Getting Wet in the Wetlands

A Test of the Effectiveness of Villanova's Wetlands Filtration System

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Abstract

Nutrient pollution is a growing problem. Nitrates and phosphates used extensively in both commercial and residential fertilizers to supplement crop growth are degrading aquatic ecosystems. High concentrations of nutrients found in aquatic ecosystems have proven to cause eutrophication by stimulating excess plant growth leading to algal blooms and other detrimental processes that starve water of oxygen and block sunlight, threatening aquatic life.

The effectiveness of the Villanova Wetlands was tested by measuring the concentration of known nutrient pollutants, nitrate and phosphate. 5ml water samples were collected on three separate occasions from four key points along the flow path. Nitrate and phosphate concentration was analyzed with a spectrometer. The raw data was compiled into mean nitrate/phosphate concentration by point as well as by date. Upon analysis, nitrate concentration proved to decrease along the flow path as hypothesized. Phosphate levels were too low and inconsistent to be able to conclude anything with confidence. Results were as expected with the exception of the day one average, which was unexpectedly higher than the rest. This can be attributed to snowmelt and consequent runoff, presumably containing high levels of nitrates and phosphates, explained by the winter sample date (Feb 27). The experiment proved the effectiveness of the Villanova Wetlands and provided further evidence for the use of wetlands as an effective, financially feasible and environmentally friendly way of mitigating nutrient pollution.

Introduction

As the environment in which we live continues to change, the importance of monitoring nutrient levels in our freshwater resources grows. Many factors contribute to the degradation of water quality, but agricultural land use changes have now become the largest source of water pollution (EPA, 2012). With the use of nitrogen based fertilizers rising steadily since the 1950's, it has become increasingly important to mitigate nutrient pollution (USDA, 2013) Nitrogen and phosphorus end up in bodies of water as a result of runoff, and in high enough concentrations can lead to eutrophication, creating the environment for hypoxic conditions. (Bortman et al.,2003). A study conducted in Lake Fuxian, China concluded that eutrophication resulting from nutrient pollution can be directly linked to anthropogenic activities such as agriculture (Liu et al., 2012). The focal point of this project was to test the effectiveness of the Villanova artificial wetlands on west campus at removing nutrient pollution, in particular nitrates and phosphates.

Eutrophication can be detrimental to aquatic ecosystems. As excess nitrates and phosphates stimulate excess plant growth, oxygen levels deplete and eventually reach hypoxic levels. If a body of water reaches hypoxic levels, fish and other organisms will begin to die and the effects can have damaging long term consequences to the aquatic ecosystem (ESA, n.d.). A group of researchers found that despite a decrease in nitrate levels between 1995 and 2009, hypoxia and eutrophication are still a "severe problem" in the Long Island Sound (Sutter et al., 2014). It was estimated that over fifty percent of lakes in the United States are eutrophic (EPA, 2010). Eutrophication and other problems associated with excess nutrient levels are a serious concern needing to be addressed.

Filtration systems are exceedingly important in populated areas as they are mechanisms by which nutrients can be removed cheaply, effectively and with little environmental impact. In a recent study, a team of researchers in China found that the artificial wetlands serving as a filtration system under study was a very efficient filter of excess nutrients; removing over 50% of both nitrate and phosphate content out of the ecosystem (Xuechu et al., 2013).

Villanova University, striving to maintain a picturesque campus, uses fertilizers containing nitrates and phosphates. These nutrients tend to runoff during rain showers leading to a high potential for impact on surrounding areas. As a means of being a good example for the community and other universities, it is a necessity that Villanova University exercise good nutrient pollution control particularly in light of recent decades where eutrophication has proved to be a detriment to freshwater systems and has caused around $2.2 billion annually in cleanup and remediation (Dodds et al., 2009).

In a study by Alexander and Smith (2006), freshwater streams with riparian zones were much less likely to increase in eutrophication annually. The artificial wetlands on Villanova's campus were built to simulate a natural filtration system of nutrients, with these ideas in mind, as a means to counteract the issue of water pollution.

In this study, data was collected on the levels of nitrates and phosphates from four different points along the Villanova artificial wetlands. It was hypothesized that both nitrate and phosphate levels would decline along the flow path, confirming that the wetlands acted as a filtration system ensuring that when water exits the wetlands and enters Mill Creek, nutrient levels are of a reasonable level.

Methods

Water samples were collected from Villanova University's Wetlands in the northeast section of Villanova's campus, adjacent to the university law building and on the north side of the train tracks (Fig. 1). Two water samples were collected from four different points along the Wetlands system, one for nitrates and one for phosphates, and were spaced out as a means to obtain information on the entirety of the system (Fig. 2). Data was collected on four separate dates: February 27th, March 6th, March 13th, and March 27th, each time around 3 o'clock in the afternoon. Data was collected on lab days with a week in between each sampling exempting the last date.

Two water samples of 5 milliliters were obtained in unused test tubes at each location. The water was removed from the wetlands with a syringe (by hand) then filtered into the test tubes by a filter attachment to the syringe. Locations with low concentrations of sediment, based on observation, were chosen, and sediments were not stirred up when taking the samples. Samples were capped and frozen in the Environmental Science Lab until our analysis on April 3rd.

Water samples were thawed, by time and body warmth, and then analyzed using a spectrometer. In total there were 32 sample tubes, 16 for nitrates and 16 for phosphates, 8 from each day. First, nitrate and phosphate stocks were created as a means of comparison to our water samples. The stocks for nitrate had 0, .5, 1, 5, 10, and 100 parts per million. The stocks for phosphorus had 0, .05, .1, .5, 1, and 10 parts per million. 32 vials were made with 2.5 mL of the sample, 16 of which for testing for nitrate and 16 for testing for phosphate. The phosphate test called for a 10mL sample so 7.5 mL of water was added to each sample and the stocks for phosphorus. Reactive agent was added to the samples and the spectrometer was used to measure the amount of nitrate and phosphate for each location on each day. Before the nitrate testing and then again before the phosphate testing, the machine was zeroed. The results were recorded.

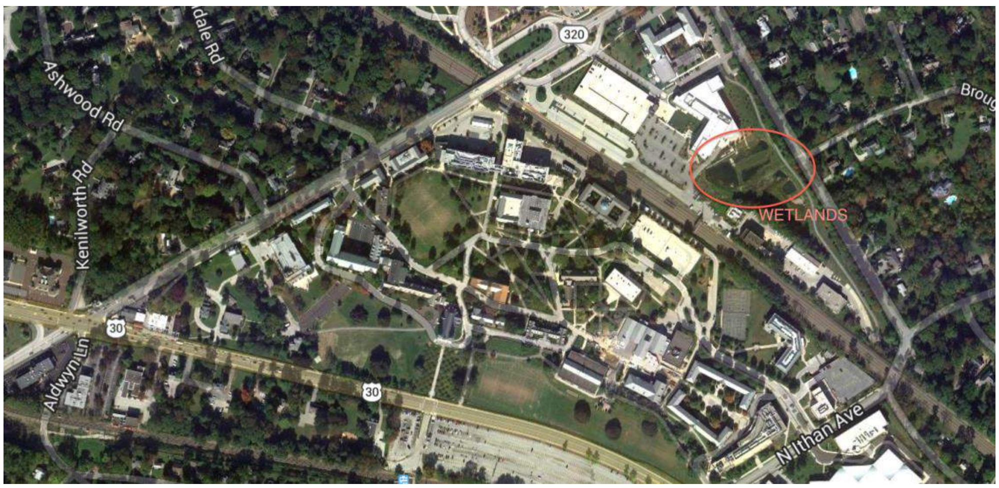

Figure 1: Villanova University Wetlands Location

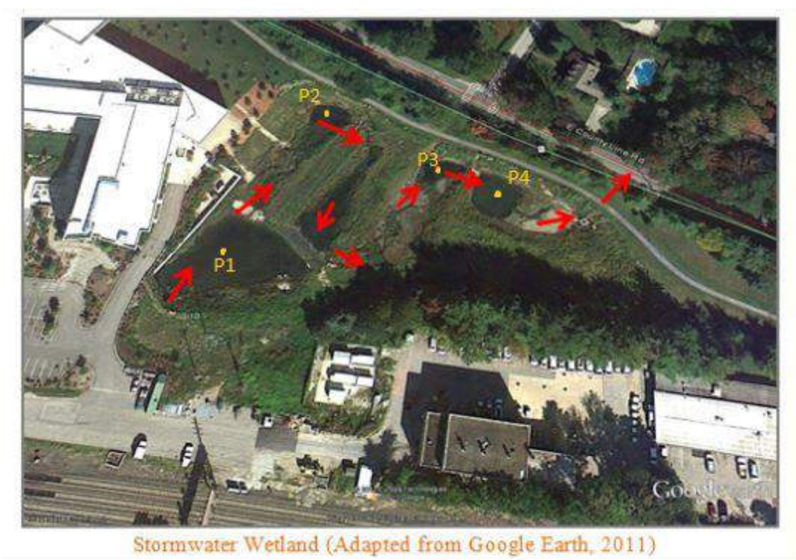

Figure 2: Villanova University Wetlands sample location.

Results

As water traveled through the Villanova University Wetlands, concentrations of nitrate decreased (Fig. 3). The results showed a significant decrease from the first to the second point, and a more leveled out decrease from point's two to four (Fig. 3). The results from the comparison of mean nitrate concentration on the various sampling days varied and depicted no outstanding trend, although the last three testing dates show an increasing trend (Fig. 4). Standard deviation and mean for the whole data set was .488 ppm and 1.04 ppm, respectively. Standard deviation for mean on separate days was .141 ppm (Fig. 4). Phosphorous content was exceedingly low and thus was omitted from our data analysis.

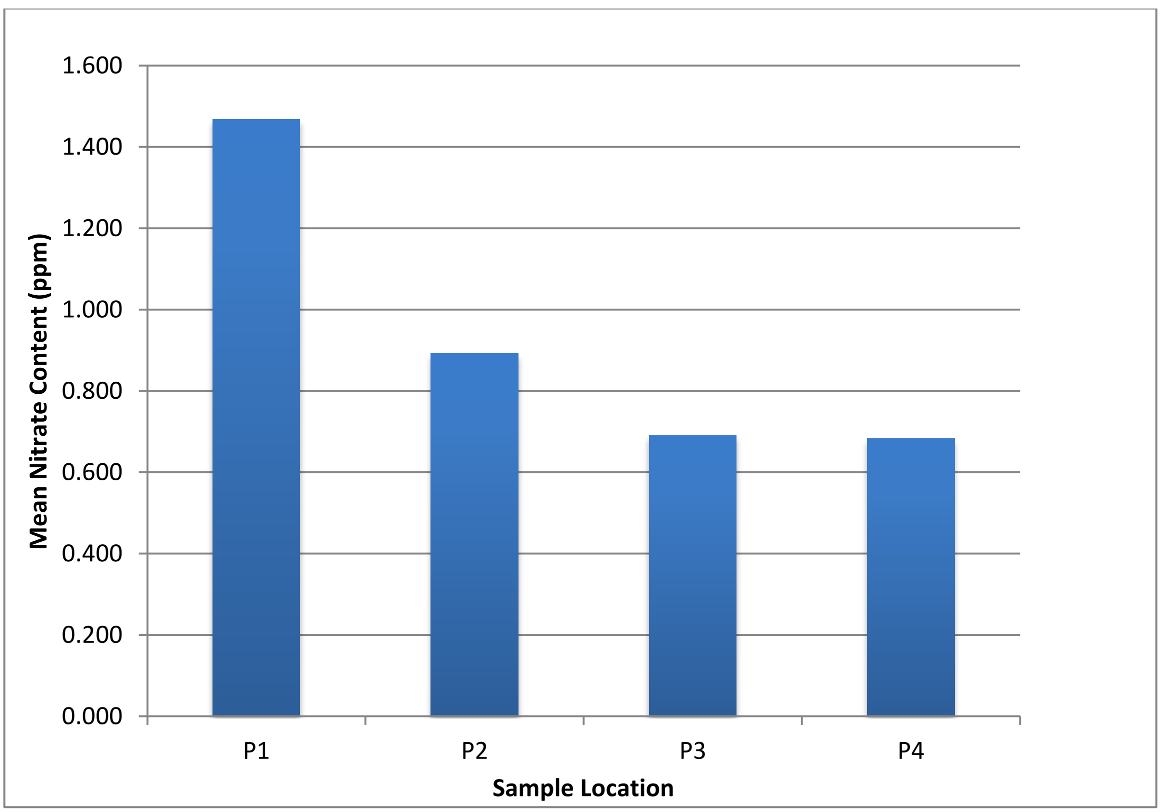

Figure 3. Mean nitrate concentration by location (PPM)

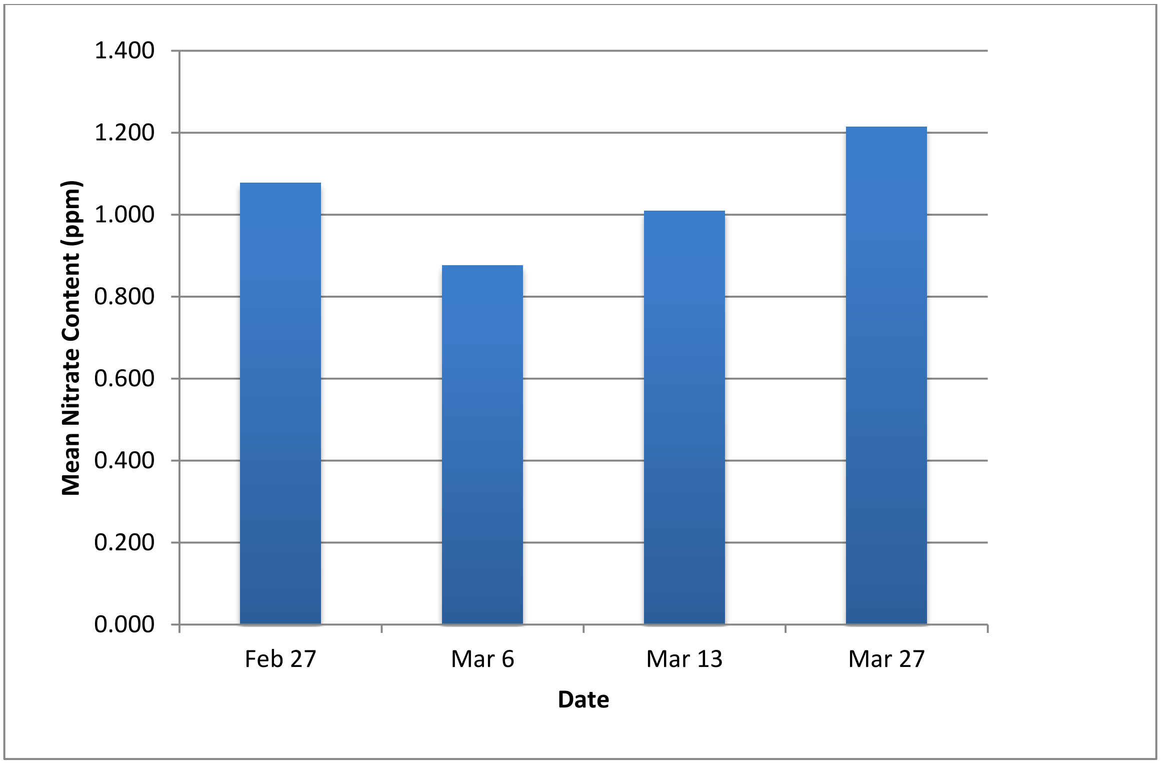

Figure 4. Mean nitrate concentration by days tested (PPM)

Discussion

In general, as water flowed from sampling point one to sampling point four (Fig. 3) there was a decrease in nitrate levels in the Villanova University Wetlands. Whereas nitrate levels depicted trends and information, phosphate levels were too low at all sampling sites to gather any meaningful data. The expected trend of nitrate was for levels to be lower at each successive pond as nutrients are filtered both through biotic and abiotic means. The data in this study confirms the expected results, and it can now be said with confidence that the constructed wetlands on campus serve as an efficient tertiary filter, removing roughly 53% of nitrates (Fig. 3).

Nitrate levels fluctuated between sample dates. Changes in nitrate inputs to the wetlands can most likely be attributed to weather or a form of increased anthropogenic pollution (Fig. 4).

Although it was beyond the scope of this study to know if there was an increase of nitrate inputs from the university or outside source, weather patterns can be analyzed to help determine reasons for fluctuations. On the final day of sampling, 27 March 2014, nitrate levels were highest at the first testing site with a level of 2.81 ppm. Over the course of the 2013-2014 winter, Villanova, PA received a very heavy snowfall much of which accumulated in the area surrounding the wetlands. In the two weeks days prior to 27 March 2014 the highs for the wetlands stretched from 1 ˚C - 20 ˚C and received 27.4 mm of rainfall (The Weather Channel, 2014). It can be speculated that, due to the changes in temperature and season, snow melt, rain, and runoff may have resulted in an accumulation of excess nutrients and have been responsible for the fluctuations. It was expected that the third day of sampling, 18 March 2014, which fell in the middle of this weather pattern, had higher levels of nitrates than the sample taken day two, 11 March 2014, and that both had lower levels than samples taken the fourth day.

On both the second and third day of sampling the nitrate levels rose between the third and fourth sampling points at the end of the flow path. Although the amount of nitrates leaving the wetlands was lower than what entered, this finding was surprising. Seeing as this only occurred on half the sampling days, and there was a drop in nitrate in this area the fourth day, this rise probably does not have to do with a lack of effectiveness in the filtration system itself. Reasons for this increase were not identified with certainty but one possible cause could have been discarded waste from humans. Pond three and four are adjacent to a pedestrian walkway, which may be an opportunity for trash and nutrient pollution. A second possible source may be the nitrates from the waste of various animals and birds that use the Wetlands for habitat.

It was concluded that the constructed wetlands could serve as an important filter at a variety of other locations. Not only could other universities construct a similar system to the one that was built on Villanova's campus, they could all but mimic the same system here to some effectiveness. Large shopping centers and malls have much waste from nutrients from human waste, discarded foods, and trash. A wetlands system could help remove many of the nutrients associated with these wastes. Not only could private sector and universities utilize this filtration technique but governments as well. Cities could build multiple wetlands throughout the city to filter out nutrients before the water returns to the main body of water running through it. Small municipalities such as Radnor Township or Lower Merion Township, which are local to Villanova, could construct wetlands to filter out nutrients before water heads to water plants or the Schuylkill and Delaware rivers. Wherever the wetlands are constructed it would not just filter out nutrients but provide a habitat for animals indigenous to the area like the one on campus has.

Artificially constructed wetlands have proven time and again to be an efficient, economically feasible way to filter out nutrient pollution, and prevent eutrophication in water systems. Eutrophication is prevalently a serious issue causing the deterioration of costal systems by causing hypoxia. The Chesapeake Bay seafood industry is just one example of an economy nearly destroyed by the effects of Eutrophication. Clearly, nutrient pollution, a type of pollution that is not only detrimental to aquatic ecosystems, but also hard to mitigate, is a growing problem.

In the future, demand for simple, economically feasible solutions to nutrient pollution will increase and currently, artificially constructed wetlands are one of the most promising solutions in terms of cost, being essentially free once constructed, and easy to mitigate and maintain.

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