Analysis of Water Quality at Marion County Lake

Josh Ward, Jason Leftwich, Kohlton Voboril, and Adelaide Manica

Kansas State University

Fall 2022

Table of Contents

Introduction

Marion County Lake is in central eastern Kansas, southwest of Marion, Kansas. We chose this location for a variety of reasons. It provided a convenient location for monitoring water quality, and this lake has also been having issues related to water quality. Algae blooms have been a recurring issue for the area and the subject of many research studies. For this study, we wanted to analyze water quality for higher levels of nutrients such as phosphorus, nitrogen, and total dissolved solids to analyze the impact of agricultural runoff on Marion County Lake. Our main objective of this research project was to analyze, locate, and single out the nutrient levels in different quadrants of the lake. This allowed us to take data from various locations to compare them.

In a lake system there are two zones. The top part is called the euphotic zone where the sunlight penetrates which is high in light, temperature, and oxygen; it is warmer and allows the water to mix, so photosynthesis is high. The bottom part is called the aphotic zone. It is high in nutrients, but the water is dense with little mixing, and nutrients accumulate. During the different seasons of the year, there is a thermal stratification where the water and nutrients at the bottom of the lake flip from the bottom to the top, mixing everything.

Another interesting fact about water is that it is a good solvent. Water helps in dissolving compounds, making it a good transport medium, which will affect its salinity and pH or hydrogen ions. In an aquatic system, salinity will affect the organisms within the water system in osmoregulation. Gases work similarly in both the atmosphere and aquatic systems, just more slowly in aquatic systems. If CO2 were to dissolve in an aquatic system, the bicarbonate released may be good for the organisms, but it would also make the water more acidic as well.

In an oligotrophic system, the iron in the lake is oxidized in the aerobic environment and binds to the phosphorus, making it insoluble or non-mobile.

Importance of Water Resources

Water is a critical resource for all living things, and it is important to have clean water to maintain a healthy ecosystem. We use water in the agriculture world to keep providing food on people's plates. We also use water in many ways every day, and it can be wasteful, therefore we need to find ways to reuse the water. Sustainable water is the combination of sustaining the natural environment, resources, and community. We meet standards to provide drinking water, drainage, urban agriculture, and recreational needs. To protect the water, we want to reuse the water as much as possible whether that is reusing water for drinking for humans or for plants.

Problems

Even though we need water in our everyday lives, there are problems with natural water supplies. Only three percent of the earth's water is freshwater and of that three percent, a lot of the water is frozen and non-accessible. Another problem with freshwater in the United States is the sediments, nutrients, and chemicals that can be moved with the water. Nutrients are important for any ecosystem but also for an aquatic ecosystem. Nutrients come into the lake from the land around it. Every time it rains the land around soaks up the water, but it still needs to flow somewhere since it makes its way through the soil. The water is then put into streams which lead to bigger bodies of water like lakes. As a stream flows into a lake, it contributes to the lake's nutrient intake. This affects the usage of freshwater and the aquatic ecosystem further downstream.

Marion County Lake

Marion County Lake is southeast of Marion, KS, on the western edge of the Flint Hills. The lake's dam was built in 1937 and opened to the public in 1940 that consists of 153 acres of water and is surrounded by 300 acres of parkland. A creek that starts in Mcpherson County and goes through Marion County ends up in the Marion County Lake. The water is contained in the lake and eventually let out in the Cottonwood River. This causes problems for the water quality of Marion Lake because of all the sediment, nutrients, and chemicals being moved with the water.

Agricultural Runoff

Agricultural runoff consists of several nutrients and minerals. By far, the most common identifiers of agricultural runoff are higher levels of nitrogen and phosphorus (Li 1). These are common elements found in fertilizers and pesticides, and when found in bodies of water, they are indicative of agricultural runoff (Li 1). When these nutrients are in excess in a body of water, they can cause serious complications. The main complication being the growth of algae blooms which have various impacts on water. They use oxygen from the water which depletes nutrients beneficial plants and animals could be using. They also decrease aesthetic appeal and can potentially be dangerous. Toxic algae can cause sickness in humans and animals and can cause serious side effects for ecosystems and environments.

Nutrients

Phosphorus is the pollutant most responsible for water contamination globally. One of the main reasons for this is the ease of transport through soil. Phosphorus transports very easily through soil, in fact most phosphorus travels through the soil and then leaches into water sources. Couple this with other methods of agricultural runoff and phosphorus is the main water pollutant (Akhtar 38). Like phosphorus, nitrogen is present in fertilizers which are then washed into tributaries and water bodies. In small quantities, nitrogen is beneficial to help plants grow, however too much nitrogen can cause increased plant growth. As we saw with phosphorus, excess nitrogen causes the growth of algae blooms. These algae blooms can cause decreased dissolved oxygen content in the water, inhibiting beneficial plant growth and biodiversity. Nitrates are also compounds that can affect water quality. Nitrate is a compound of nitrogen with oxygen and is found in insecticides and feedlots. Nitrates, like nitrogen, can lead to a decrease in dissolved oxygen. The less dissolved oxygen in the water, the fewer plants and animals can live in the aquatic ecosystem.

Eutrophication

The loss of dissolved oxygen is incredibly dangerous to biotic organisms. Too much loss of dissolved oxygen and a high concentration of other nutrients can quickly turn into eutrophication. Eutrophication is a stage of pollution where algae blooms and other harmful plants thrive, and an overabundance of other nutrients keep beneficial bacteria and life from forming. Eventually, a dead zone can form where the ecosystem can no longer support life (Kumar et al 597-598).

Causes of Runoff

The main cause of agricultural runoff is rainfall. Farmers spray their fields with pesticides, insecticides, or other chemicals. When it rains, the chemicals are then washed away and end up in tributaries and bodies of water. Another factor that can add to runoff is erosion. The chemicals and nutrients soak into the ground. Sometimes soil erodes or is washed away by rain or wind. When this occurs, the chemicals and nutrients in the soil then end up in the water sources. Permeable surfaces are a factor that can affect levels of runoff. Permeable surfaces reduce runoff by keeping agricultural products from running directly into water sources. If the product is applied to a solid surface, the excess material will run from the surface and directly to water, adding pollution and contamination (Akhtar 41).

Cyanobacteria

In recent years, Cyanobacteria, once called blue-green algae, and are photosynthetic bacteria, have dominated eutrophic water sources worldwide. Eutrophic bodies of water are called so because they are nutrient rich, rich with nutrients such as nitrogen and phosphorus. Eutrophic is also associated with anaerobic environments, the iron in the lake is reduced which does not bind with P, leaving the P in its mobile form. Another thought process of how eutrophication works is:

1. Nutrients leach into the lake
2. Algae grow
3. Algae die and sink to bottom
4. Algae decompose and reduce oxygen levels
5. The algae also produce toxins
6. Fish die from lack of oxygen and toxins are mixed with water

There are many potential uses for cyanobacteria. There has been some research on using cyanobacteria as a green renewable energy source by the Department of Energy. There has also been at least some focus on other uses for cyanobacteria, including environmental development and sustainable agriculture (11). The article talks about how cyanobacteria could be used as a bio-fertilizer, that farmers over irrigate, and over till their soil. The article does not state how cyanobacteria would be used as bio-fertilizer. The most obvious way to utilize cyanobacteria as a fertilizer would be to irrigate with it. There has not been much research on the best way to set up a pump site. One way would be to use a river-screen set-up, or a stationary floating pump and at what depth it would work best at. Since cyanobacteria has proven they cannot yet be eradicated; it might be possible to reduce enough of it, so it does not have as strong an impact. A water sample could be taken to measure the N and P concentrations in ppm. They would be much less applied to a field, based off average irrigation use. The cyanobacteria could be thought of as an aquatic cover crop, as they are preventing the mobile nutrients from moving around or floating to the bottom of the lake. Some of the other potential uses mentioned in the article include using cyanobacteria as bio-control agents against plant pathogens (reduces plant diseases), plant growth promoters, reclamation of salt/sodium-infected soils, increase soil organic matter, and food supplements.

Water Testing Methods

Important Factors

One factor that stood out was in Pothig et al. (2010) which indicated that the soil content of Phosphorus from agricultural use could leach into water supplies and become available to algae. Overwhelmingly, the nutrients in question were N and P, and no interest was shown in K, a nutrient we had hypothesized could be influential. Another study (Giorgio et al.) measured diatom abundance and diversity as indicators that correlate with eutrophication. This choice emphasized the need and potential to approach ecosystem issues at an ecosystem scale instead of focusing on the bare basics. Liu (2017) approached the problem with a unique perspective, studying which nutrient was the limiting factor in his study area, again looking at N and P as causes and Chlorophyll-A as a reliable measure of eutrophication.

Common Methods

Recurring methods include soil or groundwater samples (Pothig et al, Meinikman et al.), remote sensing of water color (Moore et al, Alvarez et al), and manual water sampling and analysis (Liu, Giorgio et al.). These methods all had different advantages. Groundwater and soil samples were the only way that I found to analyze soil and aquifer contents. Remote sensing has some unique advantages as well. Wider swaths of time can be examined at the same time, depending on the database used for remote sensing. The visible nature of remote sensing could also make it easier to communicate and interpret for laypeople. Manual water sampling provides the ability to run different tests and have samples of the water itself on hand in the future if further investigation is needed during the study. The methods used were tailored toward the question or problem the research team was approaching and a good combination of methods could help most studies gain footing.

Research

Sites

To determine locations for testing, satellite images and maps of previous studies were examined. Allen et al (2018) completed a similar study at Marion County Lake. By looking at previous teams' collection sites, it was possible to use them as a reference for current data collection (Figure 1)

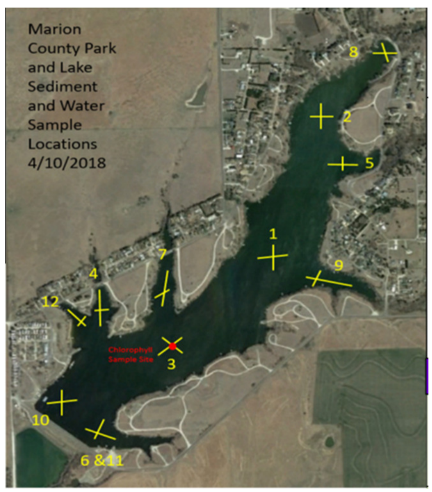


Figure 1: 12 sites selected to test for water quality at Marion County Lake by Allen et al in 2018

For the current study, six sites in the lake and three sites in readily accessible tributaries were selected for water sampling (Figure 2). The option for soil sampling also offered insight, so the team was prepared to take soil samples in conjunction with the tributary sites. The tributary and soil samples were not collected due to prohibitively dry conditions.

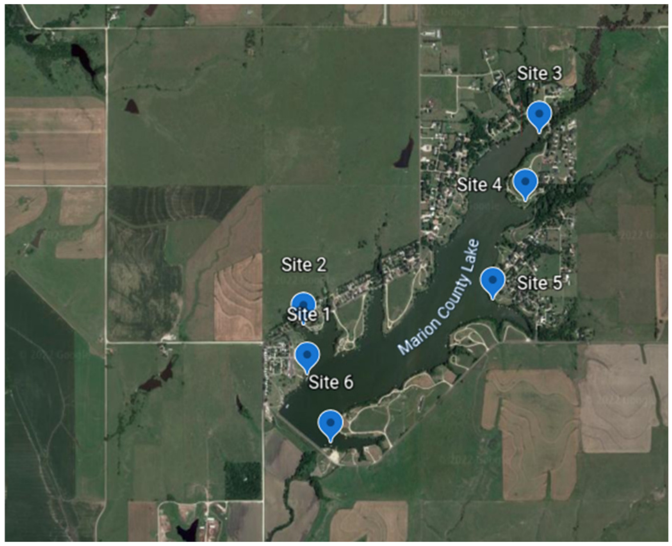


Figure 2: Six sites selected to draw water from to test nutrient loads in Marion County Park and Lake

Method

A dipper was used to extract water from the lake, and two 100ml samples were labeled and stored in a cooler for later testing. At the same time, a SONDE EXO was used to measure Chlorophyl A, Oxygen saturation, conductivity, temperature, and turbidity. At the time of sampling, the collected samples were tested using a pH strip. The lake sites were all tested without significant issue, but the locations determined along the tributaries could not be sampled. No visible water was available in the tributaries, and the soil was dry and rocky. These conditions might have been expected but did prove prohibitive to sampling by the means the team had available.

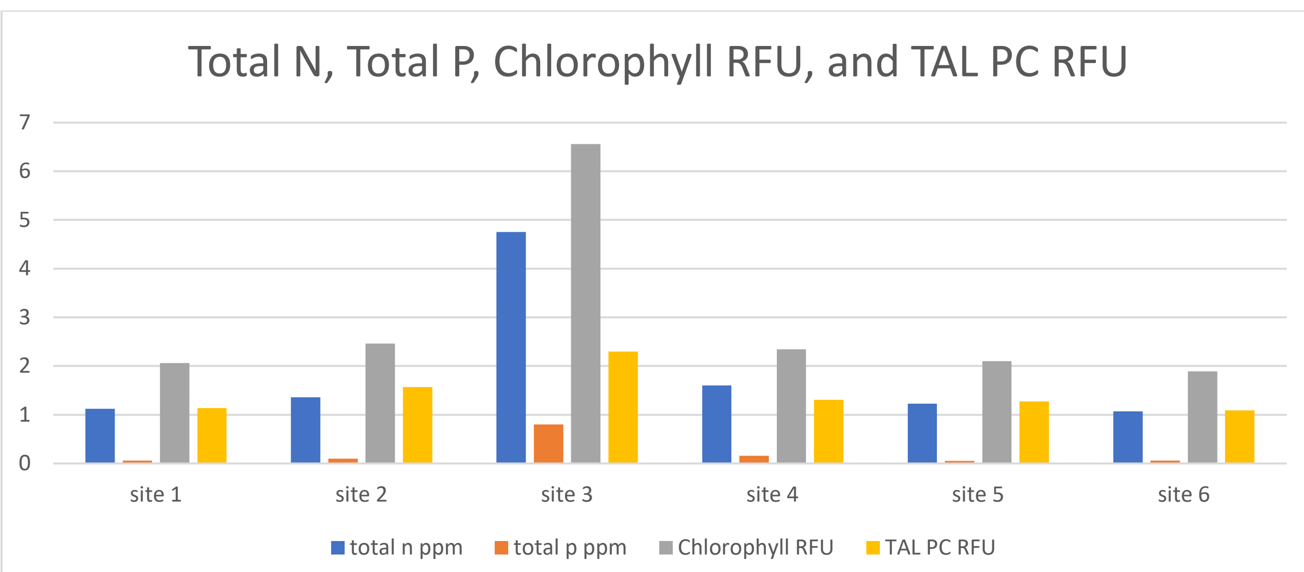
After the samples were collected, they were brought back to K-State campus to be tested further. One of the two samples was given to the KSU (Kansas State University) soils lab to be tested for total N, total P, NH4 N, NO3N, ortho P, and K. A total suspended solids analysis was conducted on the second of the two samples from each site. To determine the total suspended solids in each sample, the water was drawn through a filter using a vacuum pump. The filter was then dried in an oven to remove the water and the dried filters were weighed. To acquire total suspended solids in mg/L, the weight of each filter was subtracted from the total weight after the test. This yielded a mg reading, which could be divided by the sample size in Liters. This data was then compiled into a spreadsheet to be reviewed.

$$TSS\left(\frac{mg}{L}\right) = \frac{Dried\ filter\ weight\ (mg) - unused\ filter\ weight(mg)}{Sample\ size\ (L)}$$

Data

Background research demonstrates that N and P are often limiting factors for algal growth (Liu 2017). Chlorophyll A is an indicator of algal growth connected to the health of a water body. These three are compared below, showing that all three increase and decrease in similar magnitudes from site to site (Figure 3). Chlorophyll A is depicted as an average of six readings taken at one-minute intervals. The SONDE also measured TAL PC RFU, a measurement of cyanobacteria pigmentation in the water. This measure follows the same trends as the other metrics, with less exaggerated changes.

Figure 3: Nutrient loads compared to indicators of algal and cyanobacterial presence



Our results are comparable to some testing done in 2018 by Allen et al, with several locations matching and testing for some of the same variables (Table 1). All three matching variables, TSS, total N, and total P had increased between 2018 and 2022. Complete 2022 data is shown in Table 2.

approx. sites old/new	total n ppm	total p ppm	TSS
12/**2**	0.73	0.01	8.6
8/**3**	1.54	0.17	155.0
5/**4**	0.81	0.02	13.4
9/**5**	0.81	0.03	10.6

Table 1: Data from the 2018 study with comparable 2022 site names indicated in bold.

	total n ppm	total p ppm	Chlorophyll RFU	TSS	ODO % sat	Cond µS/cm	Turbidit y FNU
site 1	1.12	0.06	2.06	20	78.25	229.03	9.48
site 2	1.36	0.10	2.46	46	89.22	232.7	24.83
site 3	4.75	0.80	6.56	858.95	97.53	297.03	128.81
site 4	1.6	0.16	2.34	65	103.53	251.8	23.41
site 5	1.23	0.05	2.1	10	94.22	235.68	9.07
site 6	1.07	0.06	1.89	15	75.97	229.12	10.49

Table 2: Relevant data from the 2022 study conducted by this team.

Discussion

To start, we analyzed the pH at the 6 sites at the lake, but there was not much difference between them. As there are over 80 distinct species of cyanobacteria, they all have different preferences for an ideal pH. The only way to control pH would be to control it, because it would come from runoff into the lake.

The Total Suspended Solids is any type of solid that can pass through a filter around the size of 2 microns. And the type of solids can be anything from soil particles, nutrients, and even organisms like plankton. TSS measurements are like turbidity measurements. As turbidity measures the amount of light that gets reflected.

As far as sampling goes the only irregularities would be site 3, but as it is the furthest upstream site, it may have the largest watershed/runoff area. It had the highest nitrogen and phosphorus concentration, which would explain why it had the highest concentration of chlorophyll fluorescence or RFU (relative fluorescence units). The amount of chlorophyll in an area is a measurement of the amount of cyanobacteria in the area. It would also explain why Site 3 has the highest concentration of TSS and has the highest turbidity.

Optical Dissolved Oxygen or ODO measures the amount of dissolved oxygen, with the higher concentration of RFU, it would make most sense that then that Site 3 have the least amount of dissolved oxygen, though it has the 2^{nd} highest concentration of dissolved oxygen. But there are a couple of other factors that play a hand in dissolved oxygen as well. As temperature, altitude, and salinity increase, the dissolved oxygen decreases.

Conductivity of a lake measures how well a body of water can pass an electrical current through it, the higher the number correlates to the more polluted the body of water is. It can also indirectly measure the salinity, salt, dissolved solids, ion/pH concentrations. If we were to analyze Site 3 again, where it has the highest conductivity, this part of the lake would be considered the most polluted.

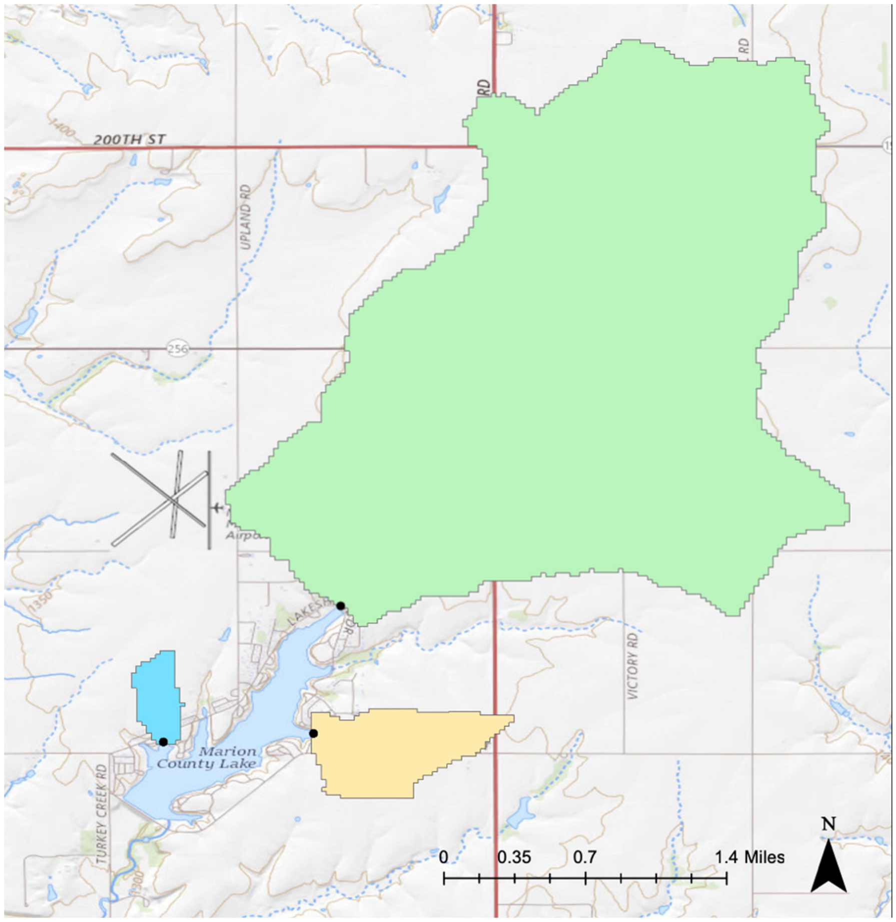


Figure 4: Delineated sub watersheds from Stream Stats for sites 2,3, and 5

Table 3: Land cover use and drainage area for sub watersheds for sites 2,3, and 5 as classified from Stream Stats

	Site 2	Site 3	Site 5
Drainage Area (sq. mi)	0.07	4.33	0.24
Cultivated Crops and Hay (%)	0	31.44	36.78
Developed Land	13.6	7.88	12.9
Forested Land	0	1.043	0.862
Herbaceous Land	80.58	59.01	46.55
Impervious Land	4.18	1.02	2.3
Open Water	5.83	0.34	1.58
Wetland	0	0.28	1.29

This table (table 3) highlights several types of land cover and land use in the watersheds surrounding some of the data points. Some interesting points are the percentage of land dedicated to cultivated crops and hay, and the impervious land. Referring to figure 3, site 3 had much more nitrogen and chlorophyll than the other sites. This could be due to the amount of cultivated land. Generally cultivated land is sprayed with insecticides, so it makes sense that a point with a large drainage basin, a high percentage of cultivated crops, and an elevated level of impervious land would result in higher levels of these nutrients.

Prevention Methods

Modeling

The National Park service has been using different modeling methods to track sources and sinks of pollution. Using these models, experts can track which pollution contaminants are coming from which area of land (Pericherla et al 831). When models like this are employed and sources of pollution can be identified, identifying prevention methods is made much easier.

Using remote sensing to explore the connection between land use and water quality is a new way to analyze interactions between land and water quality. Plotting areas of land used for different purposes and then analyzing the water quality nearby can help professionals understand which type of land use has the most impact on water quality and pollution (Cheng et al. 56902).

Constructed wetlands are one way to help mitigate agricultural runoff. An article by Li et al suggests that gravel, zeolite, and slag are the most successful materials at mitigating agricultural runoff. The review suggests that the smaller particle size, the better it is at absorbing phosphorus and nitrogen. Creating wetlands or rain gardens with beds made of these materials can help mitigate runoff before it reaches a source of water (Li et al. 27)

Knowing what soil type is around a water source can mitigate runoff as well. For instance, sandy soils will have a lower Cation Exchange Capacity than a more clay soil type, which is the type of soil that is found around most rivers, at least in the Republican River Valley. As a soil type has a lower CEC, the lower amount of cation sites it will have, so it would be even more important that type of soil if used in production, that it receives split shots of nutrients or soil-applied herbicides instead of everything at once.

Regulation

A secondary prevention method was suggested by Stoyanova. Stoyanova suggests that the solution lies in political policies. If individuals are left to their own decisions, they will not make decisions that are in the best interest of the environment. This article suggested that one method of preventing agricultural runoff would be to enact policies that would mitigate water contamination (Stoyanova 117).

Another suggested policy was to strictly monitor and regulate the use of chemicals, pesticides, and insecticides. Some of these substances already have restrictions or bans in place but adding more or intensifying punishments for violating these regulations could serve to increase the effectiveness of these measures (Akhtar 6).

As of July 2022, the Environmental Protection Agency has been taking in comments for restrictions on atrazine and is likely to set a 2 lb. limit on the amount that can be used in a year. Most farmers have switched to an herbicide that utilizes dual sites of action which might include atrazine, an inhibitor of photosynthesis at photosystem II site A, and acetochlor which is a mitosis inhibitor. However, it is probable the farmers that have been using atrazine alone will continue to make weeds that are more resistant to it, like the problem that farmers currently face with Palmer Amaranth.

Education

Education and training are proven to help people value ecosystem resources more. One suggested mitigation method was a training course on reducing runoff so farmers and agricultural workers could effectively use technologies and knowledge to prevent water pollution as much as possible (Stoyanova 117). Effective use of nitrates and fertilizers and/or pesticide is one way to definitively reduce runoff and learning how to use these chemicals properly is essential to protect watersheds.

Continuing with the education method, Chow et al suggests a different approach to fighting water contamination. Rather than focusing on education of ethical practices regarding agricultural chemicals, Chow et al suggested education in the importance of water resources. This approach focuses on education of renewability and the impact water can have on the environment to help farmers and agricultural workers understand the importance of using ethical practices. Once the importance of these resources is understood, the workers will be more willing to accept and implement environmentally ethical practices in their fields (Chow 37).

Further Research

There are several ways this research could be extended. There are still questions surrounding water quality that could be investigated. While this research was focused on agricultural runoff, there are other types of runoffs that affect water quality that could be investigated.

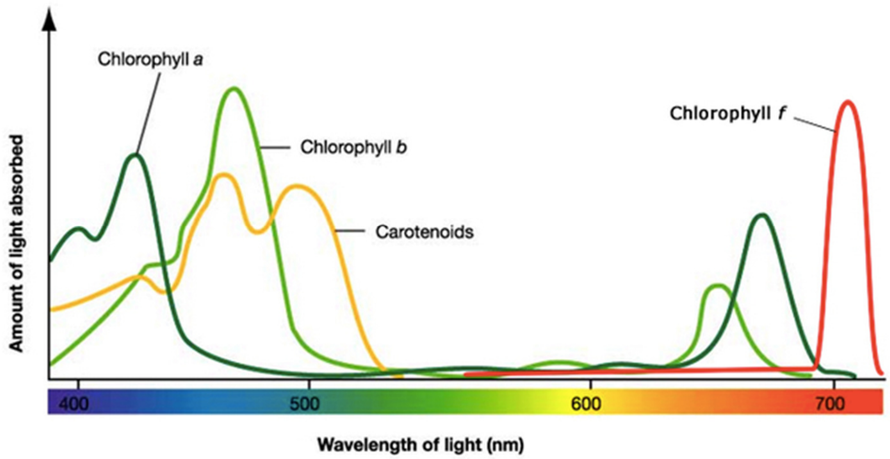
We focused purely on agricultural runoff, however there are multiple types of runoffs. Runoff from other anthropogenic activities such as factories or urban areas also affect water quality. There is some crossover between the chemicals emitted from agricultural activities and urban areas, however there are also unique signatures from the different activities. The effects of these activities would be interesting to investigate further.

Another avenue to explore would be the effects of the previously mentioned preventative measures. It would be interesting to analyze water quality before and after making changes that would reduce pollution due to runoff. Analyzing the value of permeable surfaces, rain gardens, and the like would be an interesting question to analyze.

Alternatively, while we analyzed impacts on water quality, it would be interesting to look at the impact runoff has on the biotic organisms at Marion County Lake. We know the general impacts: how eutrophication causes the death of plants and animals in the ecosystem but collecting data for this question would be interesting to analyze.

Cyanobacteria, algae, and plants can process red light through photosynthesis or photosystem II with chlorophyll-a. Red type absorbs light at 660 nm and far-red type absorbs light at 730nm. Another way of putting it is that photostem I absorb light at the wavelength at or greater than 680nm, and photostem II absorbs light at or less than 680nm. There are 2 types of cyanobacteria that can perform this reaction with far red-light using chlorophyll-d, which is resilient to photodamage, and chlorophyll-f, which is also efficient in light usage. *Acaryochloris marina* utilizes mostly chlorophyll-d and *Chroococcidiopsis thermalis* utilizes all 3 types of chlorophyll (7). Cyanobacteria are also unique in that they not only acquire energy via photosynthesis, but they can also obtain energy via respiration, as they can metabolize nutrients like nitrogen and phosphorus. Cyanobacteria are also nitrogen fixers. They perform oxygenic photosynthesis

Fig. 5 Display of wavelengths related to different chlorophylls



Chlorine has been used as a disinfectant for a variety of different microbes. Some of the other types of disinfectants commonly used to sterilize certain things might include ethanol and cyclohexane. Copper Sulfate has been used in the past for ridding an outside water source of cyanobacteria, though with some environmentally unsafe problems. Copper toxicity, for example. There has even been some research that involved the use of aluminum sulfate. One of the most common cyanobacteria blooms comes from *mycrocystis*. In another study, during algae bloom the experiment was trying to decide at what stage is the best time to use chlorine, at the developmental or maintenance stage. The study found that chlorine treatment of cyanobacteria reduced cell density and extracellular organic matter for both stages. It also found that during the maintenance stage, the chlorine disrupted the cell membrane, resulting in intracellular toxins being released. If the cyanobacteria were treated during the development stage, the chlorine could degrade total toxins during the maintenance stage (10).

Electroporation is used in molecular biology as a technique for transformation, where it increases cell membrane permeability to hydrophilic molecules, as we have also seen, cyanobacteria are hard to eradicate using chemicals as they utilize both photostem I and II. Perhaps both a chemical treatment and electro treatment could be used in treatment of cyanobacteria, It is possible an electric current could make the cyanobacteria cell membrane more permeable for chemical or chlorine usage.

Conclusion

Agricultural workers have been applying insecticides, pesticides, fertilizers, and other chemicals to their crops for years. They help the crops grow and produce the way they should. Dr. Jim Stack, in a 2016 presentation, claimed farmers would be required to feed a growing world population of 10 billion people. How do we get there in a way that preserves the quality of our aquatic resources? Should farmers stop applying nutrients and chemicals? There are many field techniques that can be used to reduce runoff. Installing riparian strips between fields and water resources, practicing no-tillage farming, and implementing split-shot applications of residual herbicides and nutrients are a few examples. Implementing stronger monitoring and bans on harmful chemicals used in agricultural fields, permeable surfaces, and modern technology to monitor sources and sinks of pollution can also help reduce runoff effects. Due to rainfall and other factors, agricultural runoff will always play a role in water quality, but there are ways to mitigate and reduce its harmful effects.

Based on data collected from the 6 study sites, Marion County Lake has been experiencing runoff effects. Especially compared with the data from a comparable study in 2018. The levels of nitrogen and phosphorus in the water at the testing sites are heightened, and the amount of total suspended solids increased from 2018 to 2022.

One interesting aspect of this study came from looking at the drainage area and basins for some of the testing sites (Figure 3). Three sites were picked with unique drainage areas on Stream

Stats. A drainage basin was delineated, and a report was produced that provided information and the drainage area and land use statistics (Table 3). It was interesting to look at the several types of land use and the correlation between cultivated crops and agricultural runoff in water.

It was clear that there was a positive correlation between cultivated crop percentage and agricultural runoff, but another contributing factor was surprising. Impervious surfaces (driveways, sidewalks, etc.) were a strong contributing factor. Agricultural chemicals cannot be naturally soaked into the ground through impervious surfaces and are then washed into bodies of water such as Marion County Lake by rainfall. It is recommended to implement some of the various methods of runoff listed above to help mitigate the harmful effects of agricultural runoff.

Bibliography

1. *The absorption of atmospheric sulfur dioxide by water solutions*. Taylor & Francis. (n.d.). Retrieved November 11, 2022, from https://www.tandfonline.com/doi/abs/10.1080/00022470.1967.10468999
2. *Adsorption kinetics and diffusion of saxitoxins on granular-activated ...* (n.d.). Retrieved November 10, 2022, from https://www.researchgate.net/publication/272420536_Adsorption_kinetics_and_diffusion_of_Saxitoxins_on_granular-activated_carbon_Influence_of_pore_size_distribution
3. Akhtar, N., Syakir Ishak, M. I., Bhawani, S. A., & Umar, K. (2021, September 27). *Various natural and anthropogenic factors responsible for water quality degradation: A Review*. MDPI. Retrieved October 13, 2022, from https://www.mdpi.com/2073-4441/13/19/2660
4. Allen, Jacob, et al. "Marion County Park and Lake Sediment and Water Quality Study." 14 Apr. 2018.
5. Álvarez, Valero, E., Santos, R. M. B., Varandas, S. G. P., Sanches Fernandes, L. F., & Pacheco, F. A. L. (2017). Anthropogenic nutrients and eutrophication in multiple land use watersheds: Best management practices and policies for the protection of water resources. Land Use Policy, 69, 1–11. https://doi.org/10.1016/j.landusepol.2017.08.028
6. Bontrager, A. (2011). *Estimation of agricultural soil erosion and surface water quality trends in the Cheney Lake watershed* [Thesis, Kansas State University]. Retrieved October 12, 2022 https://krex.kstate.edu/dspace/handle/2097/13182
7. Chen X, Schreiber K, Appel J, Makowka A, Fähnrich B, Roettger M, Hajirezaei MR, Sönnichsen FD, Schönheit P, Martin WF, Gutekunst K. The Entner-Doudoroff pathway is an overlooked glycolytic route in cyanobacteria and plants. Proc Natl Acad Sci U S A. 2016 May 10;113(19):5441-6. doi: 10.1073/pnas.1521916113. Epub 2016 Apr 25. PMID: 27114545; PMCID: PMC4868481.
8. Giorgio, De Bonis, S., & Guida, M. (2016). Macroinvertebrate and diatom communities as indicators for the biological assessment of river Picentino (Campania, Italy). Ecological Indicators, 64, 85–91. https://doi.org/10.1016/j.ecolind.2015.12.001
9. Helliwell, K. E., Lawrence, A. D., Holzer, A., Kudahl, U. J., Sasso, S., Kräutler, B., Scanlan, D. J., Warren, M. J., & Smith, A. G. (2016). Cyanobacteria and eukaryotic algae use different chemical variants of vitamin B12. *Current Biology*, *26*(8), 999–1008. https://doi.org/10.1016/j.cub.2016.02.041
10. Hudspeth, Christopher A., and Timothy E. Reeve. *Agricultural Runoff, Coastal Engineering and Flooding*. New York: Nova Science Publishers, 2009. Print. Retrieved November 10, 2022 https://ebookcentral.proquest.com/lib/ksu/reader.action?docID=3018430&query=
11. Huisman, J., Codd, G. A., Paerl, H. W., Ibelings, B. W., Verspagen, J. M. H., & Visser, P. M. (2018, June 26). *Cyanobacterial Blooms*. Nature News. Retrieved November 9, 2022, from https://www.nature.com/articles/s41579-018-0040-1
12. I;, W. H. T. J. J. M. W.-D. (n.d.). *A dual-species co-cultivation system to study the interactions between Roseobacters and dinoflagellates*. Frontiers in microbiology. Retrieved September 21, 2022, from https://pubmed.ncbi.nlm.nih.gov/25009539/
13. *Insecticides with novel modes of action: Mechanism, selectivity and ...* (n.d.). Retrieved September 21, 2022, from https://onlinelibrary.wiley.com/doi/10.1111/j.1748-5967.2007.00104.x

14. Kumar, Naveen, et al. "AGRICULTURAL ACTIVITIES CAUSING WATER POLLUTION AND ITS MITIGATION –A REVIEW." *International Journal of Modern Agriculture*, vol. 10, 1 Nov. 2021, https://doi.org/ 10(1), 590 - 609.
15. Li, J., Zheng, B., Chen, X., Li, Z., Xia, Q., Wang, H., Yang, Y., Zhou, Y., & Yang, H. (2021, February 12). *The use of constructed wetland for mitigating nitrogen and phosphorus from agricultural runoff: A Review*. MDPI. Retrieved October 13, 2022, from https://www.mdpi.com/2073-4441/13/4/476/htm
16. Li, X., Chen, S., Zeng, J., Chabi, K., Song, W., Xian, X., & Yu, X. (2020, May 7). *Impact of chlorination on cell inactivation, toxin release and degradation of cyanobacteria of development and maintenance stage*. Chemical Engineering Journal. Retrieved October 14, 2022, from https://www.sciencedirect.com/science/article/pii/S138589472031370X
17. Lilly Center for Lakes & Streams. 2021. *How nutrients enter a lake, and how to limit them*. [online] Retrieved October 12 2022 https://lakes.grace.edu/how-do-nutrients-enter-a-lake
18. Liu. (2017). The identification of nutrient limitations on eutrophication in Dianchi Lake, China: Nutrient limitations on eutrophication. Water and Environment Journal : WEJ, 31(4), 592–597. https://doi.org/10.1111/wej.12284
19. *Marion County Park and Lake History*. Marion County Park and Lake. (n.d.). Retrieved November 10, 2022, from http://www.marioncountyparkandlake.com/history.html
20. Meinikmann, Hupfer, M., & Lewandowski, J. (2015). Phosphorus in groundwater discharge – A potential source for lake eutrophication. Journal of Hydrology (Amsterdam), 524, 214–226. https://doi.org/10.1016/j.jhydrol.2015.02.031
21. Miller, T. R., Beversdorf, L. J., Weirich, C. A., & Bartlett, S. L. (2017). Cyanobacterial toxins of the Laurentian Great Lakes, their toxicological effects, and numerical limits in drinking water. https://doi.org/10.20944/preprints201703.0148.v1
22. Moore, Mouw, C. B., Sullivan, J. M., Twardowski, M. S., Burtner, A. M., Ciochetto, A. B., McFarland, M. N., Nayak, A. R., Paladino, D., Stockley, N. D., Johengen, T. H., Yu, A. W., Ruberg, S., & Weidemann, A. (2017). Bio-optical Properties of Cyanobacteria Blooms in Western Lake Erie. Frontiers in Marine Science, 4. https://doi.org/10.3389/fmars.2017.00300
23. Nutrients, eutrophication and harmful algal blooms along the freshwater to marine continuum. (2020). Wiley Interdisciplinary Reviews. Water, 7(4), e1453–n/a. https://doi.org/10.1002/wat2.1453
24. Paerl, Havens, K. E., Xu, H., Zhu, G., McCarthy, M. J., Newell, S. E., Scott, J. T., Hall, N. S., Otten, T. G., & Qin, B. (2019). Mitigating eutrophication and toxic cyanobacterial blooms in large lakes: The evolution of a dual nutrient (N and P) reduction paradigm. Hydrobiologia, 847(21), 4359–4375. https://doi.org/10.1007/s10750-019-04087-y
25. Patzelt, D., Michael, V., Päuker, O., Ebert, M., Tielen, P., Jahn, D., Tomasch, J., Petersen, J., & Wagner-Döbler, I. (2016, May 31). *Gene flow across genus barriers - conjugation of Dinoroseobacter Shibae's 191-kb killer plasmid into Phaeobacter inhibens and AHL-mediated expression of type IV secretion systems*. Frontiers in microbiology. Retrieved September 21, 2022, from https://www.ncbi.nlm.nih.gov/pubmed/27303368
26. Petroutsos, D., Amiar, S., Abida, H., Dolch, L.-J., Bastien, O., Rébeillé, F., Jouhet, J., Falconet, D., Block, M. A., McFadden, G. I., Bowler, C., Botté, C., & Maréchal, E. (2014, March 2). *Evolution of galactoglycerolipid biosynthetic pathways – from cyanobacteria to primary plastids and from primary to secondary plastids*. Progress in Lipid Research. Retrieved September 21, 2022, from https://www.sciencedirect.com/science/article/pii/S0163782714000149

27. Pöthig, R., Behrendt, H., Opitz, D., & Furrer, G. (2010). A universal method to assess the potential of phosphorus loss from soil to aquatic ecosystems. Environmental Science and Pollution Research International, 17(2), 497-504. doi:https://doi.org/10.1007/s11356-009-0230-5
28. Russo, Tess & Alfredo, Katherine & Fisher, Joshua. (2014). *Sustainable Water Management in Urban, Agricultural, and Natural Systems*. Water. 6. 3934-3956. 10.3390/w6123934. Retrieved October 12, 2022 https://www.mdpi.com/2073-4441/6/12/3934
29. Shah SAA, Akhter N, Auckloo BN, Khan I, Lu Y, Wang K, Wu B, Guo YW. Structural Diversity, Biological Properties and Applications of Natural Products from Cyanobacteria. A Review. Mar Drugs. 2017 Nov 10;15(11):354. doi: 10.3390/md15110354. PMID: 29125580; PMCID: PMC5706043.
30. Shannon, Bellamy, et al. "Marion County Lake Research Synthesis." 11 Dec. 2020.
31. Shibu, & Ayoob, S. (2022). Modelling eutrophication status of Sasthamkotta lake using geographical information system and remote sensing. AIP Conference Proceedings, 2520(1). https://doi.org/10.1063/5.0103761
32. Singh, J. S., Kumar, A., Rai, A. N., & Singh, D. P. (2016, April 21). *Cyanobacteria: A precious bio-resource in agriculture, ecosystem, and Environmental Sustainability*. Frontiers in microbiology. Retrieved October 14, 2022, from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4838734/
33. Viola S, Roseby W, Santabarbara S, Nürnberg D, Assunção R, Dau H, Sellés J, Boussac A, Fantuzzi A, Rutherford AW. Impact of energy limitations on function and resilience in long-wavelength Photosystem II. Elife. 2022 Jul 19;11:e79890. doi: 10.7554/eLife.79890. PMID: 35852834; PMCID: PMC9439682.
34. Zepernick, B. N., Gann, E. R., Martin, R. M., Pound, H. L., Krausfeldt, L. E., Chaffin, J. D., & Wilhelm, S. W. (1AD, January 1). *Elevated ph conditions associated with Microcystis spp.. blooms decrease viability of the cultured diatom fragilaria crotonensis and natural diatoms in Lake Erie*. Frontiers. Retrieved November 9, 2022, from https://www.frontiersin.org/articles/10.3389/fmicb.2021.598736/full