Assessing Wetland Restoration with Phosphorus Forms: Linking Plant Community Composition and Biogeochemical Function

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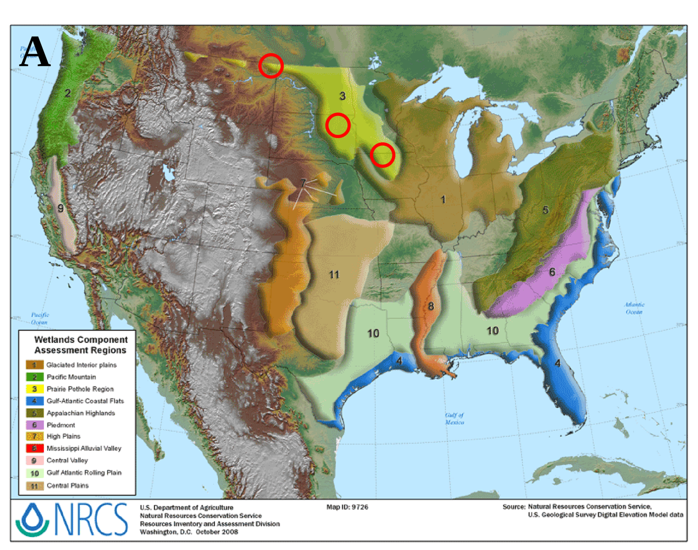
Abstract

We evaluated the use of soil phosphorus (P) forms, characterized with P nuclear magnetic resonance spectroscopy (P-NMR), as an index of biogeochemical function to assess wetland ecosystem restoration in the Prairie Pothole Region (PPR). There is currently no uniform applicable metric for assessing the success of wetland restoration on biogeochemical function. A link between wetland structure and biogeochemical function is often assumed and wetland biogeochemical function is rarely evaluated. We evaluate the biogeochemical function of restored wetlands in the PPR by examining P forms and soil properties in wetland soils from 3 topographic zones and 4 land use categories. To examine the link between wetland structure and biogeochemical function, we evaluated P forms, soil properties, and plant community structure in wetlands across topographic zones and land use categories. Our results show: 1) higher P richness in shoulder slope samples from reference and long term restored wetlands, 2) increasing relative abundance of orthophosphate for shoulder slope samples from the reference to restored to agricultural wetlands, and 3) correlation between the relative abundance of orthophosphate and species richness, mean coefficient of conservatism, and floristic quality index. While recovery of relative abundance of various P forms can take place in as little as 5 years, recovery of P form diversity took longer and was evident in wetlands restored for 15 or more years.

Introduction

- Soil P forms, identified with P Nuclear Magnetic Resonance Spectroscopy (P-NMR), may provide an assessment tool to evaluate the success of wetland restoration.
- U.S. policy encourages the restoration of degraded wetlands and their functions through conservation title programs such as the Conservation Reserve Program and Wetland Reserve Program .
- Evaluating the outcome of the restoration has been challenging, and the design and application of a uniform metric of wetland ecosystem function remains elusive [1, 2].
- Common evaluation metrics include soil condition [3, 4], water quality [5, 6], flora [7-9], and fauna [10, 11].
- Wetland biogeochemical function is rarely evaluated [12].



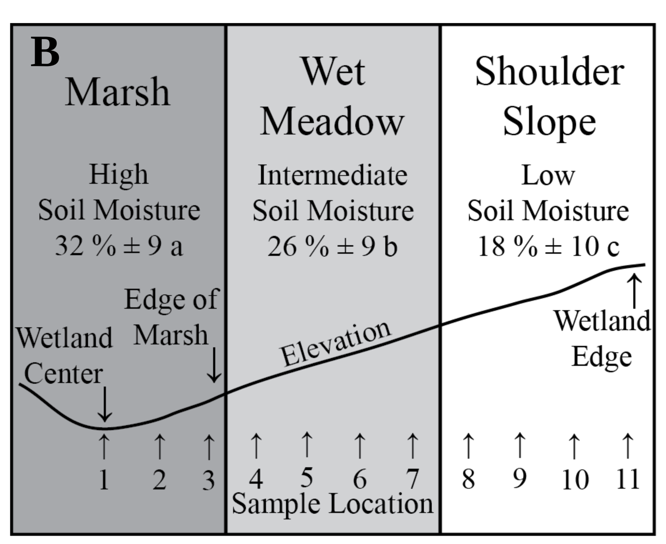


Figure 1. We selected wetlands within the 3 red circled areas of the Prairie Pothole Region, one of 11 assessment regions of the Conservation Effects Assessment Project (A). The 3 topographic zones based on soil moisture, values are mean soil moisture ± standard deviation with different letters indicating significant difference at $p < 0.05$.

Objectives

1. To develop the use of P form dynamics as an assessment tool of wetland restoration by identifying the optimal sampling location.
2. To assess the biogeochemical function of restored wetlands in the PPR.
3. To evaluate the link between a functional assessment (P forms) and a structural assessment (plant community composition).

Methods

- We selected 30 wetlands within 4 land use categories in the PPR (Fig. 1A):
  - Reference – no known agricultural usage,
  - Long term restored – CRP protection for more than 15 years,
  - Short term restored –CRP protection for less than 5 years,
  - Agricultural
- Soil samples were collected along a transect from the wetland center to the edge, and grouped into 3 topographic zones based on soil moisture (Fig. 1B).
- P forms and their relative abundance were identified with P-NMR spectroscopy on aqueous soil extracts.
- We measured total soil P, soil moisture, carbon, nitrogen, cations, and plant community structure.

Figures

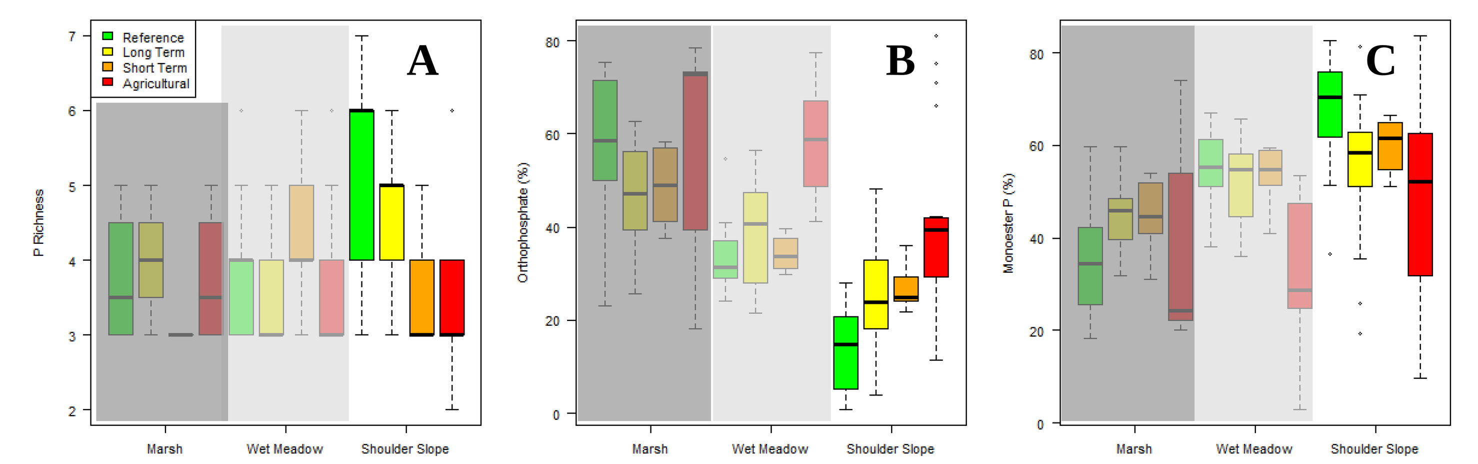


Figure 2. P richness (A), orthophosphate (B), and monoester P (C) in the marsh (dark grey background), wet meadow (light grey background), and shoulder slope (white background) across land use.

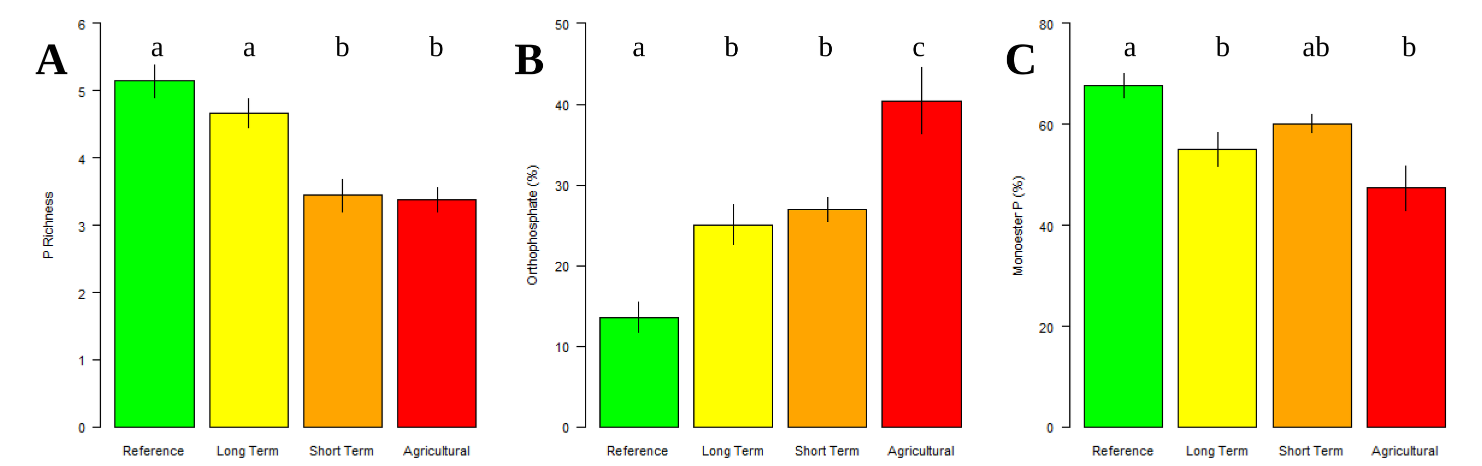


Figure 3. P richness (A), orthophosphate (B), and monoester P (C) in the shoulder slope across land use. Different letters indicate significant difference at $p < 0.05$.

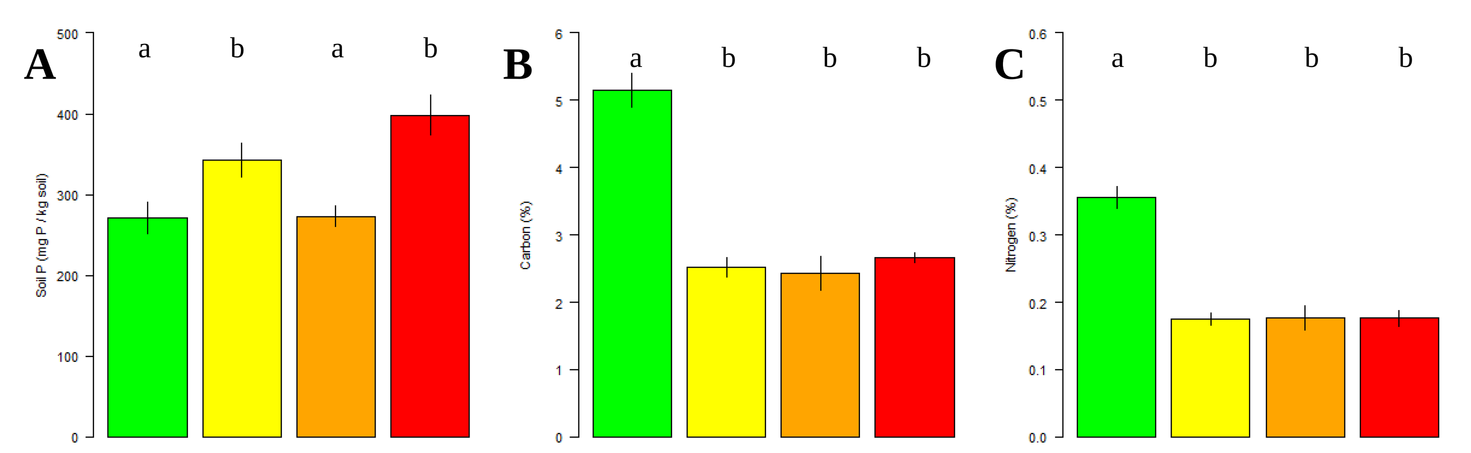


Figure 4. Soil P (A), carbon (B), and nitrogen (C) in the shoulder slope across land use.

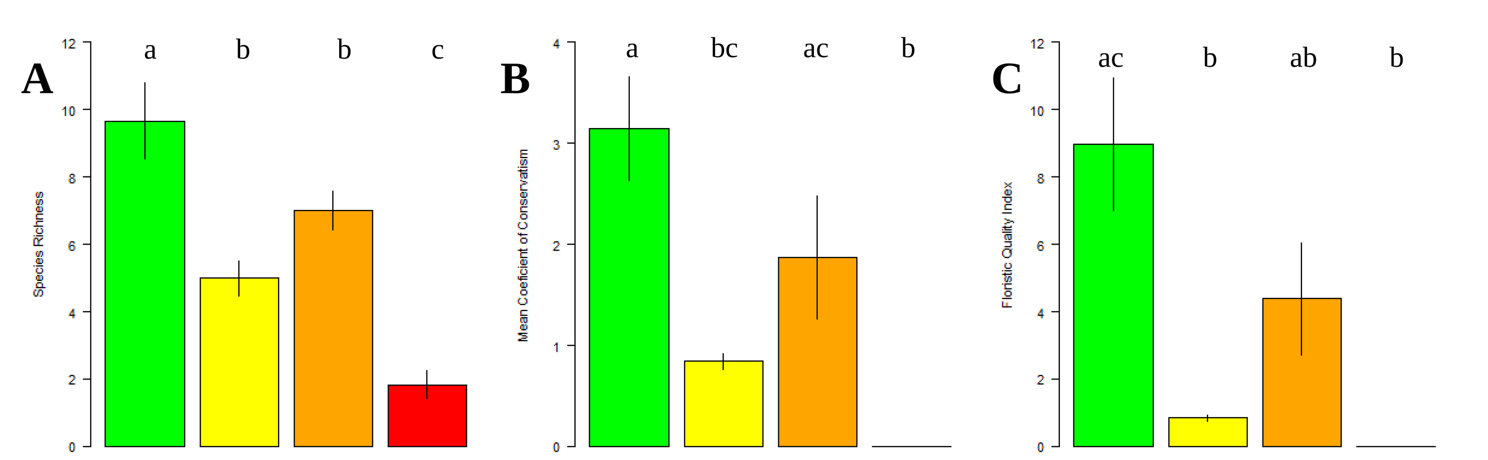


Figure 5. Species richness (A), mean C Score (B), and FQI (C) in the shoulder slope across land use.

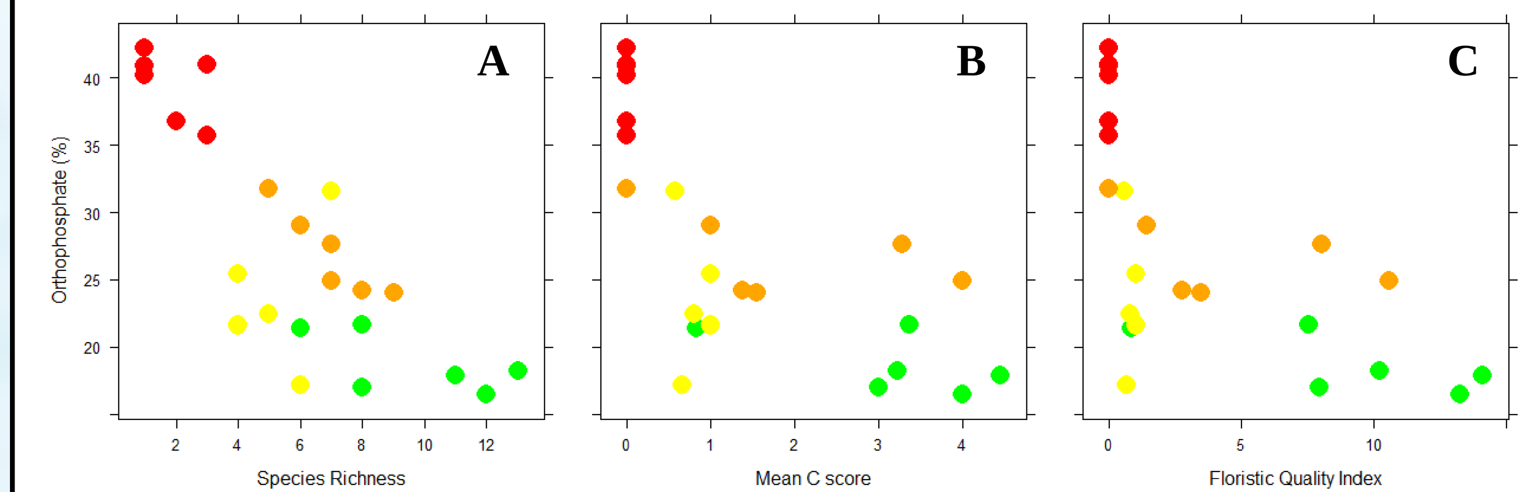


Figure 6. Relative abundance of orthophosphate vs. species richness (A) Pearson Correlation 0.78, $R^2 = 0.61$; relative abundance of orthophosphate vs. mean C Score (B) Pearson Correlation 0.68, $R^2 = 0.47$; Relative abundance of orthophosphate vs. FQI (C) Pearson Correlation 0.6, $R^2 = 0.36$. Color indicates land use category.

Results

- The mean P form richness increased from 3.7 in the marsh to 4.3 in the shoulder slope; this difference is a result of increased richness for the reference and long term restored wetlands in the shoulder slope (Fig 2A).
- While the relative abundance of Ortho P and monoester P were distinct for each topographic zone, the differences associated with land use are most evident in the shoulder slope samples (Fig 2 B, C).
- Mean P richness was highest in the reference and long term restored wetlands (5.1 and 4.7 respectively), and lowest in the short term restored and agricultural wetlands (3.4) for the shoulder slope samples (Fig. 3 A) .
- Relative abundance of Ortho P was lowest in the reference wetlands (14%), intermediate in the restored wetlands (26%) and highest in the agricultural wetlands (40%) for the shoulder slope samples (Fig. 3 B).
- Total soil P is lowest in the reference and short term restored wetlands, while soil C and N are highest in the reference wetlands (Fig 4).
- Species richness averaged 9.7 in the reference wetlands compared to 1.8 for the agricultural wetlands, with intermediate values for the restored wetlands for the shoulder slope samples (Fig. 5).
- Species richness, mean C Score, and FQI are correlated with orthophosphate) (Fig. 6).

Conclusion

1. Assessment of biogeochemical function with P forms should use samples collected in the shoulder slope zone of wetlands in the PPR.
2. Restoration practices in the PPR are making progress in returning biogeochemical function of P to natural conditions.
3. Biogeochemical function is linked to plant community structure in wetland ecosystems of the PPR, as indicated by orthophosphate and species richness.

Acknowledgment

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References

1. Sundareshwar, P.V., et al., *Nature versus nurture: Functional assessment of restoration effects on wetland services using Nuclear Magnetic Resonance Spectroscopy.* Geophys. Res. Lett., 2009. **36**(3): p. L03402.
2. Zelder, J.B. and C.J. C., *Tracking wetland restoration : Do mitigation sites follow desired trajectories?* Vol. 7. 1999, Malden, MA: Blackwell.
3. Freeland, J., J. Richardson, and L. Foss, *Soil indicators of agricultural impacts on northern prairie wetlands: Cottonwood lake research area, north Dakota, USA.* Wetlands, 1999. **19**(1): p. 56-64.
4. Maul, R., et al., *Resilience of forested wetlands located in the southeastern United States: Demonstration of a soil perturbation index.* Wetlands, 1999. **19**(1): p. 288-295.
5. Holloway, J.M., M.B. Goldhaber, and C.T. Mills, *Carbon and nitrogen biogeochemistry of a Prairie Pothole wetland, Stutsman County, North Dakota, USA.* Applied Geochemistry, 2011. **26, Supplement**(0): p. S44-S47.
6. LaBaugh, J.W., T.C. Winter, and D.O. Rosenberry, *Hydrologic functions of prairie wetlands.* Great Plains Research, 1998. **8**(1): p. 17-37.
7. Euliss, N., Jr. and D. Mushet, *A Multi-Year Comparison of IPCI Scores for Prairie Pothole Wetlands: Implications of Temporal and Spatial Variation.* Wetlands, 2011. **31**(4): p. 713-723.
8. Lopez, R.D. and M. Siobhan Fennessy, *Testing the floristic quality assessment index as an indicator of wetland condition.* Ecological Applications, 2002. **12**(2): p. 487-497.
9. Mills, C.T., et al., *Using stable isotopes to understand hydrochemical processes in and around a Prairie Pothole wetland in the Northern Great Plains, USA.* Applied Geochemistry, 2011. **26, Supplement**(0): p. S97-S100.
10. Euliss, N.H., D.A. Wrubleski, and D.M. Mushet, *Wetlands of the prairie pothole region: invertebrate species composition, ecology, and management*, in *Invertebrates in Freshwater Wetlands of North America: Ecology and Management*, D.P. Batzer, R.B. Rader, and S.A. Wissinger, Editors. 1999, John Wiley and Sons, Inc.: New York, NY. p. 471-514.
11. Tangen, B., M. Butler, and M. Ell, *Weak correspondence between macroinvertebrate assemblages and land use in Prairie Pothole Region wetlands, USA.* Wetlands, 2003. **23**(1): p. 104-115.
12. Gleason, R.A., *Conservation Effects Assessment Project Prairie Pothole Regional Studies*, U. USDA NRCS, Editor. 2008. p. 3.