Connectivity between wetlands and streams: patterns of phosphorus export in the Prairie Pothole Region

Md Aminul Haque & Genevieve Ali
Department of Geological Sciences, University of Manitoba, Winnipeg, Manitoba, R3T 2N2
Watershed System Sciences, University of Manitoba, Winnipeg, Manitoba, R3T 2N2
Center for Earth Observation Science, University of Manitoba, Winnipeg, Manitoba, R3T 2N2

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 (Wang et al., 2010). 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. Although the general impacts of wetlands loss or alteration on regional water quality dynamics are well understood (Wang et al., 2010), little is known about the local wetland properties that drive those dynamics. 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 (U.S. EPA, 2015): both are influenced by climate and basin geomorphology (Mitsch and Gosselink, 2007) and are known to vary based on the specific location of wetlands within a watershed (U.S. EPA, 2015). 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 main research objective of this study was therefore to infer wetland-stream connectivity via the comparison of water level and phosphorus concentrations in a stream reach and in a range of potholes located in the lateral contributing area to the stream reach.

Study Site and Methods

Ten intact and undisturbed pothole wetlands (hereafter simply referred to as “wetlands”), three consolidated wetlands and seven ditches (historically used to drain wetlands) were selected adjacent to a 5 km study reach in the Broughton’s Creek Watershed (BCW, southwestern Manitoba, Canada). Physiographically, the BCW is typical of the Prairie Pothole Region and intact wetlands are assumed not to contribute water and nutrients to the creek during dry to normal conditions. Stilling wells were installed at the downstream end of the creek reach as well as in intact and consolidated wetlands, while 1m-deep perched water table wells were drilled below the drainage ditches: capacitance-based loggers were used to record surface and subsurface water level fluctuations at a 15-minute frequency in May to September 2013 and 2014. During the same period, water samples were collected at least every two days at the two extremities of the study reach, and every two weeks from all intact and consolidated wetlands and from multi-depth piezometers installed below the drainage ditches.

All biweekly water samples were analyzed for soluble reactive phosphorous (SRP) concentrations. To assess the temporal variability of SRP in the study reach, 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. To test the hypothesis that gaining and losing conditions are driven by the dynamics prevailing in the lateral contributing area to the reach, 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 also used as a surrogate measure for wetland- stream hydrologic connectivity.

Results

Almost all wetlands showed statistically significant correlations between wetland water level and stream water level (Figure-1). Based on the 2013 and 2014 dataset, losing conditions prevailed for 76% of the time. The median SRP concentration at the creek downstream end was

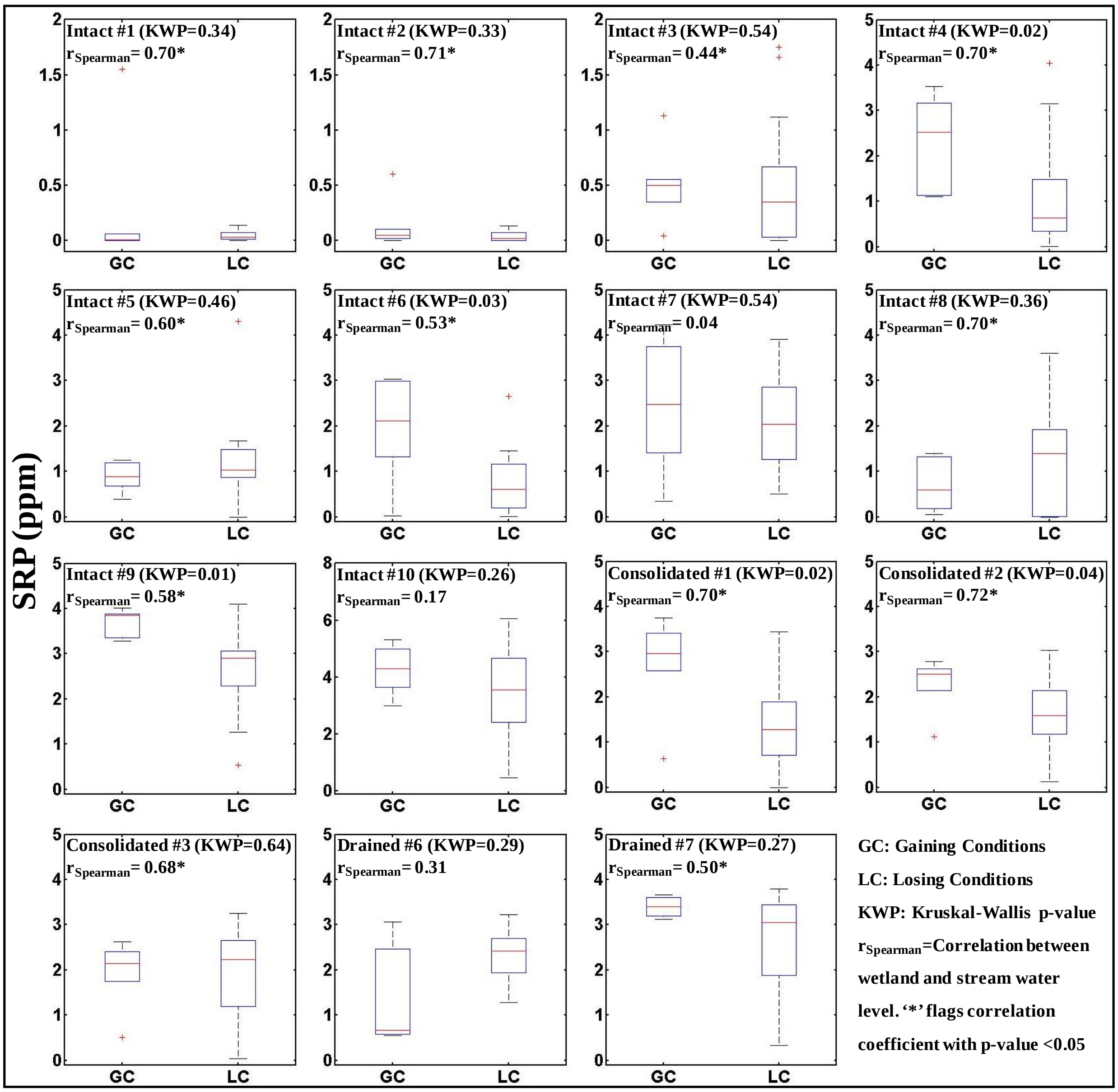

Figure-1: Summary of stream and wetland water level (or table) and SRP dynamics. For boxplots, each box has lines at the lower quartile, median, and upper quartile values, while the whiskers extend from each end of the box to show the extent of the rest of the data (minimum and maximum values). Outliers are shown as ‘+’.

1.21 ppm, with minimum and maximum values of 0.01 ppm and 10.85 ppm, respectively. At the upstream end of the creek, median, minimum and maximum values were 1.86 ppm, 0.01 ppm, and 3.75 ppm. As shown in Figure-1, intact wetlands #1, 2, 3 and 5 had generally low SRP concentrations (< 1.5 ppm) compared to other wetlands. 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-1). Most of the wetlands had upslope areas mostly made of agricultural land (Table-1).

Table-1: 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

Discussion and Conclusion

The studied intact and consolidated wetlands are located at least 0.47 km away from the stream (Table-1) 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 (Table-1), 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.

In conclusion, the preliminary data analyses performed here hint at possible exchanges of water and SRP between so-called geographically isolated wetlands and the nearby stream in the BCW. However, 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.

References

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