Factors Affecting Nutrient Variation in Alberta Prairie Wetlands

M-C Roy
Alberta Biodiversity Monitoring Institute.

INTRODUCTION

Wetlands in the prairies of Alberta risk losing ecological integrity (degradation of water quality, loss of species diversity, etc.) because of global environmental change, such as climate warming, and human activities[1]. Numerous studies have demonstrated how wetlands can be severely affected by adjacent landscape-level factors, such as industrial activity in the surrounding area or nutrient enrichment from agriculture that is known to cause algae blooms, fish kills and other changes in biological diversity. In addition to landscape-level factors, wetlands can be influenced by local-level factors such as water depth and climate[2].

The Alberta Biodiversity Monitoring Institute (ABMI) measures the state of land and biodiversity across the province to support land-use decision-making. One of the ABMI's program objectives is to determine how local- and landscape-level factors influence biotic (e.g. aquatic plant abundance) and abiotic (e.g. water quality) components of Alberta's wetlands. This information is valuable to inform the evaluation of current efforts in the province to protect and conserve wetlands. For instance, if high nutrient loads are detected in wetlands near agriculture despite measures in place to protect wetlands from such land-use, it could indicate the protection measures are ineffective.

Although ABMI monitors both biotic and abiotic components of wetlands, in this study, we present results obtained from our abiotic monitoring activities. More specifically, we test which local- and landscape-level factors influence nutrient concentration (total nitrogen and total phosphorus) of prairie wetlands.

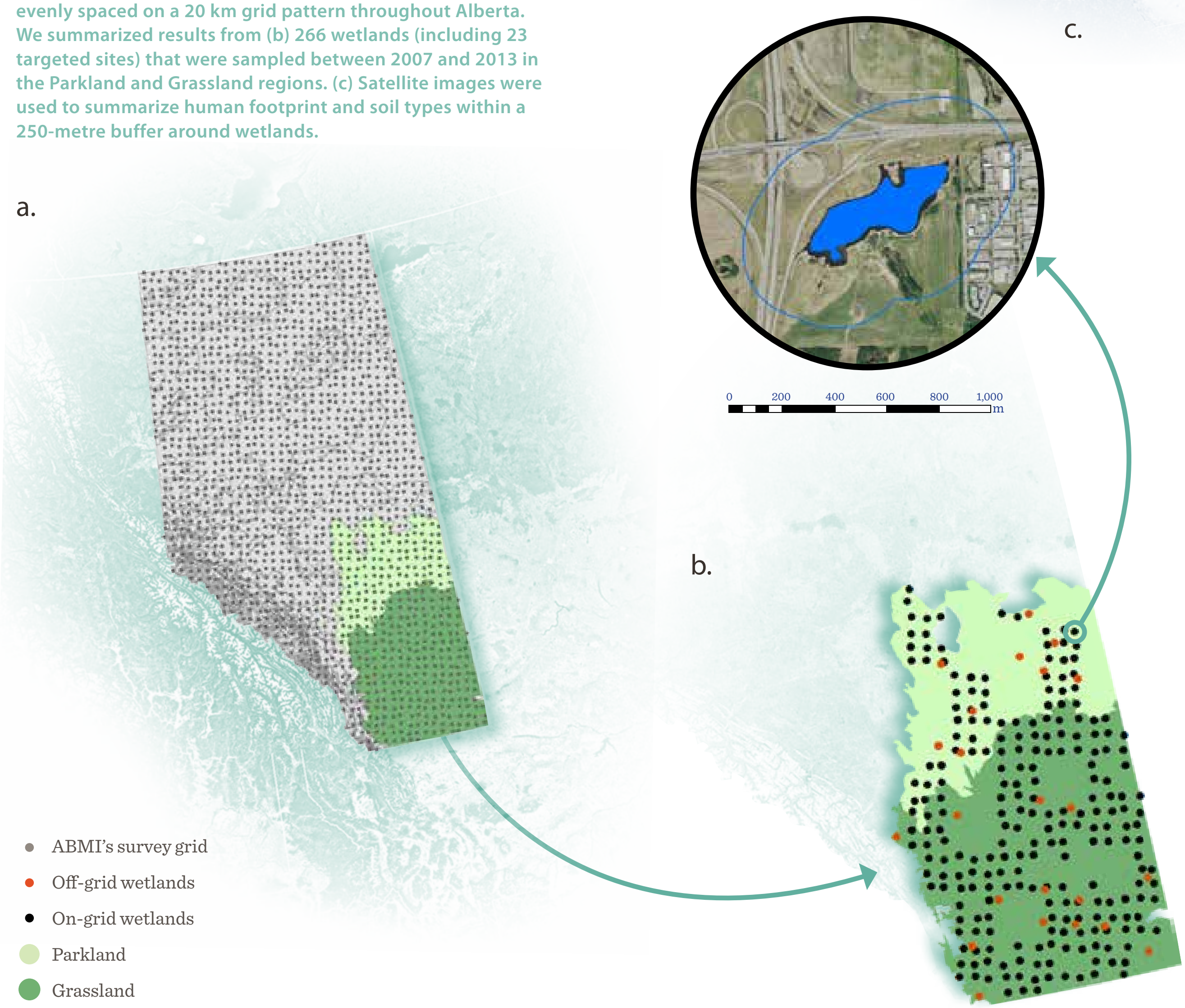
METHODS

ABMI's core survey design consists of 1,656 wetlands (mainly shallow-open waters and ponds[3]) evenly spaced on a 20 km grid pattern throughout Alberta (Figure 1). We summarized results from 243 wetlands sampled by ABMI across the Grassland and Parkland regions. In addition, we included the 23 wetlands in their vicinity that ABMI targeted for sampling as sites with relatively low human footprint. At each wetland, ABMI measured water depth, total nitrogen concentration, and total phosphorus concentration[4]. Water depth was measured at 28 locations in the open-water zone of each wetland and then averaged for our analyses. Three water samples were collected in the open-water zone of each wetland and sent to the laboratory for nutrient analyses. Human footprint[5] adjacent to wetlands was measured using SPOT satellite images. Soil information was derived from 1) the Alberta Sustainable Resource Development (SRD) geodatabase and AGRASID layers[6]. Geographic location, mean annual temperatures, and precipitation were also determined for each wetland.

1 Schindler D.W. & Donahue W.F. 2006. An impending water crisis in Canada's western prairie provinces. Proceedings of the National Academy of Science USA. 103:7210-7216.
2 Houlahan, J.E., P.A. Keddy, K. Makkay, & C. S. Findlay. 2006. The effects of adjacent land use on wetland species richness and community composition. Wetlands. 60:1078-1094.
3 Shallow-open waters were less than two meters deep whereas ponds were more than two meters deep.
4 ABMI. Reports. Wetland Data Collection Protocols. http://www.abmi.ca.
5 Human footprint refers to the geographic extent of areas under human use that have either lost their natural cover or whose natural cover is periodically or temporarily replaced by resource extraction activities. For the prairie regions, we grouped Human footprint types into nine categories: agriculture, urban-industrial, soft linear (e.g. pipelines), hard linear (e.g. roads), human-created water bodies, alienating disturbance (agriculture, urban-industrial, hard linear, human-created water bodies), successional disturbance (soft linear), linear disturbances (soft linear, hard linear) and non-linear disturbance (agriculture, urban-industrial, human-created water bodies).
6 The soil layer is produced by ABMI and is the result of merging 1) the geodatabase ("GVI_sitetypes_from_soils.gdb") provided by O. Castelli from SRD Lethbridge, Alberta. and 2) information from the Agricultural Region of Alberta Soil Inventory Database (AGRASID)(Government of Alberta).

FIGURE 1

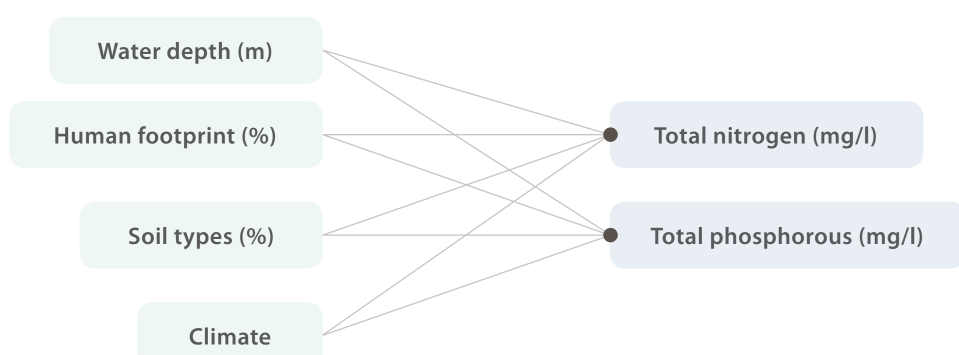
(a) ABMI's basic survey design consists of 1,656 wetlands evenly spaced on a 20 km grid pattern throughout Alberta. We summarized results from (b) 266 wetlands (including 23 targeted sites) that were sampled between 2007 and 2013 in the Parkland and Grassland regions. (c) Satellite images were used to summarize human footprint and soil types within a 250-metre buffer around wetlands.



Using stepwise multiple regressions we examined how total nitrogen and total phosphorus responded to soil types, human footprint, geographic location, and climate (Figure 2).

FIGURE 2.

Water depth, human footprint, soil types and climate were used as predictors for total nitrogen and total phosphorus. The arrows are directed from predictor toward response variables



RESULTS

Most wetlands assessed in the prairies had human footprint in their surrounding 250-metre buffer (Figure 3). Only 4% wetlands had no human footprint in the surrounding area, while 34% had more than 75% of their surrounding area occupied by human footprint. Agriculture footprint contributed the most to the total human footprint measured in the 250-metre buffer zone; on average, it comprised 79% of the total human footprint (Figure 4). Urban-industrial, transportation (soft-linear), transportation (hard-linear) and human-created water footprints represented, on average, 13%, 3%, 2%, and 1% (respectively) of the total human footprint measured in the wetland buffer zone.

FIGURE 3.
Wetland distribution based on the amount of agriculture and total human footprint measured in their 250-metre buffer zone. Each dot represents a wetland. The closer a wetland is to the diagonal line, the higher the amount of agriculture footprint in relation to the amount of total human footprint in its buffer.

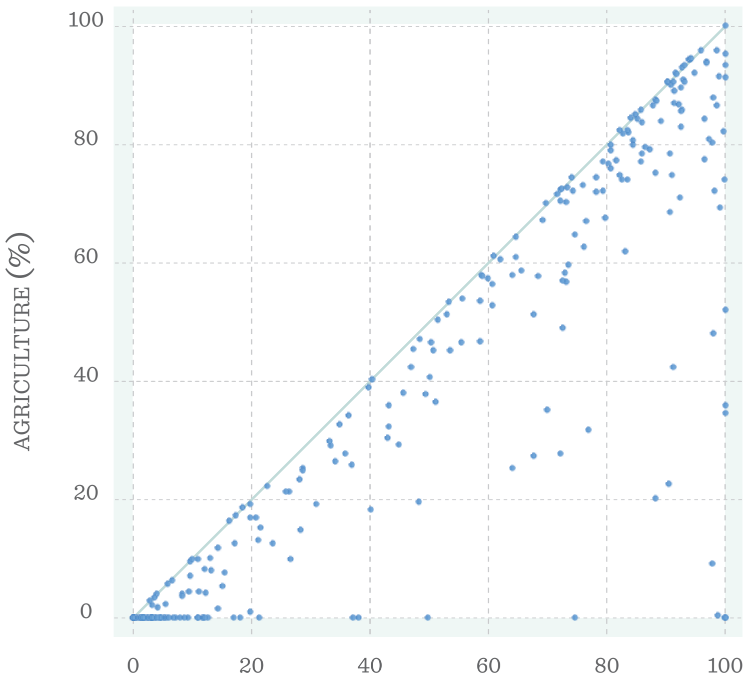
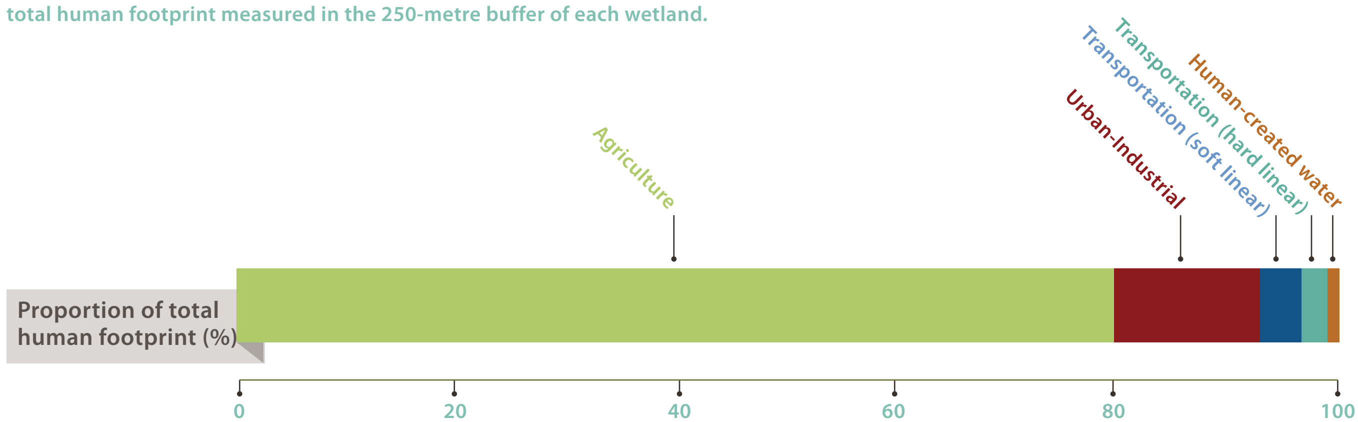


FIGURE 4.
Breakdown of the average contribution of each human footprint type to the total human footprint measured in the 250-metre buffer of each wetland.



Water depth was a significant predictor of total nitrogen and phosphorus (Table 1, Figure 5). Total nitrogen and total phosphorus were higher in shallower wetlands compared to deep wetlands (Figure 5). As the amount of surrounding agriculture increased, total nitrogen rose slightly and total phosphorus showed a stronger response. For example, wetlands with >75% agriculture in the buffer zone had an average of 25% more total nitrogen and twice as much total phosphorus than wetlands with no agriculture in their buffer. Finally, total phosphorus was higher in sites that received less precipitation, whereas this relationship was not significant for total nitrogen.

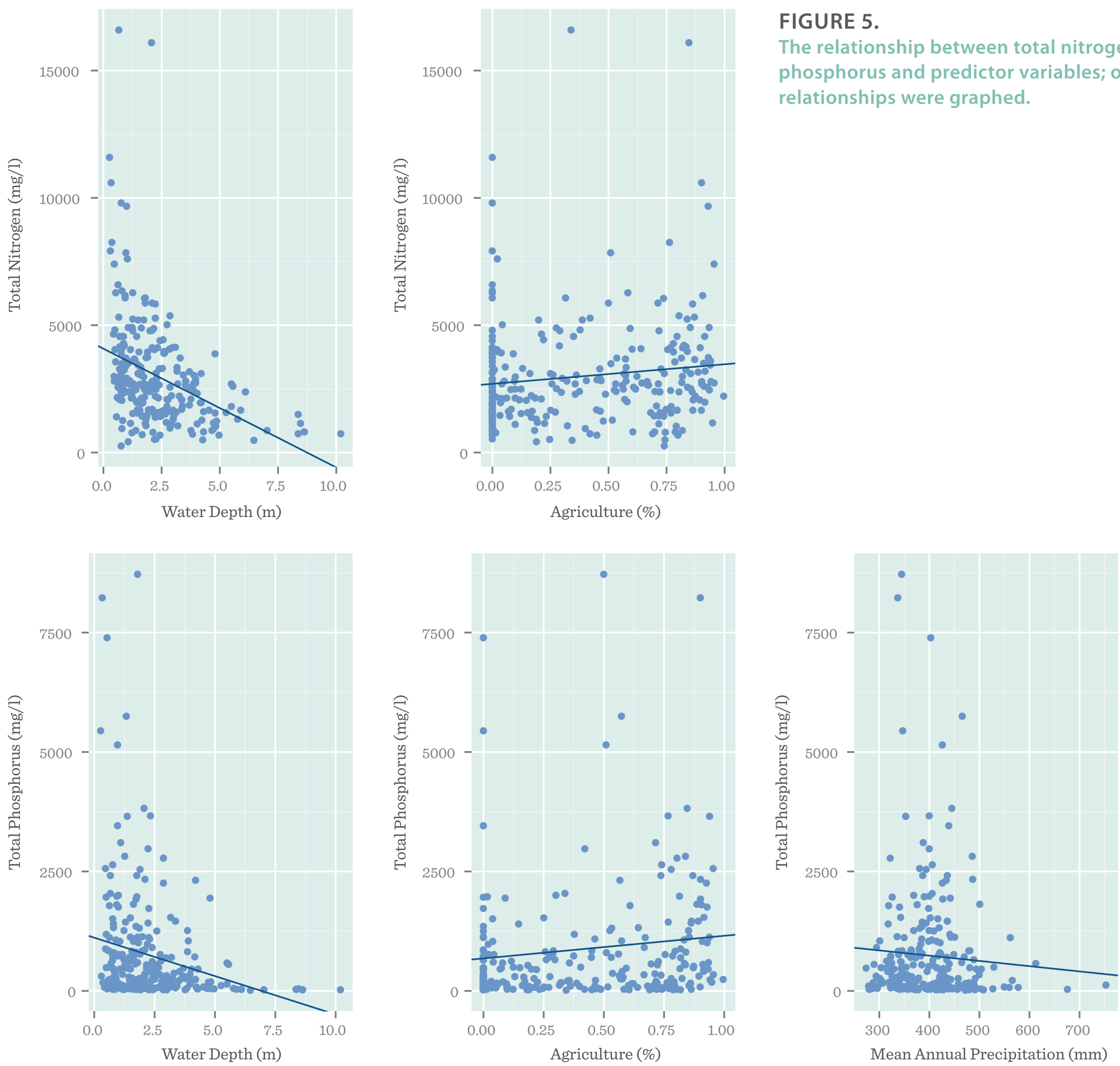


FIGURE 5.
The relationship between total nitrogen and total phosphorus and predictor variables; only significant relationships were graphed.

TABLE 1.
Predictor variables and their positive or negative (-) association with the response variables. For example, agriculture footprint is positively and more strongly associated with total phosphorus (0.31) than water depth which it is negatively associated with (-0.24). Only coefficients statistically different from 0 (p<0.05,) are shown.

Predictor Variable	Response variable	
	Total nitrogen	Total phosphorus
Soil types		
Agriculture footprint	0.15	0.31
Other footprint		
Mean annual precipitation		-0.14
Other climate variables		
Geographic position		
Water depth	-0.38	-0.24

DISCUSSION:

Our results indicate water depth, surrounding agriculture footprint, and amount of precipitation received all significantly influence the water quality of prairie wetlands in Alberta. All three factors influence total phosphorus present, whereas only water depth and surrounding agriculture footprint influence total nitrogen. The different processes that influence the nitrogen and phosphorus cycles may explain their different responses to precipitation. While the nitrogen cycle in wetlands is mainly influenced by biological processes, the phosphorus cycle is governed by geochemical processes[7]. Although our results show a decrease in phosphorus with an increase in precipitation, the opposite relationship was expected. Typically, precipitation increases sediment wetness which promotes the solubilisation of phosphorus present in the soil[7]. However, phosphorus solubility is also negatively influenced by acidity[8]. In areas with higher human footprint, precipitation may acidify wetland water, in turn, leading phosphorus to precipitate out of the water column into the sediment[8]. This latter process may explain the lower total phosphorus we observed in prairie wetlands with higher precipitation.

Our finding that nutrient loading increases with agricultural footprint is consistent with other studies—nutrient amounts in wetlands are positively correlated to the proportion of agriculture in the surrounding watershed[2]. These elevated nutrient loadings, however, do not always translate into a loss of biodiversity[9]. In prairie wetlands in Alberta, the nutrient threshold beyond which biodiversity is affected has yet to be established; this is exactly what ABMI hopes to determine. We're currently analysing the effects of adjacent land-uses on the aquatic plants and invertebrates of Alberta, and will publish a follow-up ABMI Science Letter to speak to our results.

We found prairie wetland condition to be influenced by both landscape and local factors. Thus both of these factors must be considered when creating and evaluating policy to effectively protect Alberta's wetlands. One of the main focuses of the recently introduced Alberta Wetland Policy is to protect wetlands for the long-term benefit of Albertans[10]. The policy suggests environmental impacts on wetlands be avoided, and if not reasonably avoided, then minimized. Where wetlands have been degraded or lost and restoration or mitigation is necessary, our results indicate that managers should focus their efforts—when managing for adjacent land-use effects—on wetlands with appropriate morphometry.

AFFILIATIONS

M-C Roy
ABMI Wetland Ecologist, roy4@ualberta.ca

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Alberta Biodiversity Monitoring Institute
CW 405 Biological Sciences Building
University of Alberta, Edmonton, Alberta
Canada T6G 2E9
@ABbiodiversity

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