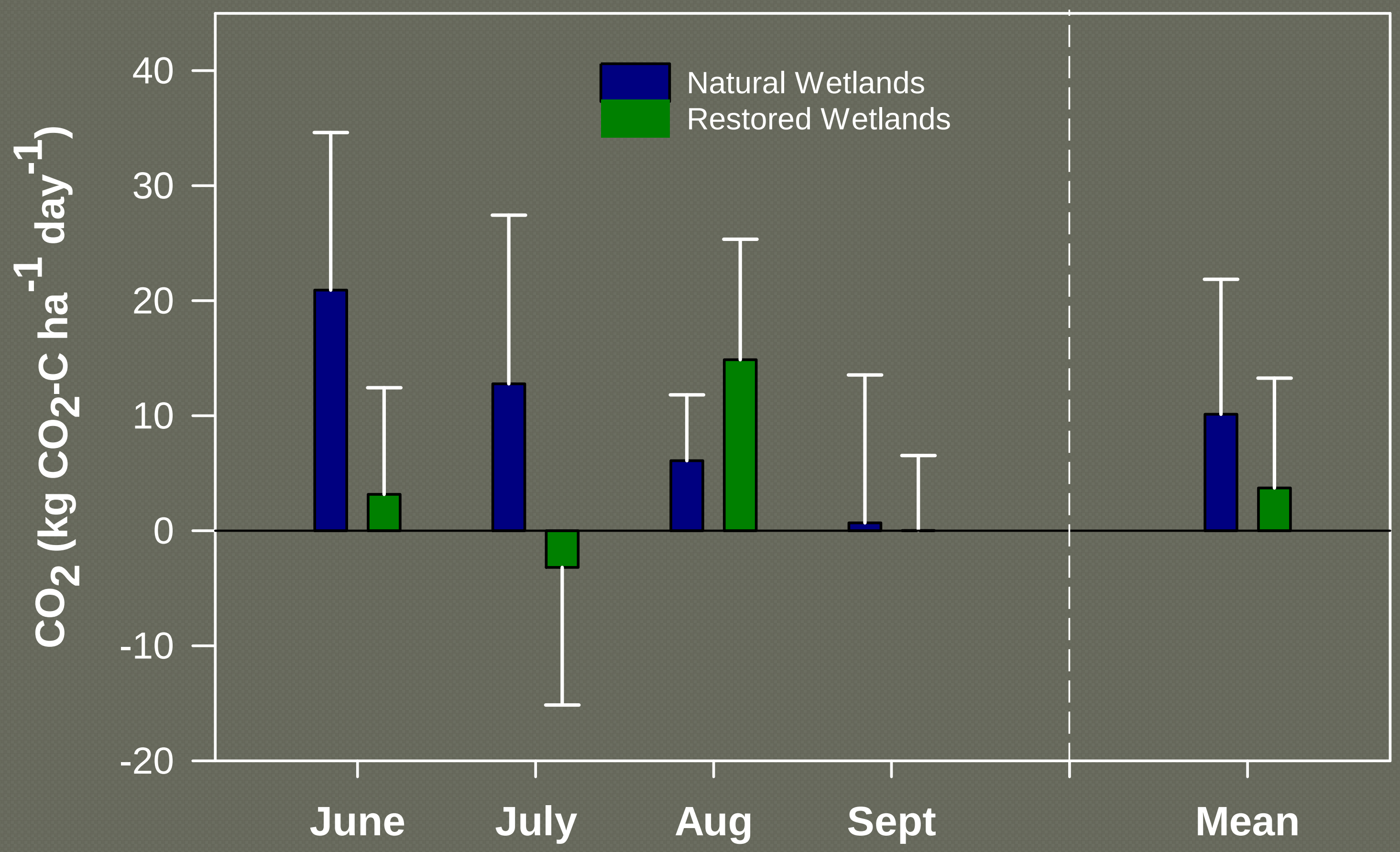
Anaerobic Incubations- CH_4



Anaerobic Incubation- N_2O

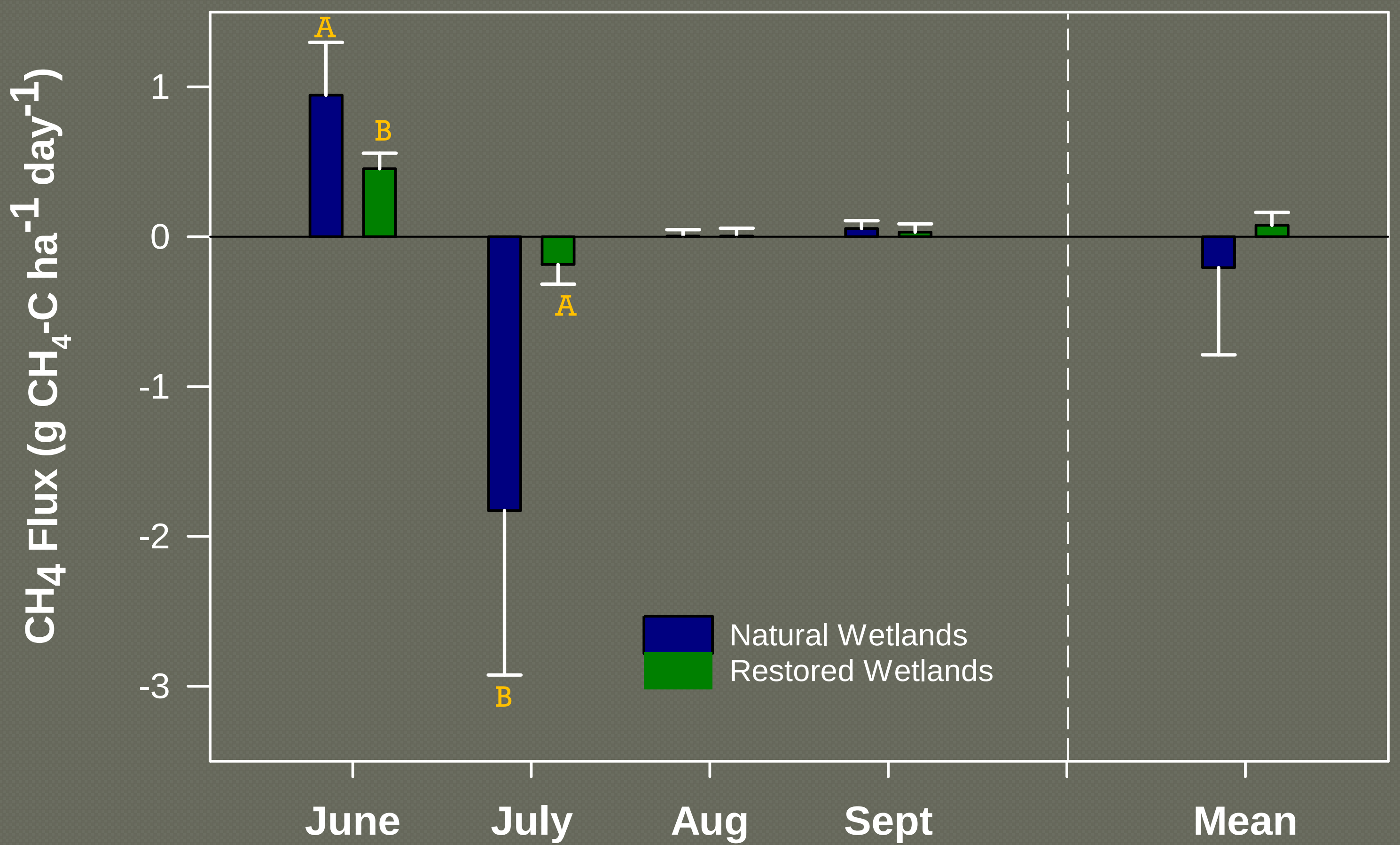


Chamber- CO_2



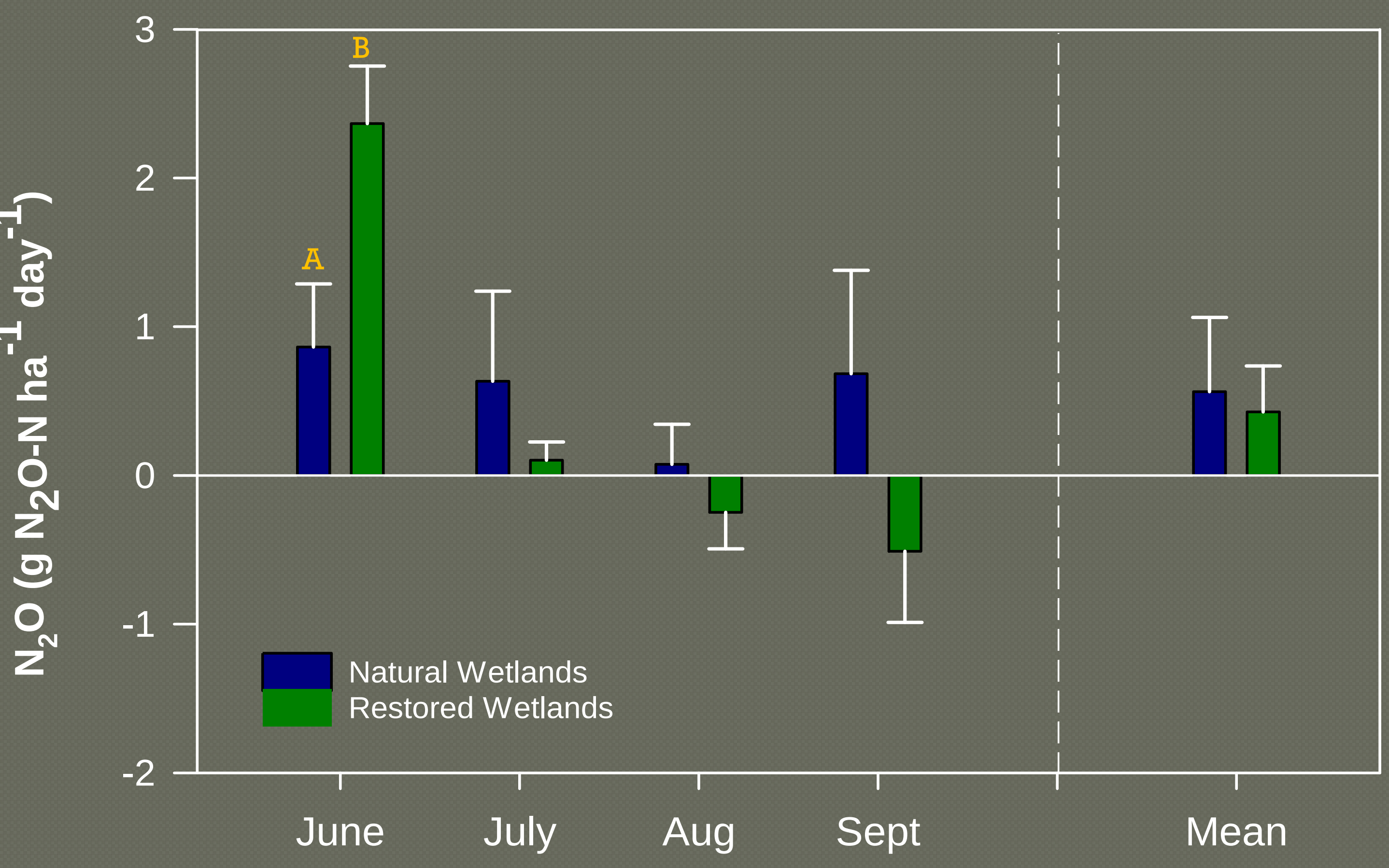
40
30
20
10
0
-10
-20
Natural Wetlands
Restored Wetlands
CO2 (kg CO2-C ha-1 day-1)
June
July
Aug
Sept
Mean

Chamber- CH_4



CH4 Flux (g CH4-C ha-1 day-1)
1
0
-1
-2
-3
A
B
A
B
Natural Wetlands
Restored Wetlands
June
July
Aug
Sept
Mean

Chamber- N_2O



N2O (g N2O-N ha-1 day-1)
3
2
1
0
-1
-2
A
B
Natural Wetlands
Restored Wetlands
June
July
Aug
Sept
Mean

Soil Data

	Bulk Density ($g\ cm^{-3}$)	Organic (%)	Total N (%)	Moisture (%)	Porosity (%)	WFPS (%)
Restored	0.97± 0.02 [a]	1.5 ± 0.6[b]	0.12 ± 0.16[b]	24.7± 0.7[a]	63.2± 0.9[a]	24.7± 1.0[a]
Natural	0.44± 0.02 [b]	6.3 ± 2.5[a]	0.58 ± 0.21[a]	41.2± 1.4[b]	83.3± 0.9[b]	18.1 ± 1.0[b]

SOC positively correlated with anaerobic incubation CO_2 emissions (r= 0.40, p= 0.0096)

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Anaerobic Incubations

	CO_2 (mg C kg^{-1} hr^{-1})	CH_4 (µg C kg^{-1} hr^{-1})	N_2O (µg N kg^{-1} hr^{-1})
Restored	0.80 ± 0.44	0.33 ± 0.12	0.51 ± 0.38
Natural	0.83 ± 0.23	0.30 ± 0.15	0.40 ± 0.24
FL Freshwater Marsh [1]	0.84 ± 1.1	280 ± 0.07	……..
Swedish Peatland[2]			
Ombrotrophic	……..	228	……..
Minerotrophic	……..	720	……..
Belgium Soils[3]	……..	……..	0.13- 39.4

[1]Inglett et al. (2012)
[2]Bergman et al. (2000)
[3]Bandibas et al. (1994)

Chamber

	CO_2 flux (kg CO_2-C/ha/d)	CH_4 flux (g CH_4-C/ha/d)	N_2O flux (g N_2O-N/ha/d)
Restored:	3.8 ± 9.6	0.08 ± 0.09	0.4 ± 0.3
Natural:	10.1 ± 11.7	-0.21 ± 0.58	0.6 ± 0.5
ND Restored Wetlands[1]:	44.6 ± 3.3	435 ± 290	4.4 ± 1.4
ND Natural Wetlands[2]:			
Deep Marsh	4.5	2,594	6.5
Shallow Marsh	11.6	463	3.6
Wet Meadow	8.6	1.6	700

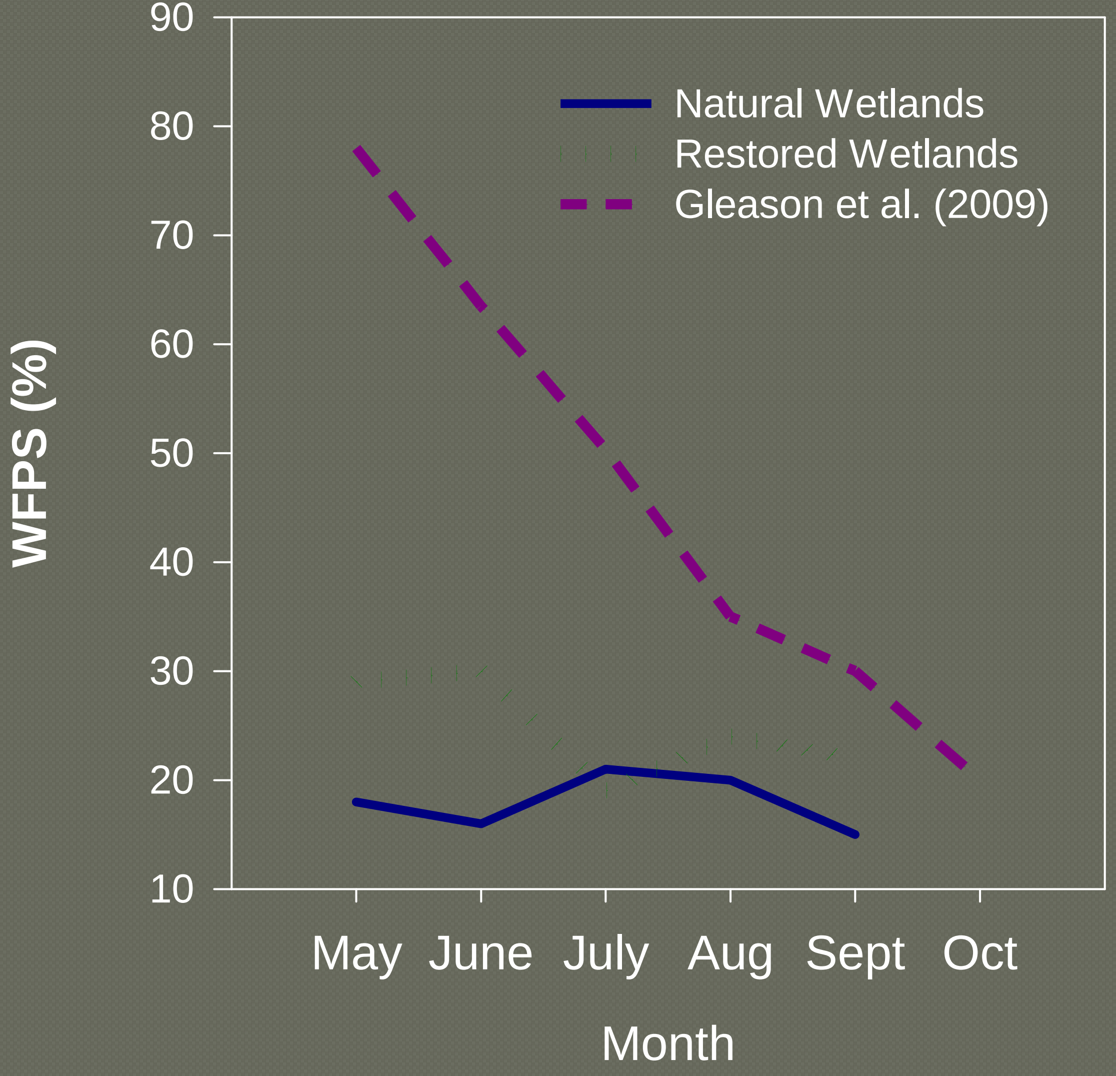
[1]Gleason et al (2009)
[2]Phillips and Beeri (2008)

Supporting Soil Data

	Organic C Mg ha^{-1}	Total N Mg ha-1	Moisture (%)	WFPS (%)
	- - - - - - - -	- - - - - - -	- - - - - - - -	- - - - - - -
Restored	21.2	1.1	24.7± 0.7[a]	24.7 ± 1.0[a]
Natural	41.9	2.6	41.2± 1.4[b]	18.1 ± 1.0[b]
ND Restored Wetlands [1]	49.8	2.9	…	20-80
ND Natural Wetlands[2]				
Deep Marsh	54	…	65	…
Shallow Marsh	54	…	55	…
Wet Meadow	49	…	45	…

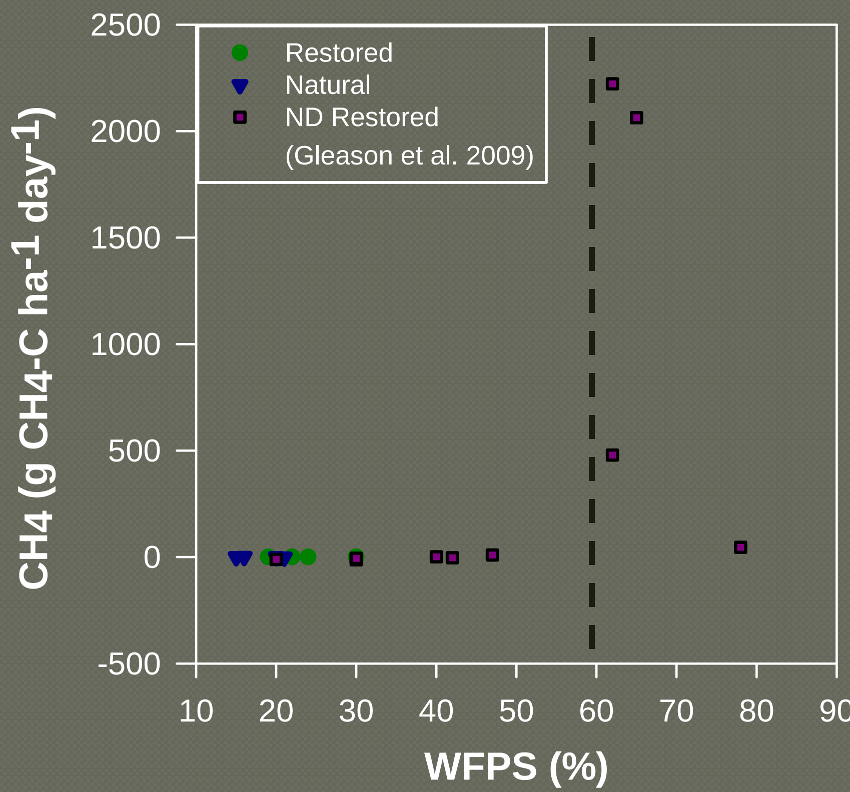
[1]Gleason et al. 2009
[2]Phillips and Beeri 2008

WFPS

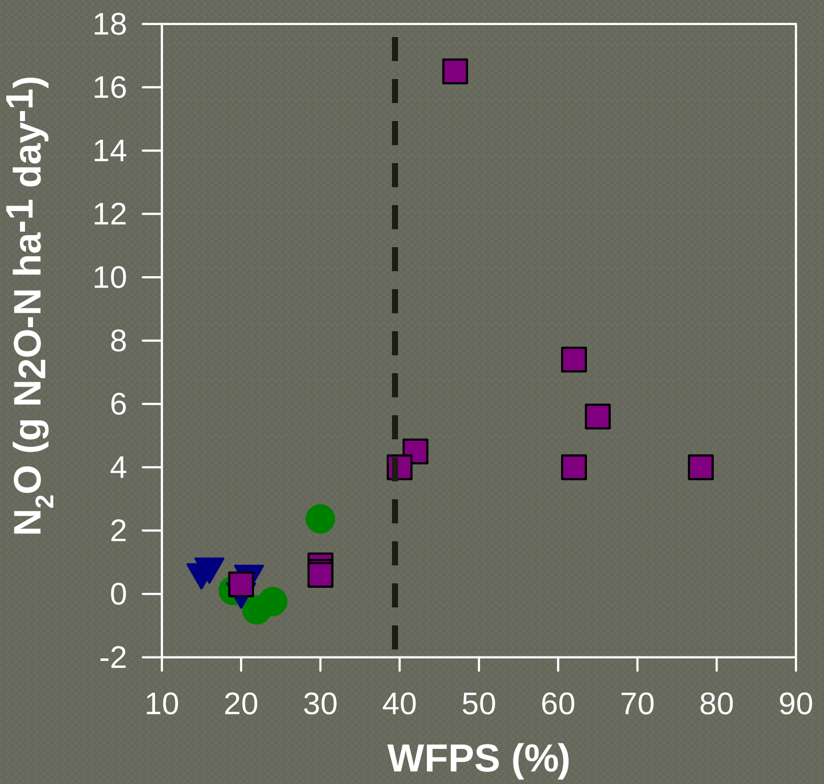


90
80
70
60
50
40
30
20
10
WFPS (%)
Natural Wetlands
Restored Wetlands
Gleason et al. (2009)
May
June
July
Aug
Sept
Oct
Month

WFPS



2500
2000
1500
1000
500
0
-500
10 20 30 40 50 60 70 80 90
CH4 (g CH4-C ha-1 day-1)
WFPS (%)
Restored
Natural
ND Restored
(Gleason et al. 2009)



18
16
14
12
10
8
6
4
2
0
-2
10 20 30 40 50 60 70 80 90
N2O (g N2O-N ha-1 day-1)
WFPS (%)

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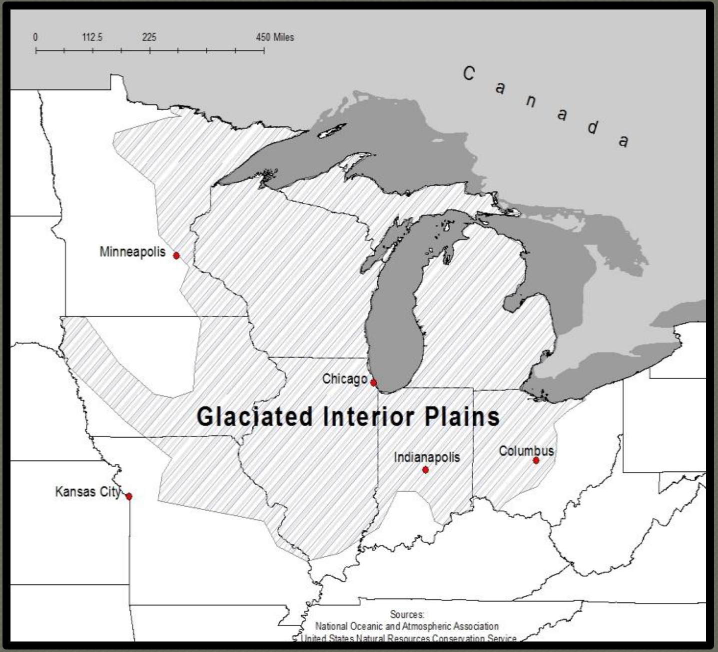
Global Warming Potential

- Natural
  - 1.9 Mg CO_2-equivalents/ha/yr
- Restored
  - 0.66 Mg CO_2-equivalents/ha/yr
- GIP Restored Wetlands
  - 72,270 Mg CO_2-C per year
  - 0.72% of GHG's from North American FWMS (Bridgham et al 2006)



Conclusions

- No difference between natural and restored wetlands
  - High spatial and temporal variability
  - Restored has greater production efficiency
- Our wetlands emit lower levels compared with other FWMS wetlands
  - Predominantly aerobic soil conditions
- GIP restored wetlands do not have a large GHG impact
  - Restoration benefits outweigh impacts

Further GHG Research

- Long term measurements
- Sample a greater diversity of GIP wetlands
- Effects of fire
  - Pre-burn versus post burn
  - Burn year versus unburned year
- Comparison with agricultural fields

Acknowledgements

- Craft Lab
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- IN DNR staff at Willow Slough

References

Bandibas, J., A. Vermoesen, C. J. De Groot, O. Van Cleemput. 1994. The effect of different moisture regimes and soil characteristics on nitrous oxide emissions and consumption by different soils. Soil Science, 158(2): 106-114.

Bergman, I. M. Klarqvist, M. Nilsson. 2000. Seasonal variation in rates of methane production from peat of various botanical origins: effects of temperature and substrate quality. FEMS Microbiology Ecology 33: 181-189.

Bridgham, S. D., J. P. Megonigal, J. K. Keller, N. B. Bliss, C. Trettin. 2006. The carbon balance of North American wetlands. *Wetlands* 26(4): 889-916.

Ehhalt, D., M. Prather, F. Dentener, E. Dlugokencky, E. Holland, I. Isaksen, J. Katima, V. Kirchhoff, P. Matson, P. Midgley, and M. Wang. 2001. Atmospheric chemistry and greenhouse gases. p. 239–287. In J. T. Houghton, Y. Ding, D. J. Griggs, M. Noguer, P. J. van der Linden, X. Dai, K. Maskell, and C. A. Johnson (eds.) Climate Change 2001: The Scientific Basis. Contribution of Working Group I to the Third Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, UK.

Gleason, R. A., B. A. Tangen, B. A. Browne, N. H. Euliss. 2009. Greenhouse gas flux from cropland and restored wetlands in the Prairie Pothole Region. *Soil Biology and Biochemistry* 41, 2501-2507.

Inglett, K. S., P. W. Inglett, K. R. Reddy, T. Z. Osborne. 2012. Temperature Sensitivity of gas production in wetland soils of different vegetation. Biogeochemistry 108: 77-90.

Phillips, R., O. Beeri. 2008. The role of hydropedologic vegetation zones in greenhouse gas emissions for agricultural wetland landscapes. Catena 72: 386-394.


Questions?