THE EFFECT OF CATTLE ON WATER QUALITY OF AN AGRICULTURAL POND IN THE CHESAPEAKE BAY WATERSHED

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ABSTRACT

The Chesapeake Bay is currently polluted with excess nutrients entering via its watershed. Many of these pollutants come from cattle accessing streams or waterways part of the Chesapeake Bay watershed. To reduce pollutants entering the Bay, the government has proposed Best Management Practices, such as building a pond, as an off-stream water source. The purpose of our study was to determine if cattle access affects the water quality of agricultural ponds. We did this by comparing the water quality of two ponds, one impacted by cattle and one not impacted by cattle. We hypothesized that cattle would affect the water quality of the pond. We collected ten water samples from each pond on two separate occasions. We found the total dissolved solids, phosphates, and dissolved oxygen concentration levels were higher in the impacted pond than in the non-impacted pond. The concentration levels of nitrates were lower in the impacted pond than in the non- impacted pond. The results supported our overall hypothesis by showing that cattle affect water quality. Results suggest that using ponds as a Best Management Practice benefits the Chesapeake Bay by retaining most, but not all, of the nutrients, preventing them from entering the watershed and further polluting the Chesapeake Bay. Ultimately, we found that even though cattle do have a negative effect on the water quality of ponds, the ponds are still useful for farmers.

INTRODUCTION

The Chesapeake Bay is the largest estuary in the United States and is located on the east coast, surrounded by Maryland and Virginia. An estuary is where fresh water from streams and salt from oceans mix together. While the bay is home to oysters, fish, birds and blue crabs, it cannot support as much aquatic life it once had due to the abundance of pollution from the Chesapeake Bay Watershed. A watershed is an area where all of the streams and rivers drain to a single point. The Chesapeake Bay Watershed includes Maryland, Pennsylvania, Virginia, West Virginia, New York, Delaware and Washington DC (Fig. 1). The waterways within these states bring pollution and contaminates into the Chesapeake Bay when they drain together. Many people refer to trash when the word "pollution" comes up. But with our study, we are looking at water pollution, specifically excess nutrients.

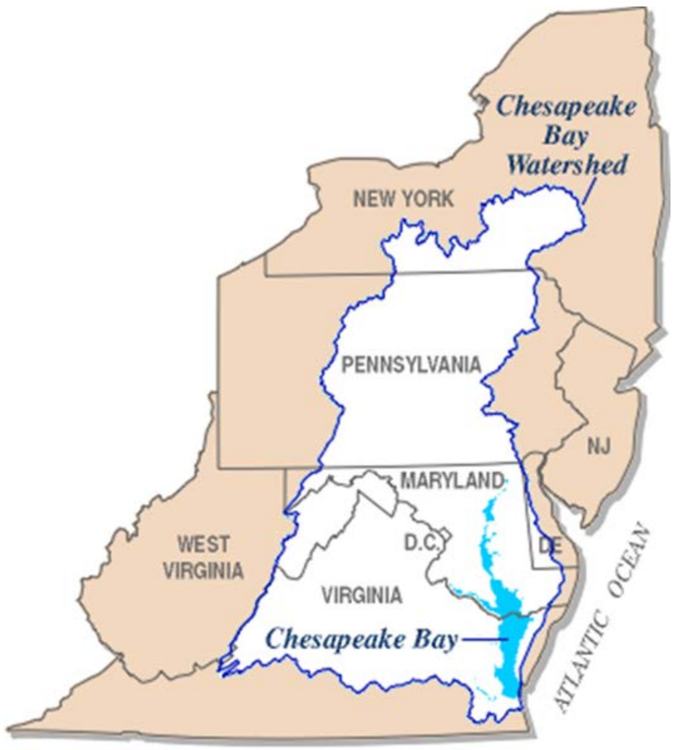

Fig. 1. - The Chesapeake Bay Watershed

Pollution entering the watershed comes from point-sources, such as factories, and pipe outflows, and non-point sources, such as runoff . There are nutrients and non-organic materials found in runoff that create nutrient abundances in the Chesapeake Bay (EPA, 2010). The nutrients include phosphates and nitrates; another type of pollutant is sediments (EPA, 2010). Sediments are pollutants that increase the turbidity of water, which blocks light and prevents photosynthesis of underwater plants. A decrease in photosynthesis results in lower levels of dissolved oxygen, which hinders the respiration of aquatic life.

Some sediments dissolve in the water to form dissolved solids, which can be harmful to fish and amphibians (Wynne, 1998). An abundance of nutrients can accelerate eutrophication in a body of water. Eutrophication is the process by which an aquatic ecosystem is enriched with nutrients. Enrichment of nutrients causes algae to bloom, grow, and decay at a higher rate. The decomposition of algae by bacteria depletes the dissolved oxygen in the water. This decrease in dissolved oxygen can result in the death of organisms that require oxygen to survive in the water. These areas of decreased oxygen are called dead zones, which have become prevalent in the Bay (EPA, 2010).

Agricultural pollution is a key non-point source of pollution and contains fertilizers and animal waste. The nitrates and phosphates in the fertilizers run into the soil and waterways, which eventually lead into the Chesapeake Bay (Hooda et al., 2000). Animal waste can enter runoff and flow to the watershed. This waste contains phosphate, nitrate, and dissolved solids, as well as harmful pathogens (Hooda et al., 2000). Phosphorus is necessary for the growth of algae and nitrates provide nutrition for the algae. These are the main nutrients responsible for eutrophication which causes the levels of dissolved oxygen in the water to decrease, resulting in dead zones- areas in the water where little to no oxygen is present and aquatic life is unable to survive.

The existence of dead zones in the Chesapeake Bay due to poor water quality caused the Environmental protection Agency to set a Total Maximum Daily Load. Total Maximum Daily Load is a calculation of the maximum amount of a pollutant that a body of water can receive and still safely meet water quality standards. States are required to find ways to meet the EPA standards. Maryland is enacting several new Nutrient Management Regulations in order to meet these EPA standards. One of these regulations specifically addresses cattle access to waterways. Beginning January 1, 2014 farmers are required to restrict livestock access to waterways by a minimum of 10 feet. This would help reduce the nitrogen, phosphorus and sediment pollution from entering the Chesapeake Bay.

Best Management Practices (BMP) have been recommended to provide farmers with the most efficient and environmentally safe methods of agricultural activity (Sheffield et al., 1997). The Maryland Department of Agriculture allows farmers to use BMPs to comply with the new regulation to restrict cattle access to streams. The process of fencing streams is considered a costly but effective method of keeping cattle away from streams (Sheffield, Mostaghimi, Vaughan, Collins Jr., & Allen, 1997). An alternative technique is vegetative exclusion (MDA, 2012), which keeps cattle from the streams by means of planting vegetation, such as trees and bushes, along the stream banks (Sheffield et al., 1997). These plants act as a natural, cost effective fence (Sheffield et al., 1997). The creation of cattle stream crossing locations is also a BMP (MDA, 2012). These facilities are designed to allow cattle crossing access through streams at designated locations, which gives cattle little room to pollute the streams (Sheffield et al., 1997). Providing off-stream water sources for livestock, such as troughs, has been shown to be an effective means of keeping cattle away from streams (Sheffield et al., 1997).

A commonly employed off-stream watering facility is an agricultural pond. An agricultural pond is a still body of water, smaller than a lake and below the waterline, often shallow enough for rooted plants to grow. What we are going to be looking at is if agricultural ponds are effective at reducing nutrients from going into the Chesapeake Bay by keeping cattle away from streams in a manner that is still beneficial to farmers. Ponds collect runoff which contains nutrients enriched from manure on pastures and plant fertilizers; ponds keep these nutrients on the farm and out of waters downstream, benefitting the Chesapeake Bay. For farmers, the collected runoff produces harvestable sources of nutritious soil that can be beneficial for future farming. Agricultural ponds can be a water source and can help with thermoregulation: temperature regulation for cattle (Sheffield et al., 1997).

Problems can arise from allowing cattle access to agricultural ponds. Agricultural ponds can develop an excess of nutrients and pollutants, some of which will eventually flow into the Chesapeake Bay. The process of eutrophication can take place in agricultural ponds if nutrients from cattle waste build up. An excess of nitrates in drinking water larger than 10 mg/L can cause sickness in humans (Wynne, 1998). An excess of nitrates in drinking water larger than 100 mg/L can cause sickness in animals such as cattle (Wynne, 1998). These problems with agricultural ponds could influence perceptions of whether agricultural ponds are a good best management practice or not.

We conducted the current study to determine if cattle access to ponds affects the water quality of the ponds and to explore whether building agricultural ponds is an effective best management practice for farmers. To do this we compared the water quality of two agricultural ponds on a farm in Garrett County, MD. The water quality was assessed with measures of phosphates, nitrates, dissolved solids, and dissolved oxygen. The phosphates and nitrates were measured to examine the nutrient pollution of the ponds. The dissolved solids were measured to examine sediment buildup. The dissolved oxygen was measured to assess the oxygen difference of the ponds as a result of eutrophication.

We tested the water quality of the impacted and non-impacted ponds because they are a part of the Chesapeake Bay watershed, and so affect the water quality of the Chesapeake Bay. The data we collected can benefit local Garrett County, MD farms as well as farms throughout Maryland. The site we chose has ideal conditions for our study. Both ponds were located on the same farm and were near each other. The ponds were similar enough in size and location that any differences in the variables we measured could be attributed to cattle access.

We had four specific hypotheses for the variables measured. The null hypothesis for phosphates was: there will be no difference in the levels of phosphates between the impacted and non-impacted ponds. The alternate hypothesis for phosphates was: there will be higher levels of phosphates in the impacted pond. The null hypothesis for dissolved solids was: there will be no difference in the levels of dissolved solids between the impacted and non-impacted ponds. The alternate hypothesis for dissolved solids was: there will be higher levels of dissolved solids in the impacted pond. The null hypothesis for dissolved oxygen was: there will be no difference in the levels of dissolved oxygen between the impacted and non-impacted ponds. The alternate hypothesis for dissolved oxygen was: there will be lower levels of dissolved oxygen in the impacted pond. The null hypothesis for nitrates was: there will be no difference in the levels of nitrates between the impacted and non-impacted ponds. The alternate hypothesis for nitrates was: there will be higher levels of nitrates in the impacted pond.

METHODS

Our study site contained two ponds: one with cattle access (impacted) and one without cattle access (non-impacted) on the Beeman Farm in Garrett County, MD. There was a barn and a farmhouse close to our study site. The study site was surrounded by a forest. The impacted pond was lightly wooded. The non-impacted pond was in a clear area of grassland 270 m from the impacted pond. There were no crops growing in the area around the ponds but there was a small garden uphill from the non-impacted pond; livestock grazing was the agricultural use of the impacted pond area.

The non-impacted pond (Fig. 2) was fenced off from the cattle. This pond was surrounded by mixed grasses, wild flowers, rush plants, and a few cat tail plants. There were trees on the southern side of the pond. There was a small dock at the pond. Two inlets ran into the pond from a spring 64 m away from the pond. The pond had one outlet opposite to the side with the inlets. The pond covered 839 m^2 of land and had a middle depth of 1.84 m. The non-impacted pond's watershed contained 0.04 km^2 of land. We observed that the pond contained minnows, salamanders, frogs, tadpoles, and snakes. There were dragonflies, butterflies, and water beetles present at the pond as well.

Fig. 2. - Sampling sites for non-impacted pond

The impacted pond (Fig. 3) was accessible to 15 cattle. There was unmaintained plant life around the impacted pond, and it was in a lightly forested area. There were various high grasses, weeds, bushes, and shrubs around the pond. The pond covered 672 m^2 of land and had a middle depth of 1.06 meters. The impacted pond's watershed contained 0.05 km^2 of land. The impacted pond had one inlet coming from a spring 32 m away and one outlet on the opposite side of the pond. The area around the outlet was marshy and swampy. We found cow feces close to the pond edges. We observed minnows, frogs, and snakes in the pond. Dragonflies, flies, and gnats were present at the pond as well.

Fig. 3. - Sampling sites for impacted pond.

We collected our data on two different days. The first data collection was on Friday, June 14th, 2013 from 10:20 a.m. to 11:50 a.m. We collected the water samples by dipping an 18 ounce Solo® cup attached with duct tape to a four meter bamboo stick into the water. We collected ten samples from the same locations in the ponds on both collection days as shown in figures 2 and 3. We used an inflatable boat to collect samples from the center of the pond. Each sample, except for the center samples, was taken four meters inside the pond. The first 20 water samples we obtained were placed in 50mL centrifuge tubes and sent to the University of Maryland Environmental Sciences Appalachian Laboratory for phosphate and nitrate measurements. The second data collection was on Wednesday, July 3rd, 2013 from 9:15 to 10:50 a.m. We collected water samples using the same methods and recorded the dissolved solids of the water samples using a TDS Testr1. We also recorded the dissolved oxygen levels of the samples using a Milwaukee SM600 Meter. The data from both collection dates were combined into one dataset for analyses.

We first compared our data collected from impacted and non-impacted ponds using graphs. These graphs give a visual representation of the data and can be found in figures three through six. We created error bars using 95% confidence intervals to visualize significant differences, if any, between the ponds. After examining the data, we tested for statistically significant differences in pollutant levels using a Student's T-test.

RESULTS

Overall, results showed significant differences in all levels of pollutants between the ponds (Table 1).

Table 1. - Average water quality measurements for ponds not impacted and impacted by cattle followed by standard deviation (sd)

Pond	Nitrate and Nitrite (mg/L)	Phosphate (mg/L)	Dissolved Oxygen (mg/L)	Total Dissolved Solids (ppm)
Non-Impacted	0.3478 (0.29)	0.01692 (0.055)	9.44 (0.34)	37 (4.83)
Impacted	0.01354 (0.007)	0.06136 (0.007)	11.23 (0.58)	70 (0)

There was a large difference in the phosphate levels between the two ponds (Fig. 4). The impacted pond had phosphate levels more than 3 times greater than the non-impacted pond ($p < 0.001$).

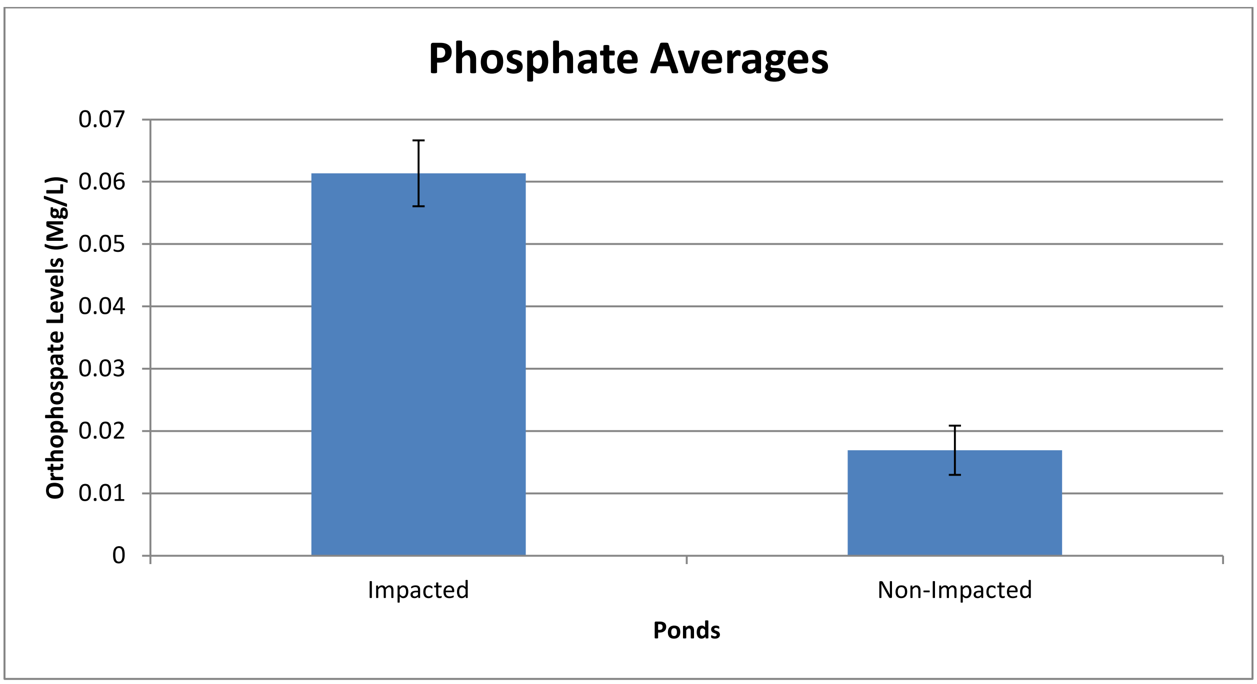

Fig. 4. - The average phosphate levels in the ponds.

The average TDS level of the impacted pond was 70 ppm, which was 33 ppm greater than the average total dissolved solids of the non-impacted pond (p < 0.001; Fig. 5).

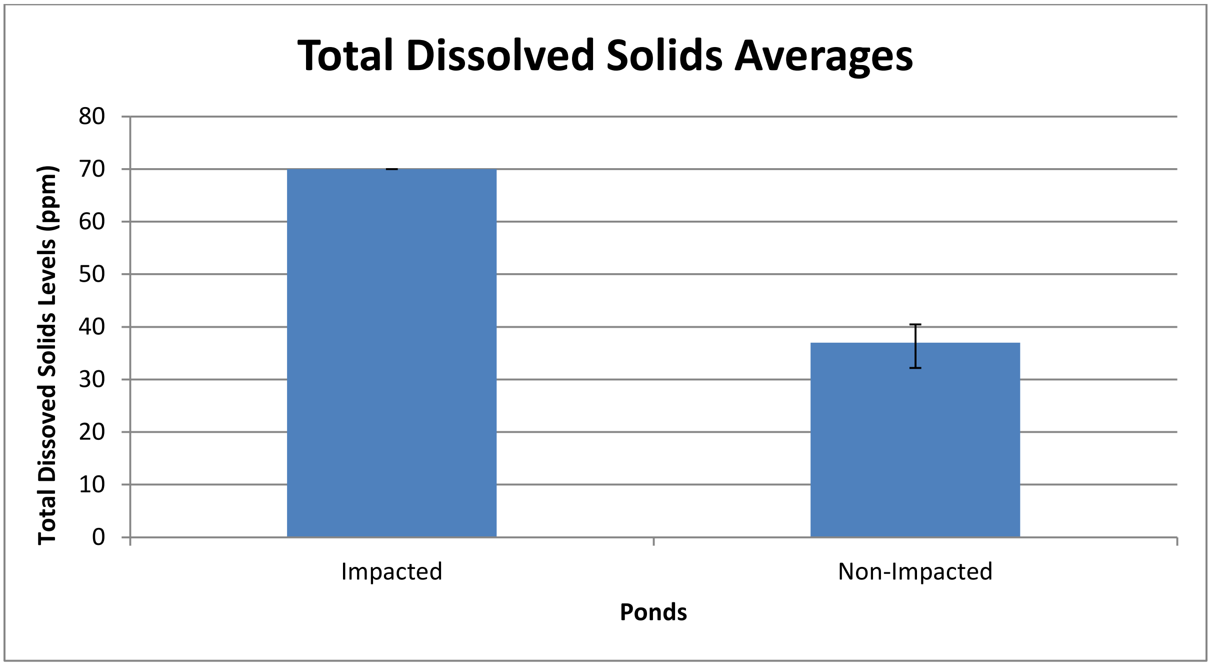

Fig. 5. - The average levels of total dissolved solids in the ponds.

The difference in the levels of DO between the two ponds is not as great as the differences in the levels of other variables we measured, but it was statistically significant (p < 0.001; Fig. 6).

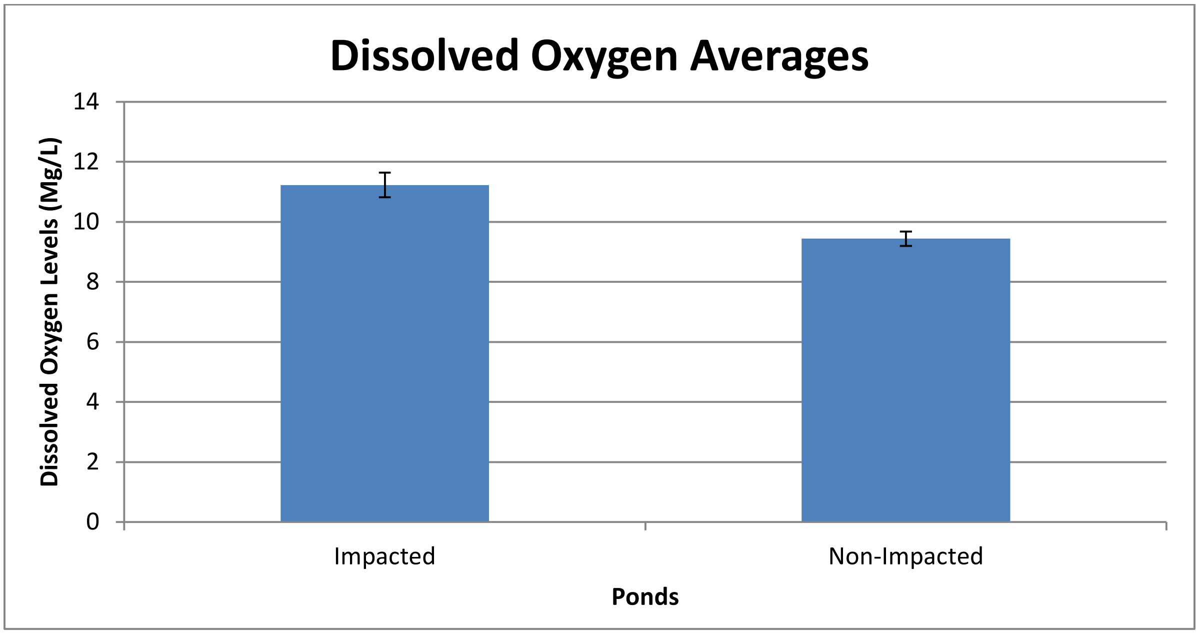

Fig. 6. - The average dissolved oxygen levels of the ponds.

The levels of nitrates in the non-impacted pond varied greatly so it had a larger confidence bar (Fig. 7). The average nitrates level of the impacted pond was 0.01354 mg/L which was 0.33426 mg/L less than the average for the non-impacted pond (Table 1). The levels of nitrates were more than 25 times higher in the non-impacted pond ($p < 0.001$).

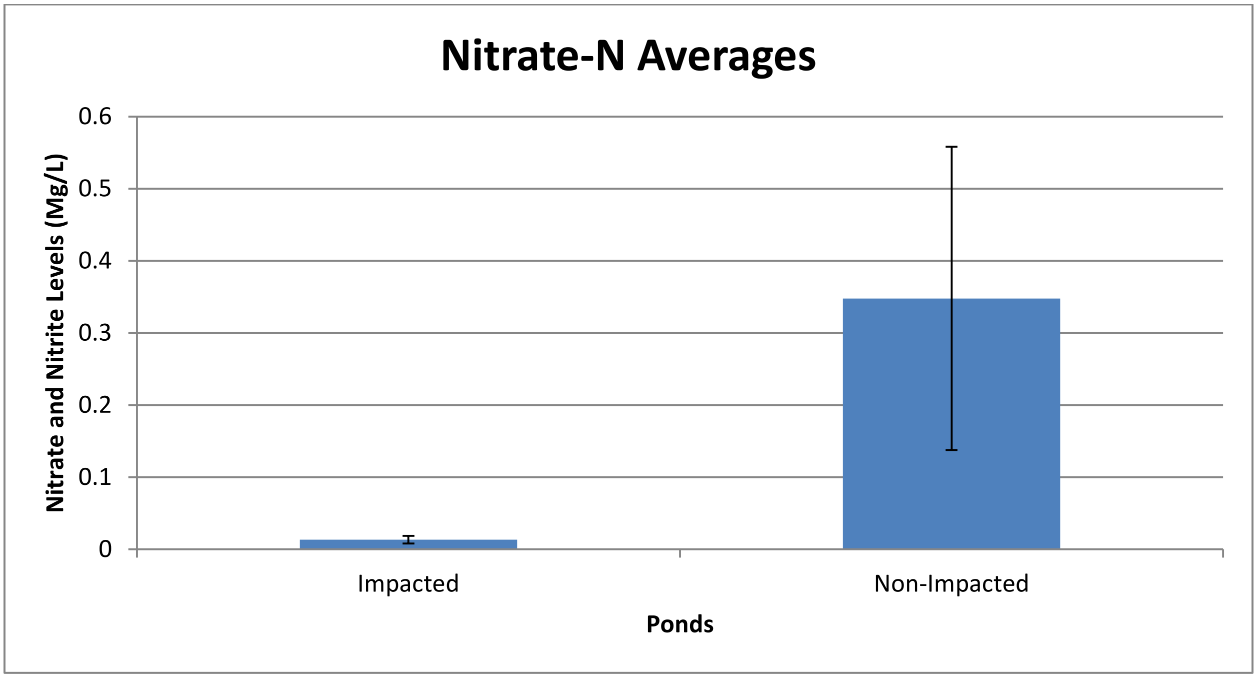

Fig. 7. - The average nitrate levels in the ponds.

DISCUSSION AND CONCLUSION

Our results indicate that the water quality of the ponds was affected by the cattle access, supporting our overall hypothesis that cattle access does affect the water quality of the cattle impacted pond. Our data showed significant differences in the levels of phosphates, nitrates, total dissolved solids and dissolved oxygen between the two ponds.

Our results showed that the pond impacted by cattle had higher levels of phosphates than the non-impacted pond (Fig. 4). We rejected our null hypothesis which stated that there would be no difference in the levels of phosphates between the two ponds and we accepted our alternate hypothesis which stated that there would be higher levels of phosphates in the pond impacted by cattle. Our study was conducted during the growing period of algae; during this time the algae do not absorb phosphates. The higher levels of phosphates in the impacted pond may also be related to cattle having access to the pond and walking along the banks of the pond, eroding the ground. The erosion loosens the soil and sediment washes into the pond. Phosphates are primarily transported in particulate forms (Hooda et al., 2000), which means they stay bound to sediments. The sediment-bound phosphates wash into the pond as a result of cattle initiated erosion and increase the levels of phosphates in the pond. Also the cattle defecated in and around the pond, releasing phosphates in the water from their feces.

The data we collected shows that the levels of total dissolved solids were higher in the non-impacted pond (Fig. 5). We therefore rejected our null hypothesis that there would be no difference in the levels of total dissolved solids between the two ponds and accepted our alternate hypothesis that there would be higher levels of total dissolved solids in the cattle impacted pond. This could be a result of cattle walking along and eroding the banks of the pond, causing sediment to run into the pond. Additionally cattle feces in the pond could increase the amount of total dissolved solids.

We found the levels of dissolved oxygen were higher in the cattle impacted pond (Fig. 6). Thus we rejected our null hypothesis which stated there would be no difference in the levels of dissolved oxygen between the two ponds and we rejected our alternate hypothesis which stated that there would be lower levels of dissolved oxygen in the cattle impacted pond. These findings could be due to the time of year we tested the ponds. Our water samples were collected during the algae growing season. During this time the algae were alive and releasing oxygen into the water. The impacted pond had a large amount of algae in the water and that could have contributed to the higher levels of dissolved oxygen in that pond. When the algae eventually die after absorbing all of the nutrients, or from cool water temperatures, we expect the dissolved oxygen levels to decrease.

Our results revealed that the nitrate levels were higher in the non-impacted pond (Fig. 7). We rejected our null hypothesis that there would be no difference in the nitrate and nitrite levels of the two ponds. We also rejected our alternate hypothesis which stated that there would be higher levels of nitrates in the cattle impacted pond. During the algae growing period, algae consume more nitrates. Therefore, the nitrate levels of the impacted pond would be lower due to the large amount of algae growing in the pond.

The purpose of our experiment was to determine if cattle access to ponds affects the water quality of ponds which are used as a Best Management Practice by farmers to keep cattle out of waterways. One use of ponds is keeping pollutants out of the Chesapeake Bay. When cattle defecate in the ponds, they release nutrients. Those nutrients then promote algae growth. The algae eventually die. The dead algae along with sediments and nutrients then end up at the bottom of the pond. As a result, when cattle use ponds instead of streams, fewer nutrients enter the Chesapeake Bay. We conclude this pond is an effective way to reduce pollutants entering the Chesapeake Bay.

Another use for ponds is as a habitat for fish and other wildlife. The cattle impacted pond we tested contained 11.23 mg/L of dissolved oxygen (Table 1). Water quality standards of dissolved oxygen for fish culture are above 5mg/L (Wynne, F. 1998). This shows that the cattle impacted pond contained enough dissolved oxygen for fish to live in. The impacted pond's levels of total dissolved solids were 70 ppm (Table 1) and the standard for fish is <400 mg/L (Wynne, F. 1998). The impacted ponds levels of total dissolved solids met the standards for fish. The standards of nitrates for fish are from 0 – 3.0 mg/L (Wynne, F. 1998). The impacted pond contained 0.01354 mg/L and met the standards (Table 1). We concluded that agricultural ponds are still useful as a habitat for fish. They are also useful as a habitat for other wildlife such as snakes and frogs, which we observed while at the pond.

Agricultural ponds are also used as a water source for cattle. One method of determining if the water in a pond is safe for cattle consumption is by looking at the nitrate levels because they are a potentially toxic substance for livestock. The recommended concentration limit of nitrates is 110 mg/L (Wynne, F. 1998). The cattle impacted pond we tested contained 0.01354 mg/L (Table 1), which is well below the limit. This pond is still useful for cattle as a source of drinking water as well as a place to cool down.

There were several limitations of our study. One limitation was time; we collected data only on two days at the beginning of the eutrophication process, which was while the algae were growing. If we had sampled before the algae started to grow, nitrate levels may have been higher in the impacted pond than our results show. By sampling through the entire eutrophication process, we could have a better understanding of how cattle impact pond water quality at different stages of eutrophication. Another limitation was the difference in water volume between the two ponds. The impacted pond’s lower volume could explain why it had higher concentration levels considering it would be less diluted. This is limiting because the non-impacted pond may not be classified as the best control. Additionally, not testing the inlet or outlet flow rate of the two ponds was another factor that limited this study because if the flow rates between the two ponds were significantly different, this could be another difference between the two ponds other than the impact of cattle.

In light of the limitations of our study, future studies should be sure to take a more representative sample of agricultural ponds. This will help validate the study. Future studies should also examine more variables that affect water quality, such as ammonia, barium, mercury, and sulfate, to see if there are differences in the levels of those variables. Additionally, future studies should examine natural causes of nutrient variation, such as soil type, decomposing materials, and wildlife outputs.

Our research shows that cattle have an impact on water quality; and a future study could expand on our findings and examine how cattle specifically impact fish in ponds. Future researchers could also examine how results change when multiple testing sites are added, and how the amount of time cattle spend in ponds affects the water quality of those ponds.

In summation, we found support for our hypothesis that cattle have an impact on the water quality of agricultural ponds and have offered suggestions for future research to examine this in further detail. Overall, we concluded that agricultural ponds are an effective means of keeping pollutants out of the bay; cattle impacted ponds are still useful for farmers and are an effective best management practice.

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