Occurrence of Total Nitrogen and Total Phosphorus during Storm Events in the Lamoille River Basin

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Introduction

The need to provide sufficient resources for the global population has heightened the intensity of conventional farming practices. Intensive farming, including crop cultivation and livestock production, is prompting the degradation of farm lands and ecosystems adjacent to these areas (Trautmann et al., 2012).

Storm events act as a primary mechanism by which nutrients from land surfaces, such as runoff, leaching, and eroded soils, are transported into surface waters. Although nutrients are required for the growth of plants and algae, excessive phosphorus loading can result in the eutrophication of aquatic ecosystems (Woodward et al., 2012). Lake Champlain has been subject to such nutrient pollution for the past several decades.

Streams and rivers experience phases of growth and decline during storms which can be analyzed by plotting a hydrograph, discharge (ft^3/sec) over time (Shuster et al., 2008). Furthermore, the relationship between fluctuations in discharge and nutrient cycling within these ecosystems can be determined by collecting water samples during each phase of a storm.

Utilizing this experimental design, a storm event occurring between June 8th and June 12th of 2015, was monitored at ten sites in the Lamoille River Basin, of the Lake Champlain Watershed, to analyze how ratios of total nitrogen to total phosphorus (TN:TP) change within an aquatic ecosystem throughout a peak hydrograph.

Methods

Stream data, including flow measurements (discharge) and water samples (nutrient analysis), was collected from ten tributary sites on each day of the storm. Sample sites were near confluence with the Lamoille River, had independent watersheds, and diverse land use compositions.

Corresponding discharge data for the Lamoille River was obtained from the USGS river gauge located on the Lamoille in Johnson, VT. The Lamoille River hydrograph was plotted, including date, time, and discharge. Phases of the storm were divided into time steps and designated by a series of 24 hour segments using the peak discharge level as the origin.

Hydrographs for all tributary sites were generated and used to analyze how the molar ratios of TN:TP occurred at each sample site, during each time step of the hydrograph. To increase sample size, nutrient measurements from 2012 through 2014 were retrieved using the same method to determine where data points fell within the hydrograph's time steps.

After this was completed for each site, all of the relevant data was compiled by averaging the TN:TP ratios at each site, from all five time steps, during every year.

After the final TN:TP averages were calculated, those numbers were plotted in correspondence to the days around the peak. Subsequent graphs encompassed the TN:TP ratios and the percentage of agricultural and forested land in the total catchment from a 2010 GIS dataset.

Results

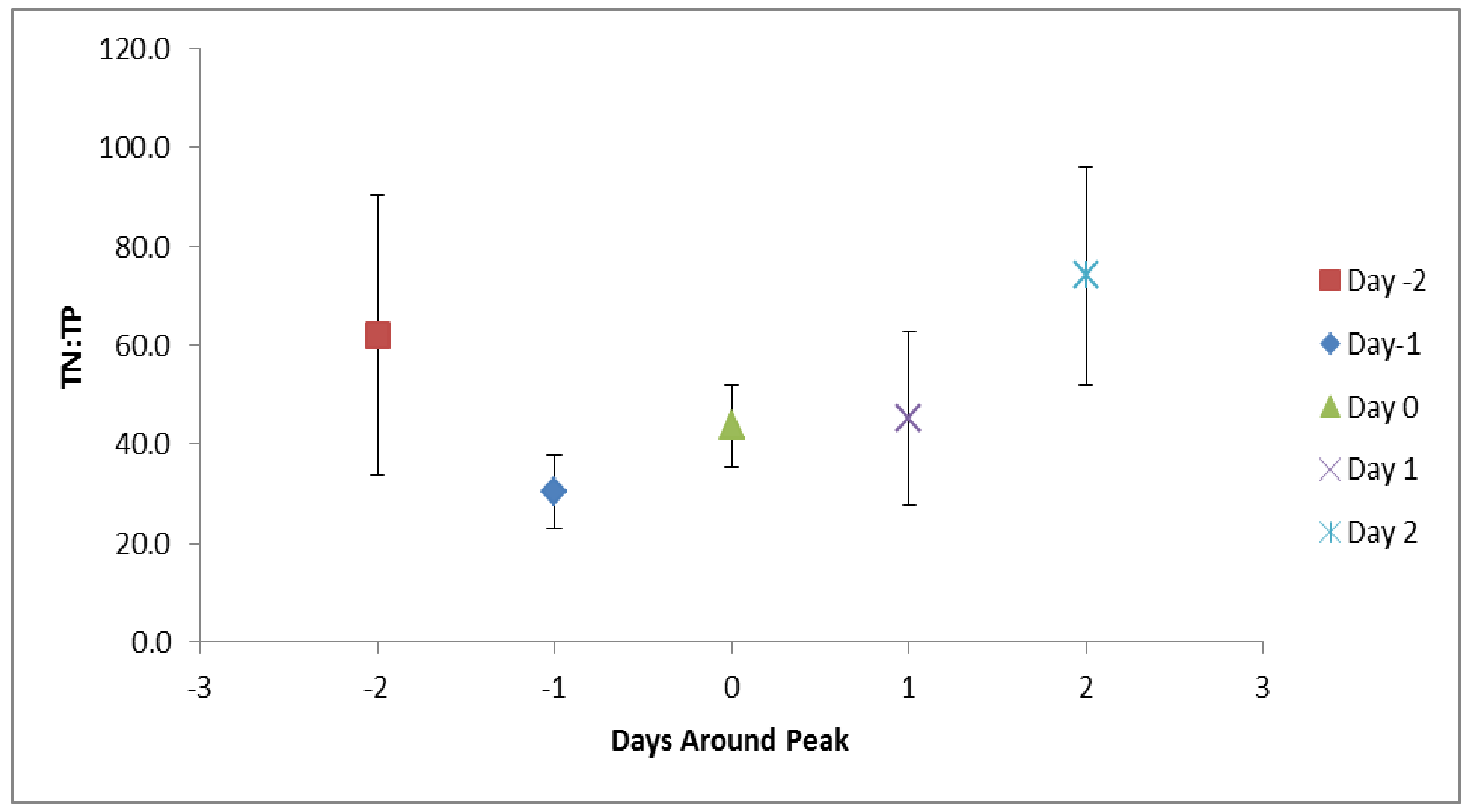

Figure 1. Fluctuation of TN:TP throughout the storm event with a 95% confidence interval

- Figure 1 shows the final TN:TP ratio calculated from nutrient data collected between 2012 and 2015, at 10 tributary sites in the Lamoille River Basin, with a 95 percent confidence interval.
- This figure demonstrates that TN:TP falls as the hydrograph rises, but is markedly high at the beginning and end of the storm.
- Overlap in the confidence intervals of each point suggests that they may not be statistically different.

A small effect size is $R^2 \geq 0.01$, a medium effect size is $R^2 \geq 0.09$, and a large effect size is $R^2 \geq 0.25$ (Cohen, 1988).

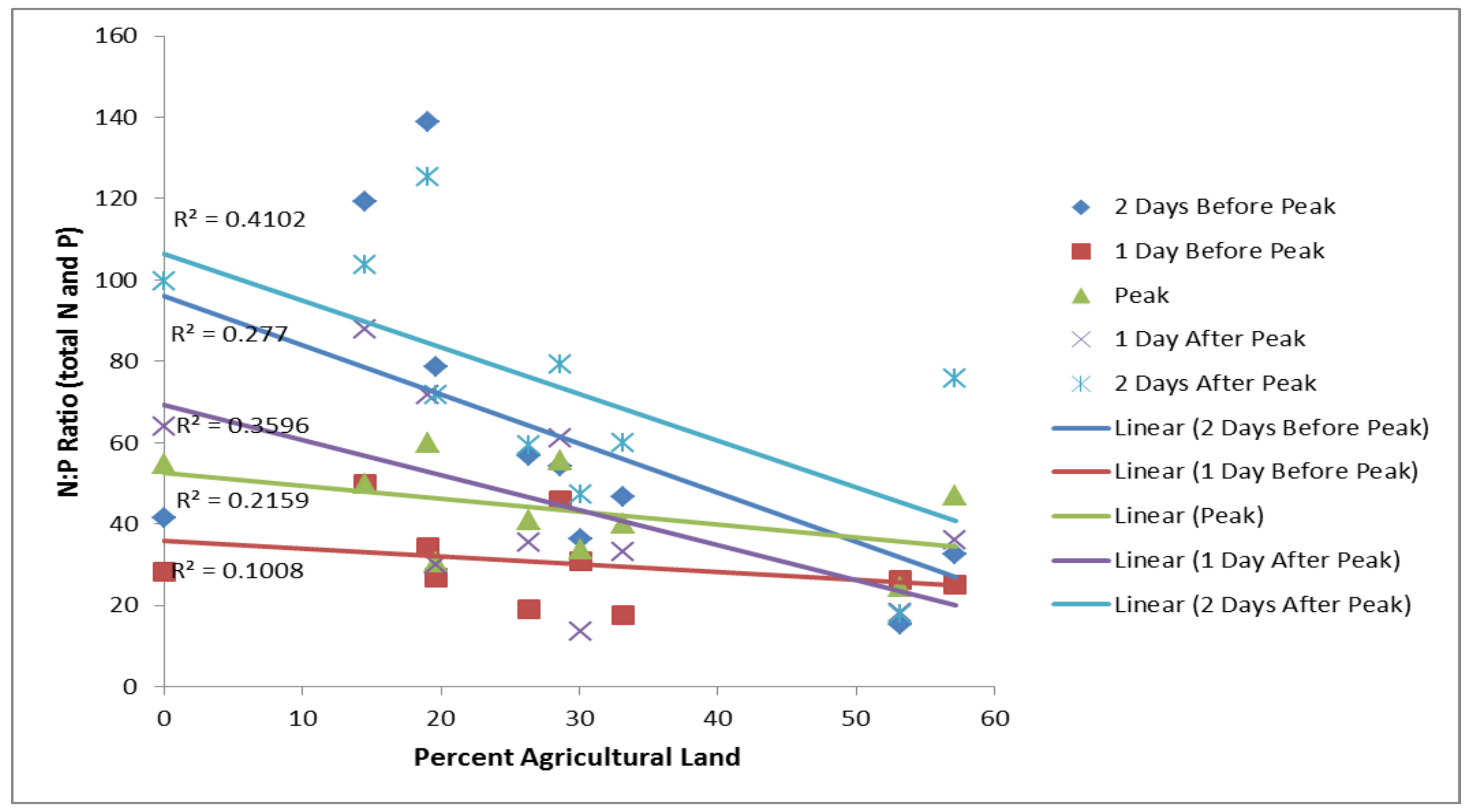

Figure 2. TN:TP during the storm event, percent of agricultural land in the total catchment area, and R^2 coefficients for trendline effect size

- Figure 2 shows the final TN:TP ratio plotted with the percentage of agricultural land in the total catchment.
- This figure demonstrates that those days farther from the peak, including two days before and after, have a higher TN:TP ratio.
- During the peak, and 24 hours before and after the peak, a decrease in TN:TP is measured regardless of the percentage of agricultural land in the catchment.
- The R^2 coefficient is most significant two days after the peak with a large effect size of 0.4102, and least significant one day before the peak with a medium effect size of 0.1008 (Cohen, 1988).

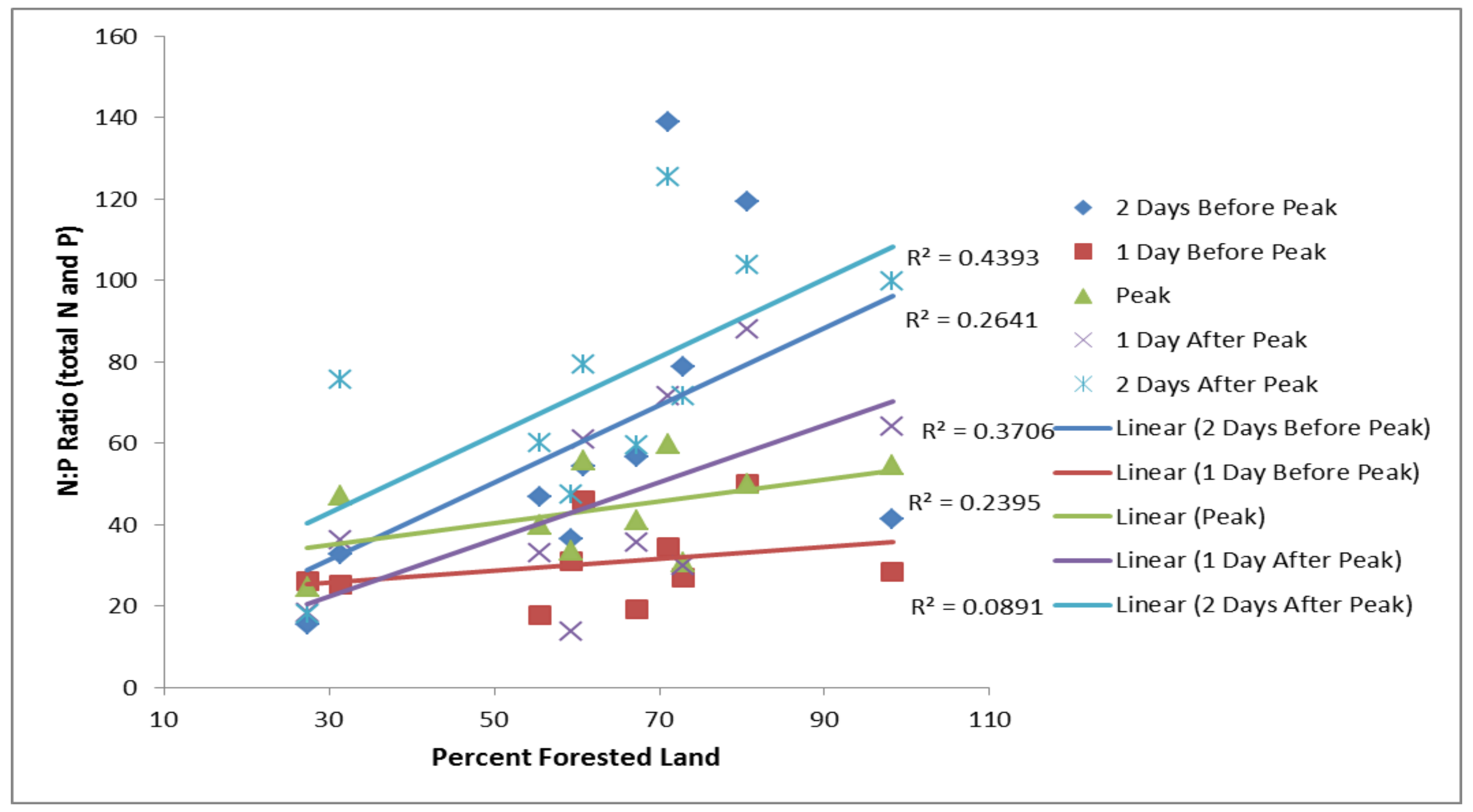

Figure 3. TN:TP during the storm event, the percent of forested land in the total catchment area, and R^2 coefficients for trendline effect size

- Figure 3 shows the final TN:TP ratio plotted with the percentage of forested land in the total catchment.
- This figure demonstrates that those days farther from the peak, including two days before and after, have a higher TN:TP ratio.
- During the peak, and 24 hours before and after the peak, a decrease in TN:TP is measured regardless of the percentage of forested land in the catchment.
- The R^2 coefficient is most significant two days after the peak with a large effect size of 0.4393, and least significant one day before the peak with a small effect size of 0.0891 (Cohen, 1988).

Discussion

Fluctuations in TN:TP is influenced by a number of variables as demonstrated by the high ratios shown on the days farther from the peak, and within those areas with high levels of forested land and low levels of agricultural land. (Figures 2 and 3). Moreover, variability in the R^2 values shows effect sizes decreasing in correspondence with the days around peak flow. Regardless of the land surfaces within the catchment, it is shown that TN:TP decreases as the hydrograph rises. Two possibilities could account for this; either the amount of total nitrogen is decreasing within these aquatic ecosystems throughout the storm event, or more plausibly, total phosphorus levels are increasing with the influx of stormwater effluents.

As the Clean Water Act attributes nitrogen and phosphorus pollution to being one of the leading pathways for water quality degradation, such variance in nutrient levels due to uploading, can result in the impairment of biogeochemical processes within affected streams (Bergman, 2011). To reduce nutrient pollution corresponding to storm events and land use practices, environmental remediation has been a focus for intergovernmental efforts (Osherenko, 2013). Some of which include the establishment of reduction goals for Lake Champlain and best management practices within agricultural and urban areas.

Environmental systems are greatly influenced by anthropogenic activity, and these complex interactions prompt the need for further study. Analysis of peak hydrograph events and nutrient cycling is necessary to understand the extent to which nitrogen and phosphorus pollution occurs throughout aquatic ecosystems. Relevant research, such as the June 2015 storm event monitored at ten tributary sites within the Lamoille River Basin, must be continued to ensure positive progress towards goals to remediate impaired aquatic ecosystems.

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