CONNECTIVITY BETWEEN WETLANDS AND STREAMS: PATTERNS OF PHOSPHORUS EXPORT IN THE PRAIRIE POTHOLE REGION

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1. INTRODUCTION

The loss or alteration of Prairie Pothole wetlands, which are usually considered as geographically isolated, has modified the frequency of water and pollutant exchanges between land and streams and thus affected regional water quality. Indeed, while intact wetlands act as nutrient sinks by effectively trapping runoff and associated pollutants, lost or altered wetlands are prone to release nutrients to nearby streams. In general, the role of wetlands in maintaining downstream water quality by storing excess nutrient (e.g., phosphorus) is closely related to wetland hydrology and wetland-stream connectivity: both are influenced by climate and basin geomorphology and are known to vary based on the specific location of wetlands within a watershed. Here we hypothesize that one possible way to address the influence of local wetland properties on stream water quality is to examine the synchronicity (or lack thereof) between nutrient dynamics in wetlands and adjacent streams. The current study includes preliminary analyses in that regards.

2. RESEARCH OBJECTIVES

(i) Examine the influence of spatial wetlands characteristics on wetland nutrient (e.g., phosphorus) fluctuations

(ii) Infer wetland-stream connectivity by comparing water level and phosphorus concentrations in a stream reach and potholes located within the same region

3. STUDY SITES and DATA COLLECTION

- ❖ Broughton's Creek Watershed (BCW, Prairie Pothole Region, southwestern Manitoba, Canada)
- ❖ 5 km study reach (Figure-1)
  - ➢ Upstream end: surface water sample collection every two days
  - ➢ Downstream end: water level recorded every 15 minutes + surface water sample collection every two days
- ❖ Ten intact and undisturbed pothole wetlands and three consolidated wetlands with stilling wells (water level recorded every 15 minutes) + surface water sample collection every two weeks
- ❖ Seven ditches (historically used to drain wetlands) with 1m-deep wells (water table depth recorded every 15 minutes) + subsurface water sample collection (from piezometers) every two weeks
- ❖ Intact wetlands assumed not to contribute water and nutrients to the creek during dry to normal conditions.
- ❖ Data collection period: May to September 2013 and 2014
- ❖ All water samples analyzed for soluble reactive phosphorous (SRP) concentrations.

4. DATA PROCESSING METHODS

- ❖ Research objective (i):
  - ➢ Spearman's rank correlation coefficients were calculated between different wetland characteristics (e.g., surface area, storage volume, etc) and summary statistics of SRP concentrations in the wetlands.
- ❖ Research objective (ii):
  - ➢ Sampling dates were categorized into gaining conditions (downstream SRP > upstream SRP) and losing conditions (downstream SRP < upstream SRP), which potentially reflect opposite scenarios of wetland–stream connectivity and phosphorus export.
  - ➢ Kruskal-Wallis tests were performed to assess if SRP concentrations in wetlands and ditches were statistically different between "gaining dates" and "losing dates".
  - ➢ The Spearman's rank correlation coefficient between stream water level and wetland water level (or ditch water table depth) was used as a surrogate measure for wetland-stream hydrologic connectivity.

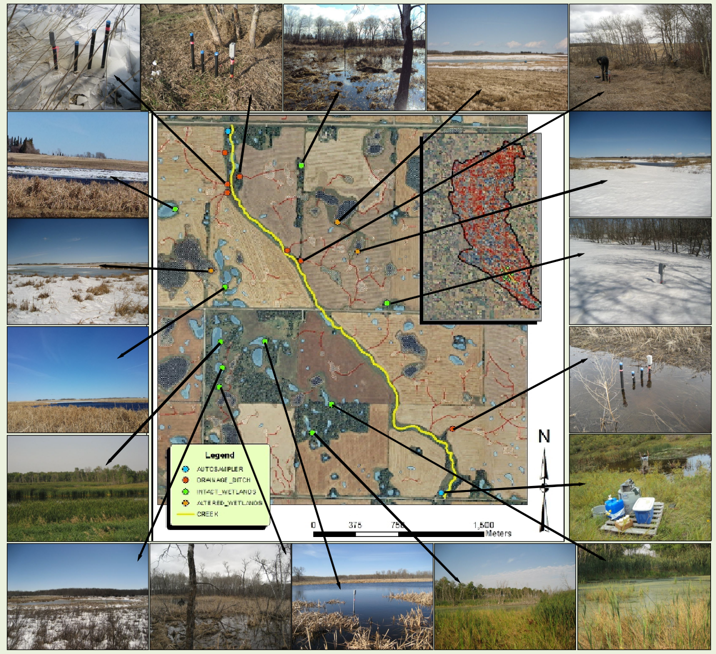

Figure-1: Study sites and experimental setup

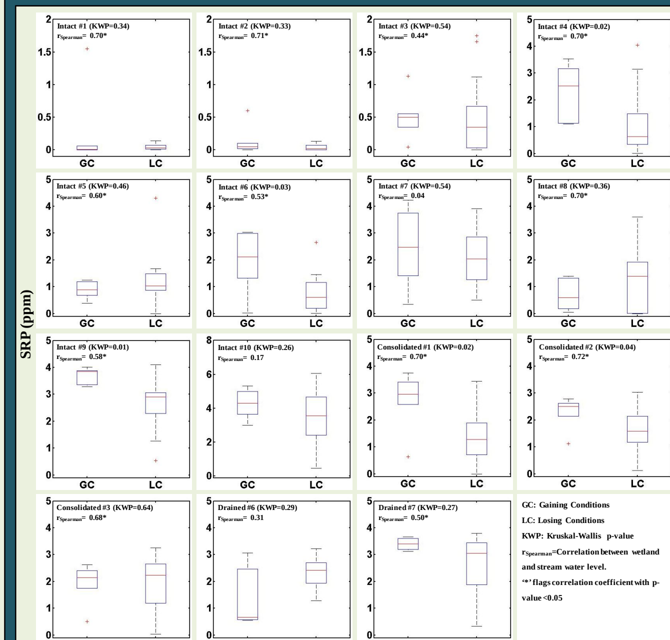

Figure-2: Summary of stream and wetland water level (or ditch water table) and SRP dynamics. For boxplots, each box has lines at the lower quartile, median, and upper quartile values, while the whiskers extend from each end of the box to show the extent of the rest of the data (minimum and maximum values). Outliers are shown as '+'.

Table-1: Spearman's correlation coefficients between wetland spatial characteristics and different SRP statistics. '' indicates correlation coefficient with p-value <0.05. na: not applicable*

Wetland SRP Statistics	Wetland type	Surface area	Storage volume	Basin area	Ratio between catchment and wetland Area	Total contributing area	Ditch length
Median SRP	Intact and consolidated	-0.05	-0.25	0.33	0.33	0.31	na
	Drained	-0.54	-0.54	-0.14	0.09	-0.49	0.31
Mean SRP	Intact and consolidated	-0.13	-0.34	0.26	0.37	0.25	na
	Drained	-0.6	-0.6	-0.26	0.14	-0.6	0.37
Min SRP	Intact and consolidated	-0.12	-0.27	0.22	0.52	0.22	na
	Drained	0.31	0.31	-0.14	-0.43	-0.03	-0.09
Max SRP	Intact and consolidated	-0.49	-0.74*	-0.28	0.14	-0.28	na
	Drained	-0.6	-0.6	-0.37	0.25	-0.49	-0.09
Std SRP	Intact and consolidated	-0.6*	-0.74*	-0.3	0.24	-0.32	na
	Drained	-0.37	-0.37	-0.31	0.08	-0.32	-0.03
CV SRP	Intact and consolidated	-0.05	0.18	-0.38	-0.28	-0.37	na
	Drained	-0.26	-0.26	0.2	0.2	-0.09	-0.49

Table-2: Selected spatial wetland characteristics.
I: Intact wetland, C: Consolidated wetland, D: Drained wetland, F: Forest, A: Agriculture.

	I1	I2	I3	I4	I5	I6	I7	I8	I9	I10	C1	C2	C3	D1	D2
Dominant land cover in upslope area	F	F	F	A	F	A	A	A	A	F	A	A	A	A	A
Distance from stream (km)	0.90	1.02	0.60	1.00	0.75	0.50	0.47	0.56	0.58	0.60	0.55	0.65	0.65	0.22	0.22

5. RESULTS

- ❖ Drained wetlands: no statistically significant correlation between summary statistics of SRP concentrations and wetland characteristics.
- ❖ Intact and consolidated wetlands: maximum SRP showed significant negative correlation with wetland storage volume; standard deviation of SRP showed significant negative correlation with wetland storage volume and surface area (Table-1).
- ❖ Almost all wetlands showed statistically significant correlations between wetland and stream water level (Figure-2).
- ❖ Intact wetlands #1, 2, 3 and 5 had lower SRP concentrations (< 1.5 ppm) than other wetlands (Figure-2)
- ❖ In 2013 and 2014, losing conditions prevailed for 76% of the time.
  - ➢ Creek upstream end: median SRP = 1.86 ppm, min SRP = 0.01 ppm, max SRP = 3.75 ppm.
  - ➢ Creek downstream end: median SRP = 1.21 ppm, min SRP = 0.01 ppm, max SRP = 10.85 ppm
- ❖ Kruskal-Wallis tests revealed that only three intact (#4, 6, 9) and two consolidated (#1, 2) wetlands showed a statistically significant difference in SRP concentrations between gaining and losing dates, with higher values associated with gaining dates (Figure-2). Most of these wetlands had upslope areas mostly made of agricultural land (Table-2).

6. DISCUSSION

The studied intact and consolidated wetlands are located at least 0.47 km away from the stream (Table-2) and have no visible surface connections between them and the stream. Spillage events were not observed; therefore, it likely that wetland-stream hydrologic connectivity, when it exists, is due to shallow or deep subsurface flow. The use of a correlation coefficient between stream and wetland water level as an indication of wetland-stream connectivity could however be challenged as it might not necessarily reflect causality between wetland and stream dynamics but rather highlight the fact that similar drivers are behind stream and wetland dynamics. Many wetlands did not show any difference in SRP concentrations between gaining and losing conditions, which is probably an indication that they are disconnected (isolated) from the stream or do not respond to the same climatic drivers as the stream. Wetlands that did show significant differences between gaining and losing conditions are located within agricultural fields and do not have any forest in their upslope area (Figure-2, Table-2), a factor that may play a role in their subsurface flow-driven connectivity with the stream. Consolidated wetlands did not appear to behave in a significantly different manner than intact wetlands, making it unclear whether changes in wetland-stream connectivity can be predicted based on the degree of wetland alteration.

7. CONCLUSION AND FUTURE ANALYSIS

- ❖ For intact and consolidated wetlands, surface area and storage volume are negatively correlated with SRP variability.
- ❖ Preliminary data analysis hints at possible exchanges of water and SRP between so-called geographically isolated wetlands and the nearby stream in the BCW.
- ❖ Tracer studies are likely needed to confirm or infirm the role of subsurface flow in wetland-stream connectivity, and to identify specific wetland characteristics that control it .

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