The Effects of Rainfall Runoff on Suburban Wetland Water Quality

By

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ABSTRACT

Wetlands within the boundaries of suburbs can be adversely affected by rainfall runoff and storm water inputs. These wetlands may need to be monitored more frequently and drainage patterns modified to protect the wetlands from excessive exposure to potentially toxic runoff entering the wetland waters. This is especially true if more suburban development with its associated construction of buildings, roads, lawns, and loss of natural landscapes occurs around the wetlands. Suburban nature preserve workers noted less frog calling in the past few years in two suburban wetlands. There was concern about the water quality of these wetlands, especially since an expansive new lawn had been added adjacent to one of the wetlands within the past few years. It is speculated that an increase in lawn runoff has adversely changed the quality of the wetland water and that this should be more evident after significant rainfalls. During the summer and autumn of 2014, and the spring of 2015, water samples were taken from these two wetlands and tested for pH, nitrates, and phosphates and compared to the amounts of precipitation during the 24 hour period of the sampling date. It is anticipated that wetland phosphate and nitrate levels would increase, and pH levels would decrease with increasing amounts of precipitation. Macroinvertebrate sampling was also done in the late autumn of 2014 to assess for species diversity and richness as bioindicators of wetland health. Results showed that the pH did decrease with increasing amounts of precipitation at the wetland with the newly added adjacent lawn, but not at the other wetland. However, the mean pH values at both wetlands were not statistically different. The phosphate levels were abnormally high at both wetlands being 1.0 ppm. However after a rainfall of ~5 inches the phosphate levels increased at one wetland but decreased at the other wetland. The nitrate levels were within the healthy range at both wetlands throughout the study. Macroinvertebrate sampling results lacked biodiversity showing a predominance of scrapers at both sites.

INTRODUCTION AND LITERATURE REVIEW:

WETLANDS AND URBANIZATION:

Urbanization endangers many wetlands and native wetland species by loss of habitat, habitat fragmentation and isolation, and degradation of habitat quality (Hammer and McDonnell, 2008). Degradation of wetlands from changes in water quality can occur from increasing water runoff which may have point source and nonpoint source pollutants. Degradation can also be from changes in the quantity of water and how the water flows and distributes sediment. The introduction of non-native species can occur more readily when the wetland is disturbed by construction activities and increased runoff. This can cause a decrease in native species and an overall decrease in biodiversity (USEPA 1994b).

Wetlands are lands on which water covers up the soil, or is present on the surface or near the surface of the soil by the root zone either all year or for certain periods of the year (USEPA, 10/2012). The soil is saturated with water, but the water is less than 1 meter deep (Dodson, 2005). Under the Clean Water Act, the definition of wetlands is used for regulatory purposes to help establish bodies of water in need of wetland protection. The definition of wetlands under the Clean Water Act is “those areas that are inundated or saturated by surface or groundwater at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions. Wetlands generally include swamps, marshes, bogs and similar area”, this quote is taken directly from the EPA Regulations listed at 40 CFR 230.3(t), (US EPA 9/2013). The wetlands studied in this thesis can be classified according to plant and soil conditions. These wetlands have hydric soils and hydrophytes, and are also known as bogs, swamps, and marshes. They fall within the Palustrine system of classifying wetlands and deeper bodies of water. The wetlands within the Palustrine system are influenced by similar biological, chemical, hydrologic, and geomorphic issues (Tiner 1984). The study wetlands can be considered as wet meadows, a type of freshwater inland marsh that occurs in areas with poor drainage. These types of wetlands typically have water in them most if not all of the year (US EPA 7/2013).

Wetlands are beneficial in many ways. They act as pollution, pathogen and sediment filters. When pathogens such as fecal coliform bacteria and protozoans drain into wetlands through urban storm water runoff and agricultural runoff, wetlands can act as a filter and help clean the dirtied water. The bacteria attach to solids in the water and then are trapped by wetland plants (Hammond and Benoit 1988). The pathogenic bacteria eventually die from excessive harsh conditions such as sunlight, low pH, and excreted toxins from nearby plant roots (Hemond and Benoit 1988; Kennish 1992). When it comes to nutrient removal, it is estimated that wetlands can remove between 70-90% of entering nitrogen from the water system (Reilly 1991; Gilliam 1994). The estimated mean retention of phosphorus by wetlands is 45% (Johnston 1991).

Some wetlands recharge groundwater supply, while other wetlands get much of their water supply from the groundwater. Wetlands protect areas from flood and erosion damage (Winter 1988). Watersheds need wetlands to help store water, during dry periods they give water to surface and ground water, and during wet periods they store water (Winter 1988). Wetlands can protect adjacent and downstream properties from potential floods and the damage associated with it. Urban areas that are full of impervious concrete surfaces greatly increase the rate and volume of runoff, thus increasing the risk of flood damage. When it comes to erosion control, wetlands and marshes on the side of a lake protect the shoreline and stream banks against erosion. Wetland plants are able to hold the soil in place with their roots, absorb wave energy and reduce the velocity of stream or river currents.

It is unfortunate to see the amount of wetlands in America that have been lost to urbanization. This is especially prevalent in the Midwest. In fact, in the early 1600's there was over 220 million acres of wetlands that existed in the lower 48 states of North America (Dahl and Johnson 1991). Since the 1600's more than half of the original wetlands in the lower 48 states of America have been drained or destroyed in other ways. Twenty states have lost up to 50% of their original wetlands. In the Midwestern states of Illinois, Indiana, Missouri, Kentucky, and Ohio there has been a decrease of 80% of the original wetlands. California and Iowa have lost almost 99% of their wetlands (EPA 1995a). Since the 1970's the most extensive losses of wetland acreage have occurred in the southern portion of the United States (Dahl and Johnson 1991). During the mid-1970 to the mid 1980's about 4.4 million acres of freshwater wetlands and 71,000 acres of coastal wetlands were destroyed. The conversion of wetlands to agricultural land is responsible for 54% of the losses of both freshwater and coastal wetlands. The drainage of wetlands for urban development and other development has accounted for 45% of the wetlands lost (Dahl and Johnson 1991).

Many of the wetland areas of Lake Forest, Illinois, the location of the wetlands studied in this thesis have been developed for agriculture and suburban sprawl. However, over the past few decades many of these land parcels have been acquired by the Lake Forest Open Lands Association (LFOLA), an independently funded conservation organization which preserves and works on restoring its land purchases back toward their original state. LFOLA is the first Illinois land trust to be accredited by the Land Trust Accreditation Commission. In 1999 LFOLA issued 10 million dollars in tax-exempt public bonds to fund its restoration work, and was the first land trust to use this type of funding tool (LFOLA.org). LFOLA has restored 6 natural areas, including the Skokie River Nature Preserve and the West Skokie Preserve the sites of study for this thesis. One of the more famous agricultural estates is the present day Mellody Farm Preserve which use to be part of the 1,000 acre estate of Ogden Armour. It was purchased in the early 1900's by the son of Phillip Armour, the famous meatpacking industrialist. (LFOLA.org)

HYDROLOGY:

Urbanization causes an increase in the amount of impervious surfaces that rainwater will not soak into, such as roads, buildings, and parking lots. If rainfall cannot percolate into the soil and enter the groundwater, it becomes runoff, which collects and carries pollutants to larger bodies of water including wetlands, streams, rivers and lakes. Some wetlands get their water from a groundwater source, so when groundwater recharge decreases, wetland water quantity also decreases (Winter 1988). This can lead to a wetland drying up completely. The hydrology of wetlands can change from runoff causing erosion and channelization of the wetland (USEPA 1993c). The temperature of runoff water can increase markedly if it travels over hot pavement, this can actually increase the temperature of the wetland water, which causes an increase in the release of nutrients from the wetland sediment. This increase in nutrient level can lead to a wetland becoming overly eutrophic. Eutrophication can stress wetland organisms and lead to a decrease in populations of organisms. The dissolved oxygen content of runoff water can decrease when it travels over hot pavement, this can lead to a decrease in the dissolved oxygen content in the wetlands, which can stress organisms in the wetland (USEPA 1993c).

HABITAT FRAGMENTATION:

Urbanization can cause habitat fragmentation of wetland areas. Since the value of freshwater wetlands is not well defined by the public and the legislature, wetlands are not as highly valued from an economic standpoint. In fact, when roads have to be built near wetlands construction companies are allowed save more money by building over wetlands rather than around them (Winter 1988). When this happens wetlands are fragmented which makes it harder for animals to cross habitats, often putting them at risk of death and also decreasing their available gene pool. When the gene pool decreases more inbreeding occurs which can lead to an unhealthy population and possible extirpation (Eastman et al 2007). When habitats are disturbed from digging and moving dirt during construction, non-native plant and animal species can be introduced and stimulated to grow. These non-native sometimes invasive species can push out the less tolerant and less aggressive native species (McColligan and Kraus 1988) (Mitsch and Gosselink 1993).

WATER QUALITY:

Degradation of wetland water quality is a common occurrence from man's use of land near any wetland areas. Urban, suburban and rural land uses can cause toxic water runoff, and increase in suspended sediments in wetland water. Increase in suspended sediments cause a decrease in light in the wetlands and may affect plant growth and the health of benthic organisms (USEPA 1993c). There are two types of pollutant inputs, point source and non-point source pollution (USEPA 1994b). Point source pollution can be identified by a single source, like a factory pipe discharging toxic industrial waste directly into a river or wetland. Non-point source pollution is harder to be traced back to its source; a common example of this is fertilizer runoff from farm fields and lawns.

Landfills can be full of household hazardous waste, sewage sludge, and industrial waste which, if not properly managed and located, can cause surface water runoff contamination (Lambou et al 1990). There is a lot of nitrogen and phosphorus in storm water and wastewater treatment plant runoff, when this reaches wetlands it can cause algae blooms, with subsequent decrease in dissolved oxygen causing death of benthic organisms (Kennish 1992). Nearby roads have rock salt, heavy metals, hydrocarbons and deicing chemicals in their storm water runoff which can be detrimental to wetland plants and animals (USEPA 1993a). Heavy metals can accumulate in benthic organisms since these metals collect in the sediments that these organisms eat and live on. When other organisms feed on these benthic organisms they also ingest the heavy metals and so the heavy metals work their way up the food chain (Dodson 2005). Heavy metals such as iron, arsenic, lead, cadmium, and mercury can easily be biomagnified and all have harmful biological effects such as cancer and kidney failure. Bio magnification itself is the process by which chemicals are passed up the food chain from prey to predator (Dodson 2005).

Industrial agricultural practices cause increase in erosion, as well as runoff of large amounts of animal waste, synthetic fertilizers, pesticides and herbicides. The increase of fertilizers in wetlands, especially the phosphate component of fertilizers, causes algae blooms with resultant eutrophication. The decrease in dissolved oxygen from algae blooms causes death to benthic organisms that cannot come to the surface of the water to get more oxygen. It also decreases the light in the water causing death to other aquatic plants that are crucial for stabilizing sediments and also supplying both habitat and food for other wetland organisms (Dennison et al 1993).

LAWNS:

Lawns in general adversely affect wetlands by increasing the quantity of nonpoint polluted runoff because rainfall is not absorbed into the soil of a lawn monoculture as well as it is absorbed into the soil of with a more biodiverse planting i.e. a virgin prairie. This increase in runoff also causes more soil erosion and thus more soil sediment and soil chemicals being deposited into the wetlands (Grable 2014). The water quality of wetlands could be affected by lawn runoff by changing the pH, nitrate, and phosphate levels, which could impact amphibian populations, macroinvertebrate populations, and overall wetland health. Rainwater is typically acidic with a pH of 5.5 to 6.0. Acid rain contains nitric and sulfuric acids. When nitrates and phosphates found in lawn fertilizer enter wetlands due to runoff, the chemicals alter the pH levels making the water more acidic, and also increase the phosphate and nitrate levels of the water. Ammonium found in fertilizers is converted into nitrates by the soil nitrification process from bacteria found in the soil. Phosphoric acid can be found in lawn fertilizer and can add to the soil acidity and also decrease pH of rainfall runoff (Nitrogen Fertilizers, 2015). The increase in nitrates and especially phosphates, can dramatically cause eutrophication with subsequent decrease in oxygen levels and unhealthy water conditions for many wetland species (Ewel 1990). This lawn fertilizer runoff is considered a source of nonpoint pollution for freshwater wetlands. Some studies in Wisconsin have shown that lawn runoff has total phosphorus content up to 5.0 ppm and a nitrogen content of 20 ppm (Garn 2002).

ACID-BASE:

Wetland water chemistry values tend to change with the season, weather, even the time of day, therefore it is difficult to define normal values for a particular wetland. However small changes in a wetlands water chemistry values can greatly affect the types of plants and animals that live in a wetland (USGS 2013). Also, changes as small as 0.3 in the pH can frequently be related to large changes in other water chemistry values such as the amount of soluble iron, copper, and calcium as well as the amount of CO_2. Freshwater wetlands tend to have neutral pH and an abundance of nutrients, including nitrates and phosphates (EPA 2012). Rain water is a weak acid and can effect solubility of minerals in wetland waters.

The chemical equation for pure water can be written as follows:

$$H_2O \leftrightarrow H^+ + OH^-$$

The two charged ions, H^+ (hydrogen ion) and OH^- (hydroxyl anion) are in a constant state of equilibrium with the non-ionized water molecules. The equilibrium of this equation can be affected by many things, including the concentration of H^+ ions available. The concentration of H+ ions can be assessed by measuring the pH of the water. pH is related to the negative log of the hydrogen ion concentration, as in the following equation: pH= $^{-}$Log[H^+]. So that the more hydrogen ions in the water the lower the pH since they are negatively related. Alkaline water tends to have more bicarbonate in it. For the sake of biological systems, acidic solutions have pH<7, neutral pH =7, and basic pH>7 (Dodson, 2005). However for freshwater wetlands the following Table 1 shows the effects of pH on freshwater organisms. This table defines pH <6.5 as acidic, pH= (6.5-8.0) as neutral, and pH> 8.0 as alkaline (Robertson-Bryant, Inc. 2004). Skokie Valley River testing at the Deerpath test station in Lake Forest, IL, located several blocks away from the Dixon wetlands tested in this study, showed pH= 7.65, nitrates and nitrites combined equal to 0.27 ppm, and total phosphorus=0.26 ppm (Flood 2014).

Table 1. The pH Ranges of Freshwater Wetlands and the Effects on Freshwater Organisms

pH	Effects on Freshwater Organisms
3.0-3.5	No fish can survive. Only very tolerent invertebrates can survive.
3.5-4.0	Lethal to most fish.
4.0-4.5	Few fish, amphibians, or insects can survive.
4.5-5.0	Most fish eggs with not hatch.
5.0-5.5	Benthic bacteria and plankton die off, few clams and snails can survive.
5.5-6.5	Most plants and animals survive: exceptions include mollusks.
6.5-8.0	Optimal for most organisms.
8.0-9.0	Most plants and animals survive.
9.0-10.5	Harmful to amphibians, some fish and many invertebrates.
10.5-11.0	Lethal to most species, including stoneflies and dragonflies.
11.0-11.5	Lethal to almost all species, only sime caddis flies can survive.
11.5-12.0	Lethal to all living organisms.

(Robertson-Bryant, Inc. 2004).

PHOSPHORUS:

Phosphorus is a component of lawn and garden fertilizer and it can be found in lawn runoff especially after heavy rainfalls. Under normal circumstances, phosphate in wetlands can be found in clay and fine particulate matter, as well as in animals and water plants (see Figure 1). Primary producers are very sensitive to phosphate levels, if the levels decrease too much their growth is limited and if there is too much phosphate there can be overgrowth, i.e. algae blooms (Dodson 2005). Phosphate (PO4) tends to accumulate in freshwater wetlands because of the tendency for freshwater wetlands to have large amounts of calcium and magnesium. The calcium and magnesium tend to form insoluble precipitates with phosphates that are largely found in the sediment (Dodson 2005). In acidic, hydric, clay soils decreasing the pH of the water causes soluble phosphate to precipitate with ferric ions and aluminum ions (Reddy et al 2005). The organic forms of phosphorus (P) can be found in soil biomass, soil organic matter, decaying and living plants, microbes, and animals, and soluble organic P. It is difficult to find PO_4 normal ranges for freshwater wetlands, but the total phosphorus (TP) levels in good quality wetlands are TP< 0.1 ppm and TP<0.7 ppm in lower quality wetlands (Kalic et al 1995). Since most of TP in wetlands is in the form of PO_4, this will be used for this thesis. PO_4 <0.1 is the cut off for healthy water according to the LaMotte water test kit used in this thesis.

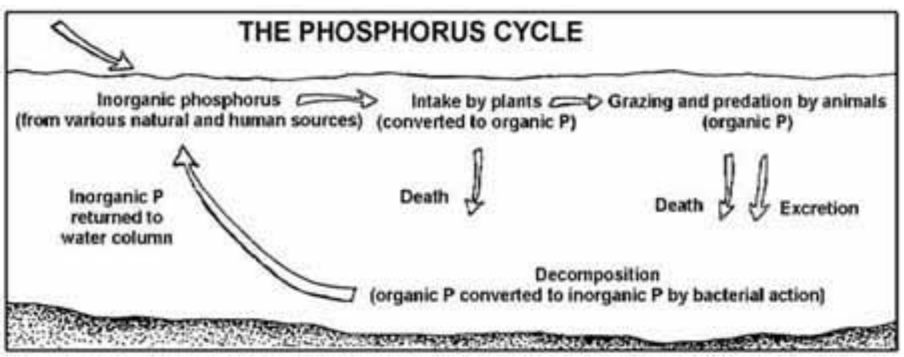


Figure 1: Phosphorus Cycle in Wetlands. Phosphorus in organic and inorganic forms.

(EPA 3/2012) http://water.epa.gov/type/rsl/monitoring/vms56.cfmhttp

Phosphorus is an important growth limiting nutrient and the addition of P to freshwater wetlands can easily change them from being poor in nutrients (oligotrophic), to moderately rich in nutrients (mesotrophic), to extremely well nourished (hypereutrophic) (Smil 2000). Since the mid 1800's when inorganic phosphorus fertilizer was first produced from rocks, there has been an increase in the mobilization of phosphorus in the phosphorus cycle from harvesting the phosphorus from rocks. Also the use of this P fertilizer has augmented industrial agricultural food production and increased the production and ingestion of meat by people. Industrial agricultural practices also cause increase in runoff and soil erosion contributing to increases of P in the water systems including the wetlands (Smil 2000).

Most phosphorus is in rocks, soil minerals, and ocean sediment. In nature, phosphorus is fairly steady in the sediment form, i.e. in rocks, soil minerals and ocean sediment. When the rocks and sediment are eroded phosphate is released. This process is accelerated by man making inorganic phosphorus fertilizer with rock phosphate. The mineral forms of P are found as insoluble precipitates of calcium phosphate and magnesium phosphate in wetland sediment. Organic forms of P are found in wetland biomass of dead and living plants and animals. Living organisms need phosphorus, it is found in DNA among other things. Some bacteria are able to dissolve phosphates, and then release phosphorus and make it more readily available in the soil and water. Phosphorus is not found in any significant amount in the atmosphere (Smil, 2000).

In figure 2 the anthropogenic effects on the phosphorus cycle show and increase in P from runoff of P into waterways from less water being absorbed by urbanized land, an increase in P found in decaying plants and animals and untreated human waste, phosphate containing detergents, and mining rocks for P to then be used as fertilizer (Smil 2000).

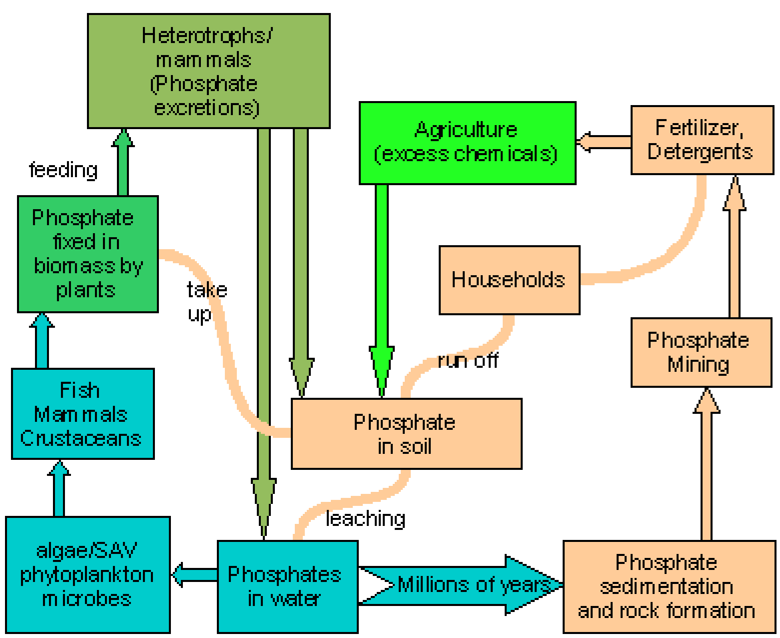
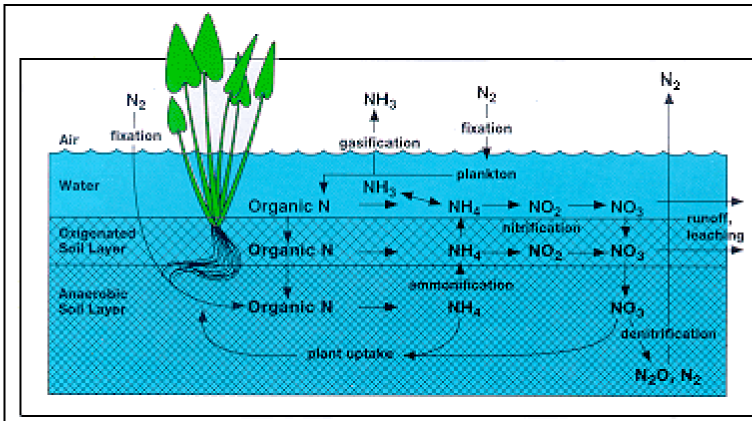


Figure 2: Anthropogenic Effects on the Phosphorus Cycle (www.amyhremleyfoundation.org)

NITROGEN:

Testing for nitrogen in the form of nitrates in wetland water is important because it is the second most important inorganic nutrient to effect wetland plant growth and nitrogen is also a large component of fertilizers, human waste and industrial waste. High nitrate levels can cause plant over growth and eutrophication of a wetland. See Figure 3 for an overview of the nitrogen cycle.



Nitrogen cycling in wetlands progresses more rapidly where there is a thin oxygenated soil layer present.

After Mitsch & Gosselink 1993

Figure 3: Nitrogen Cycle in Wetland (Mitsch and Gosselink 1993)

Note that unlike phosphate, nitrogen compounds are very soluble in wetland waters. N_2 (nitrogen gas) dissolves easily in water. Lightening and some bacteria can fix nitrogen gas into nitrogen oxides (NO_x) or ammonia (NH_4). A part of acid rain is made up of nitric acid (HNO_3) which is formed when nitrogen oxides (NO_x) are dissolved in rain water. Nitrate ions (NO_3^-) are formed when water and nitrogen oxides react.

Nitrate levels of < 1.0 ppm are found in freshwater wetlands with high water quality, and nitrate levels between 1.0 to 1.8 ppm correspond to fair water quality. Fair to poor water quality has nitrate levels of 1.8 to 2.0 ppm, and nitrate levels > 2.8 ppm correspond to poor wetland water quality (Robert-Bryant, Inc. 2004).

In Figure 4, the anthropogenic effects on the nitrogen cycle are delineated such as runoff of nitrates from fertilizers, and ammonia compounds found in organic waste which can lead to eutrophication of water. Also the contribution of nitrogen in air pollution from fossil fuel emissions is noted. Nitrogen is the most abundant gas in the air we breathe.

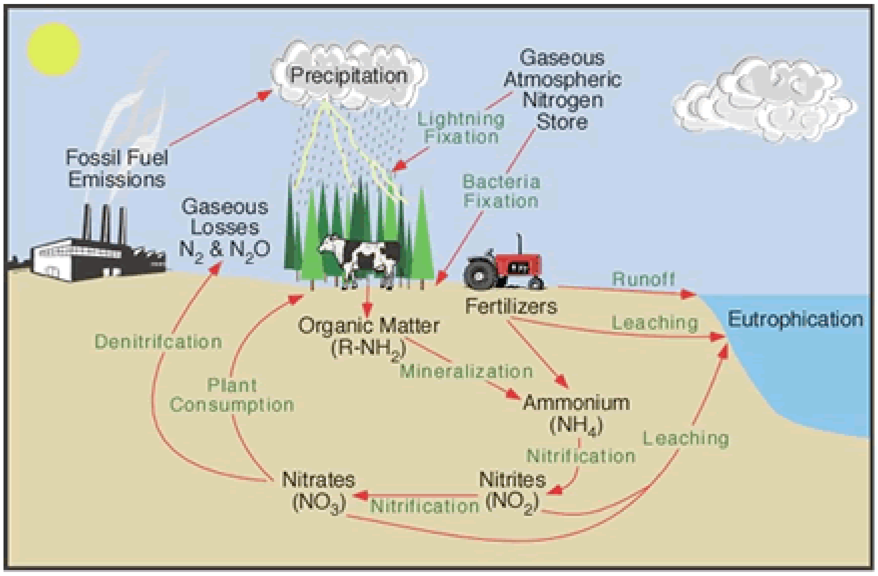


Figure 4: Anthropogenic Effects on Nitrogen Cycle (www.oregonstate.edu)

MACROINVERTEBRATES:

Another test parameter for wetland water health is to look at the macroinvertebrate populations. The most effective time to collect macroinvertebrate populations is from late spring to early fall when there is maximum reproduction and diversity. This study only collected macroinvertebrates in the late fall because that was when it became clear that there was no amphibian data available. There are many macroinvertebrates that are very sensitive to stress caused by pollution, habitat fragmentation, and other things like invasive species, and there are some that are very tolerant of environmental stress (Voshell 2002)

There are several types of macro invertebrate species that have commonly been used as bio indicators of wetland trophic states and are useful for identifying wetlands that have received excess nutrients from lawn runoff for example. The proportion of scrapers increases with increases in eutrophication. Scrapers graze on algae, periphyton and other organic matter that is attached to rocks and plants. Some examples of scrapers found at the wetlands studied in this thesis are Planorbid and Bithyniid snails. The Bithyniid snail was introduced to the Great Lakes region from Europe in the 1870's. They are scrapers that eat algae, but can also feed by filtering through their gills which is one reason they can be found in abundance in areas enriched with nutrients. They can be identified by their opening being on the right side when the shell is held upright, and the presence of an operculum. The operculum is a shell lid at the foot of the snail so that the shell can be closed completely (Voshell, 2002). Since increases in eutrophication are associated with increased algae production, it makes sense that the population of Scrapers would also increase as their food supply increases. Planorbid snails are identified by having a shell that is flat and coiled instead of being in a spiral form and they can appear reddish from the hemoglobin in their blood. It has no operculum (Voshell ,2002). The Planorbid snail is semi-tolerant to pollutants that can be found throughout North America and can survive in water with low dissolved oxygen content because they have hemoglobin. They are collector- gatherers, but some are scrapers (Voshell, 2002).

A large biodiversity of macroinvertebrate populations in general is a sign of a healthy wetland. Various ratios of different types of macroinvertebrates can be looked at when studying wetland health. For example, increases in the ratios of tubifex worms to sedentary aquatic insects, increases in the ratios of the midge sub families of *Tanypodinae* and *Chironomini*, to the subfamily *Orthocladiinae*, increases in the ratios of non-burrowing mayflies to burrowing macro invertebrates have all been used to indicate excessive nutrient runoff in wetlands (US EPA 2012).

The aquatic earthworm (*Oligochaeta)* are most commonly found in the mud and sediment of slow moving water of wetlands such as the wet meadow marshes studied for this thesis. The majority of aquatic earthworms are collector-gathers, but they mostly eat mud as they burrow. The most known kind of aquatic earthworm used as a bio-indicator are the long red worms. These are found in areas of high pollution, and sometimes low dissolved oxygen since they have hemoglobin in their blood which enables them to hold onto whatever oxygen there is. However, only when the long aquatic red earthworms represent the majority of the invertebrate sample, are they considered a pollution (Voshell Jr, 2002). The fingernail clam *(Sphaeriidae)* can be found in lentic-littoral habitats, and are spread throughout North America. They are collector-filter feeders and are facultative to somewhat tolerant of pollution (Voshell Jr, 2002).

Macroinvertebrates are also important because they influence the amount of contaminants that are available to other components of the food chain and the rate of contaminants cycling through wetlands. There are several characteristics of macro invertebrates that make them ideal for monitoring wetland ecosystem health. They have consistent responses to stressors that have been documented and indicator species that have been identified. Their larval lifespans are varied, ranging from short (*cladocerans*) to long (dragonflies). This allows them to be used as indicators for short and long term studies. Non-insect macroinvertebrates reflect the quality of the wetland itself because they complete their entire life cycle in a single wetland. Last but not least the decay resistant material like snail shells provide historical conditions of a wetland (US EPA 3/2012).

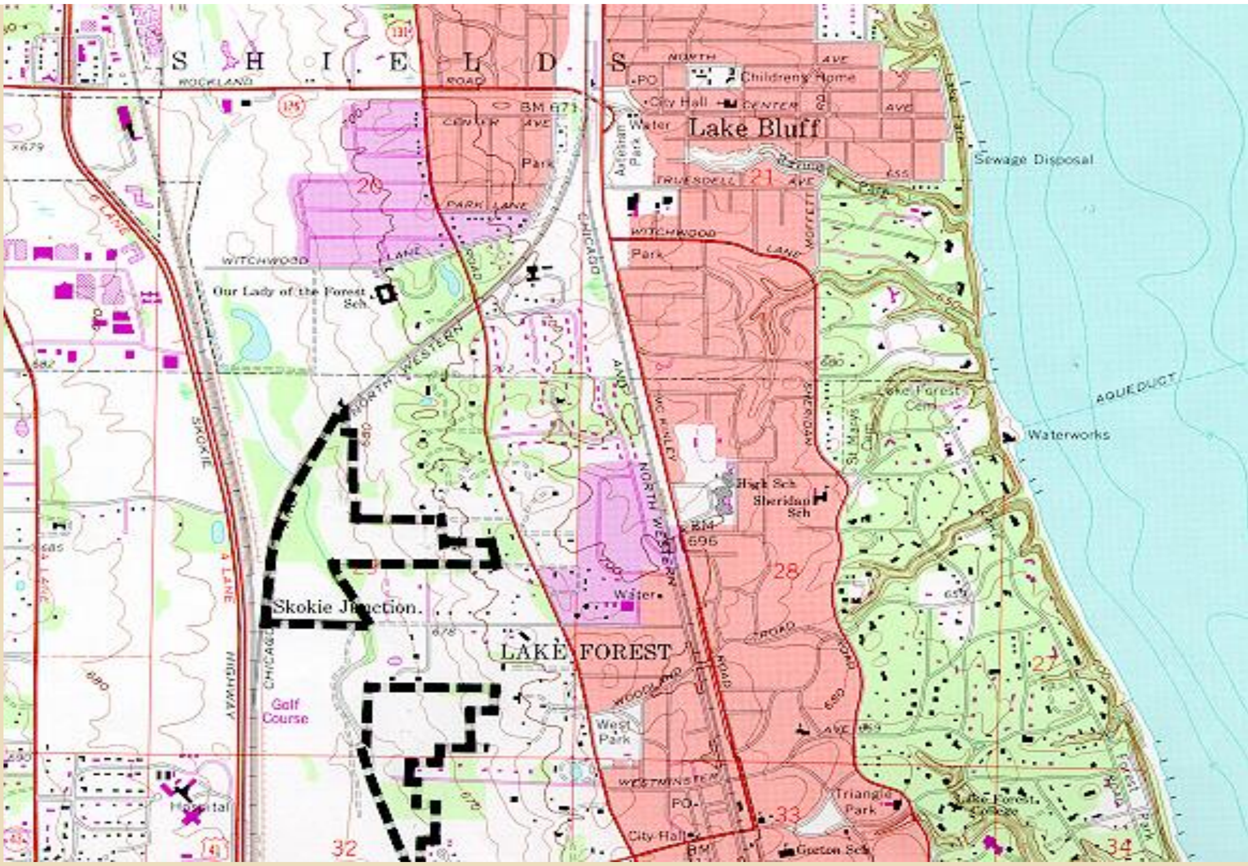
Macroinvertebrates are also used as indicator species to look for pesticide and heavy metal contamination. Synthetic pyrethroids like deltamethrin are more toxic to invertebrates than the organic pesticides like organochlorine. Mayflies and amphipods are more sensitive to insecticides than midges and beetles. Herbicides in general are not as lethal and toxic as insecticides are to macroinvertebrates. In fact some herbicides actually cause an increase in the population of aquatic worms. Many aquatic worms are tolerant of low oxygen levels which can be the result of oxygen deficiency from the decay of plants that have been killed from herbicide in the water. Amphipods like the ostracod and many zooplankton species are very sensitive to some pesticides while most aquatic worms and snails are less sensitive (EPA 2012).

Wetlands within a suburban sprawl can be adversely affected by the rainfall runoff and storm water inputs. These wetlands may need to be monitored more frequently and their management changed to protect the wetlands from excessive exposure to potentially toxic runoff entering the wetland waters. Suburban workers noted less frog calling in the past few years in two suburban wetlands. An expansive new lawn had been added adjacent to one of the wetlands within the past few years and it is speculated that increase in lawn runoff has adversely changed the quality of the wetland water and that this should be more evident after significant rainfalls. Water samples from each wetland were tested for phosphates, nitrates, and pH and compared to the amounts of precipitation that had occurred during the 24 hour period of the sampling date. The pH and phosphate data from the two wetlands was also compared to see if there were significant changes between the two wetlands. It is hypothesized that wetland phosphate and nitrate levels would increase, and pH levels would decrease after rainfall events. It is predicted that the wetland with the added new adjacent lawn may have lower pH, and higher phosphate levels compared to the wetland without an adjacent lawn.

METHODS

CASE STUDY AREA:

I sampled water from two wetlands in Lake Forest Illinois; the Dixon Wetlands in LFOLA Skokie River Nature Preserve, and the West Skokie Wetland at LFOLA West Skokie Nature Preserve. The ephemeral Dixon wetland studied is within the boundaries of the Skokie River Nature Preserve in Lake Forest, Illinois (see figure 5). This nature preserve is positioned along both sides of the Skokie River, and has woodlands, wetlands, wet-mesic and mesic prairies, including the Shaw Prairie, a 15 acre mesic prairie which has been preserved since the early 1900s (https://dnr.state.il.us/conservation/naturalheritage/Documents/INPC_by_County.pdf, 2014). The Dixon wetland is 5,713.5 ft^2 based on ArcGIS measurements. The Skokie River Nature Preserve is preserved under the Illinois Nature Preserve Commission (https://dnr.state.il.us/conservation/naturalheritage/Documents/INPC_by_County.pdf 1995). The Skokie River is 32 kilometer long and flows parallel to Lake Michigan from Waukegan to Chicago. It use to drain into Lake Michigan via the Chicago River, but when the Chicago Sanitary and Ship Canal was built in 1900 it changed the flow of the Chicago River and its tributary the Skokie River, to flow southwestward eventually emptying into the Mississippi River.



(DNR.gov)

Contact: Lake Forest Open Lands Association, Educational Director, 560 N. Oakwood, Suite 103, Lake Forest, IL 60045 (708/234-3880)

03/10 R. Heidorn

Figure 5: The Skokie River Nature Preserve

The West Skokie Preserve wetland studied is 6,393 ft2 based on measurements using ArcGIS. It is surrounded by restored prairies. The West Skokie Preserve had been farmland and was full of invasive species when it was purchased by LFOLA in 1980. This particular wetland is in close proximity to a recently placed lawn and may have potential problems with an increase in runoff containing fertilizer and herbicides. The West Skokie River, also known as the middle fork of the north branch of the Chicago River, is on the western edge of this preserve in close proximity to the wetland. It is located west of Skokie Highway, east of Waukegan Road, on the south side of Westleigh Road. (LFOLA.org).

WETLAND WATER SAMPLING:

Water testing for nitrates, phosphates, and pH was performed, and amounts of precipitation within the 24 hour sampling period were recorded. Water samples were collected during the summer and autumn months of 2014, as well as the spring of 2015. Water sampling was done when the water testing kit and time were available, with particular attention to sampling after a rainy day since the available sampling period was relatively dry. Some samples were discarded because of the presence of large air bubbles. Macroinvertebrate sampling began later in the study when it became apparent that amphibian data was not available. Macroinvertebrate sampling occurred during the late autumn of 2014.

The LaMotte Water Pollution Detection Outfit Model # AM-21 Code 5905-01 test kit was used to test the water for pH, nitrates and phosphates. The water sample bottles were slowly submerged into visually clear water, allowed to fill while attempting to avoid mixing bottom sediment into the water sample. The wetland areas available for sampling were about 1 foot deep. Any air bubbles in the sample bottle were tapped out, and the sample bottle was filled to jjthe brim. Debris and air bubbles can cause chemical reactions like oxidation which will skew the results of the tests. Water samples were tested using the specific nitrate, phosphate, and pH test tubes that are provided in the kit.

NITRATE TEST:

To test for nitrates a kit test tube was filled with sample water to the 2.5mL mark and an acid reagent is added, followed by a Nitrate Reducing Agent which turns the water light pink to deep magenta with increasing concentrations of Nitrate from reducing NO_3^- ions. The tested sample solution is compared to the color standards of known values of Nitrates. For complete details on the procedures see the LaMott test booklet.

PHOSPHATE TEST:

To test for phosphates a kit test tube was filled with 5 mL of sample water and test reagents were added and a light blue color was looked for as the color indicator of the presence of phosphate. The tested sample solution is compared to the color standards of known values of phosphates with a phosphate comparator. Any shade of blue more than a faint blue was considered as suspicious for phosphate pollution. The Detailed instructions for this test are found in the LaMotte manual.

pH TEST:

To test for pH a kit test tube was filled with 5 mL of sample water and ten drops of the Range Finding Indicator Solution were added to the water sample. A color readout was used to assess the pH level by comparing the sample color with the color standards of known pH value. If the colors of the test sample do not match the color of one of the standards, the sample value is assigned to the midpoint between the two standards that are adjacent to it. For example if the water sample pH test color is between 7.0 and 8.0 the sample pH is given the value pH of 7.5.

MACROINVERTEBRATES:

Macroinvertebrates were sampled using a dip net. A dip net is a triangular net that has a mesh bottom which allows water to be filtered out leaving the samples inside the net. Dip net samples were taken by moving the net across the bottom of the pond with 3 arm length sweeps at a depth of 1 foot. The samples collected were put in a bucket of clean, clear water and taken back to the lab for analyzing. Macroinvertebrate identification was done using the freshwater invertebrate guidebook, *A Guide to Common Freshwater Invertebrates of North America* by J. Reese Voshell Jr. Submerged aquatic vegetation and *Lemna minor* (Duckweed) were seen at both sampling sites, as well as narrow leaf pond weed.

ArcGIS:

The sizes of both wetlands were measured by ArcGIS Online, using the measurement tool. ArcGIS Online is a geographic information system that is developed by Esri to work with maps and geographic information and data. It is primarily used to create maps, compile geographic data, and analyze mapped data. ArcGIS Online allows access to the program via the internet instead of physically buying the program and downloading it. ArcGIS Online also allows existing maps online to be used for map creation and analysis. It allows for the area, distance, and location of an area to be measured and analyzed on an existing map that is provided by google maps.

STATISTICAL ANALYSIS:

To test the hypothesis that rainfall and its associated runoff effects wetland water pH several t-tests were performed. The t-test on Excel was used because it can examine small sample sizes to look for statistical relationships, since small sample sizes do not follow a normal distribution curve, they follow a t-distribution curve. The t-test was also done because the variance or the spread of the data from the mean was unknown. The t-test looks for statistical significance between the averages of different sets of data (Field, 2009).

An independent t-test was done using two sample sites of pH data (or unpaired data), from the Dixon and West Skokie wetlands to see if there was a statistical difference between the average pH at each wetland. The independent t-test was also done to compare the mean phosphate levels of both wetlands.

Regression analysis was used to make and evaluate scatter plots that compare the pH values and phosphate values with amount of precipitation. The P-value is percentage chance that the slope of the regression analysis will be zero. If the slope is zero there is no relationship between the x-axis and the y-axis. P-values < 0.05 are considered statistically significant in that there is a $< 5\%$ chance that the slope will be zero. These evaluations helped test the hypothesis that an increase in rainfall and its associated runoff will cause a decrease in the pH and an increase in phosphate levels of the wetland.

RESULTS

To assess the water quality of suburban wetlands and determine if increase in runoff after rainfalls changed the water quality parameters, wetland water samples were collected during times with and without rainfall over a period of several months and tested for pH, phosphates, and nitrates and compared with rainfall amounts. Macro invertebrate collections of both studied wetlands were used as bio indicators of wetland health. Raw data can be found in Appendix A.

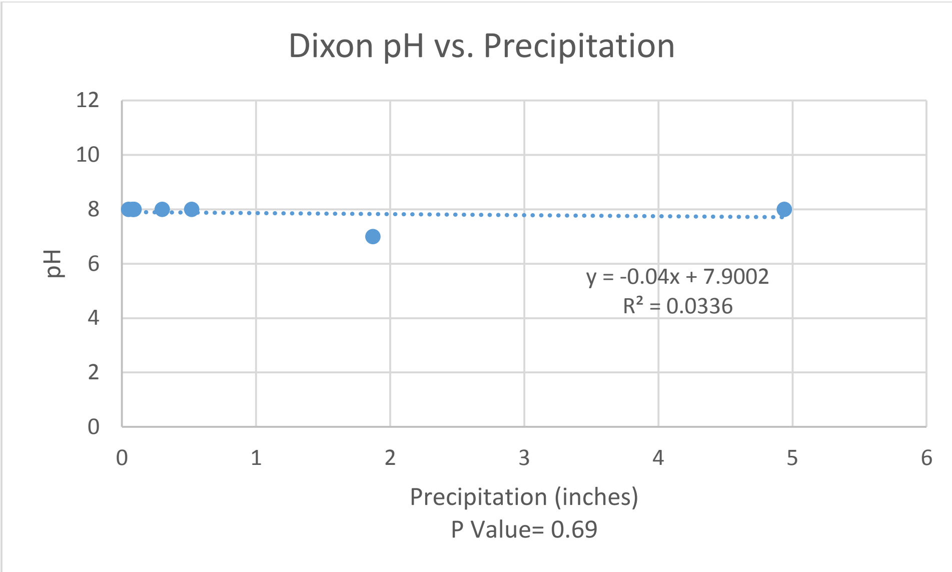


Figure 6: Dixon pH vs. Amount of Precipitation

Table 2: Regression Analysis for Dixon pH vs. Amount of Precipitation.

SUMMARY OUTPUT Dixon

Regression Statistics	
Multiple R	0.183219382
R Square	0.034
Adjusted R Square	-0.15971679
Standard Error	0.407030499
Observations	7

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	0.028773722	0.028774	0.1736769	0.694151475
Residual	5	0.828369136	0.165674		
Total	6	0.857142857			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*
Intercept (b=y intercept)	7.90	0.185381453	42.61618	1.342E-07	7.423710333
Precipitation (m=slope)	-0.04	0.092234144	-0.41675	0.6941515	-0.27553359

In Figure 6 the scatter plot of Dixon pH on y-axis and precipitation on x-axis shows a slope of - 0.04, and a y-intercept=7.9 which were obtained by regression analysis see Table 2. The R Square indicates that only 3% of the variation in pH values was affected by the amount of precipitation which could be consistent with the fact that the pH stayed at 8.0 in 6 of 7 water samples from Dixon. The P-value of 0.69 shows that there is a 69% chance that the slope would be zero, which is consistent with the fact that the pH did not change much with increasing rainfall. The P-value is > 0.05 so there is no statistical relationship between pH and precipitation at Dixon.

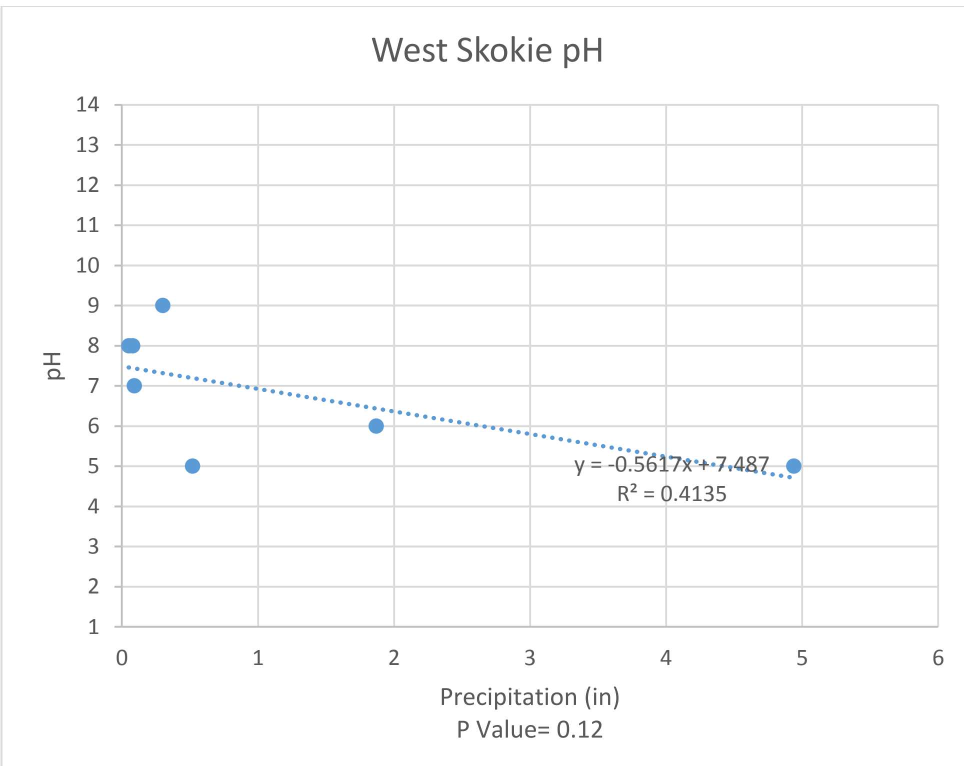


Figure 7: West Skokie pH vs. Amount of Precipitation

Table 3: West Skokie Regression Analysis pH vs. Precipitation

SUMMARY OUTPUT West Skokie

Regression Statistics	
Multiple R	0.64
R Square	0.41
Adjusted R Square	0.30
Standard Error	1.32
Observations	7

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	6.143993626	6.143994	3.525702	0.119230613
Residual	5	8.713149231	1.74263		
Total	6	14.85714286			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*
Intercept (y intercept)	7.49	0.601231744	12.45282	5.92E-05	5.941513183
Precipitation (inches)	-0.56	0.299135079	-1.87769	0.12	-1.330632739

y=7.49-0.56x y=b+mx
m=-0.56

In Table 3 West Skokie regression analysis of pH vs. precipitation shows the slope is negative 0.56 and the pH value at the y intercept is 7.49. R^2 of 0.41 can be interpreted as 41% of the variation in pH values was affected by the amount of precipitation. The P-value of 0.12 shows that there is a 12% chance that the slope is 0, and also means that there is not a statistically significant relationship between pH and precipitation. Figure 7 shows the negative slope as the pH goes down with increase in precipitation at W. Skokie. The pH decreased with increasing rainfall at West Skokie but not so much at Dixon.

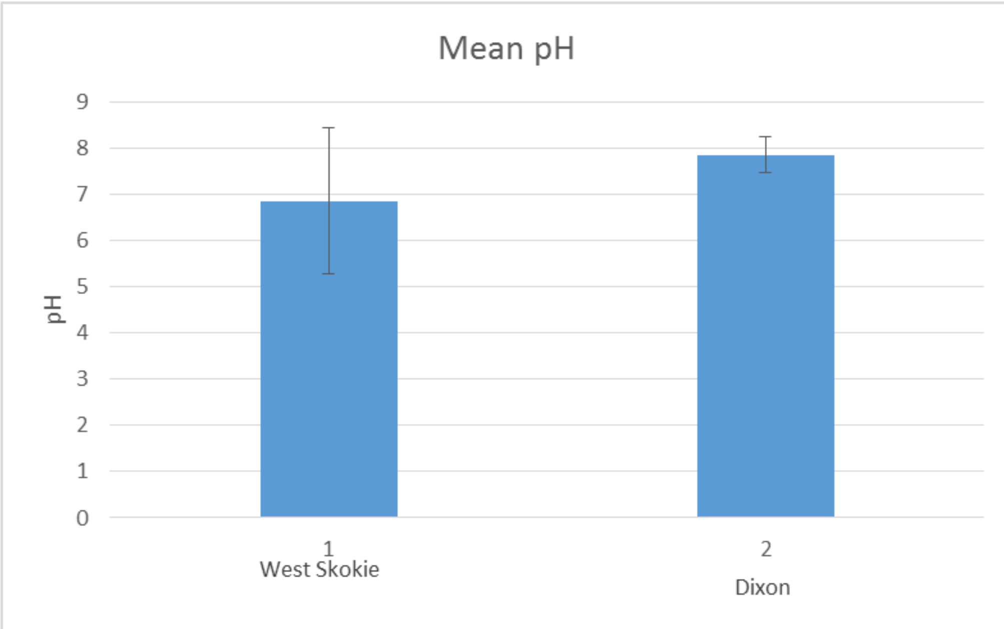


Figure 8: Mean pH of West Skokie and Dixon

Table 4: Unpaired Samples Comparing Mean pH of West Skokie with Mean pH of Dixon

t-Test: Two-Sample Assuming Unequal Variances		
	West Skokie pH	*Dixon pH*
Mean	6.86	7.86
Variance	2.476190476	0.142857143
Observations	7	7
Hypothesized Mean Difference	0	
Df	7	
t Stat	-1.634847783	
P(T<=t) one-tail	0.073048285	
t Critical one-tail	1.894578605	
P(T<=t) two-tail	0.14609657	
t Critical two-tail	2.364624252	

In Figure 8 the mean pH at both wetlands are compared and are not statistically different. Note in Figure 8 that the standard error (SE) bar at West Skokie is greater than the SE bar at Dixon. The standard error equals the square root of the variance, and the variance at W. Skokie is much larger than the variance at Dixon. This larger SE at West Skokie is consistent with the pH range (5.0-9.0) being larger at West Skokie than at Dixon. In Table 4 the mean pH of Dixon and the mean pH of West Skokie are compared with a t-test and the p= 0.14 is >0.05, and so the null hypothesis is true and there is no statistical difference between the mean pH of Dixon and the mean pH of West Skokie wetlands.

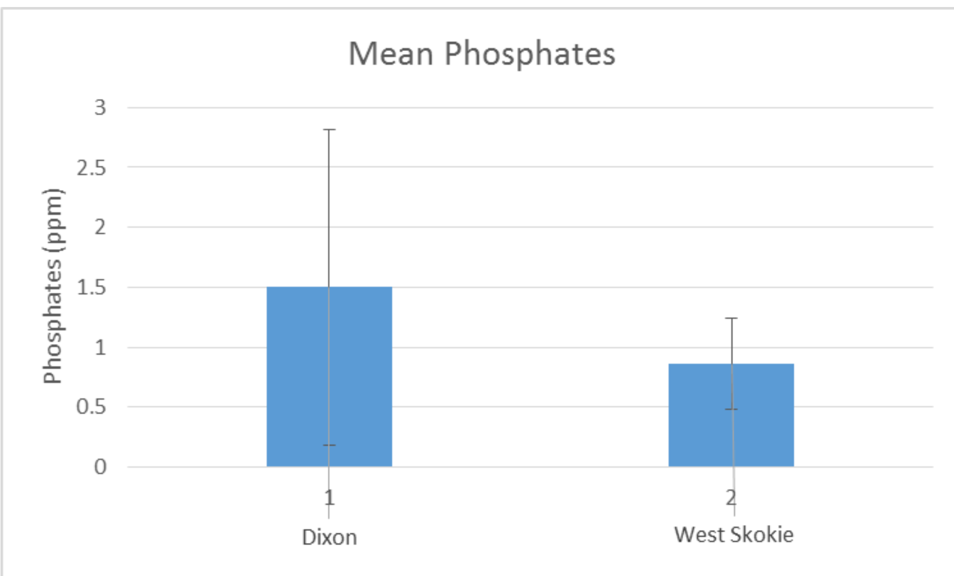


Figure 9: Mean Phosphate Levels at Dixon and West Skokie

Table 5: Unpaired Samples Comparing Mean Phosphate at Dixon and Mean Phosphate at West Skokie

t-Test: Two-Sample Assuming Unequal Variances

	Phosphate Dixon ppm	*Phosphate West Skokie ppm*
Mean	1.5	0.86
Variance	1.75	0.14
Observations	7	7
Hypothesized Mean Difference	0	
df	7	
t Stat	1.236245076	
P(T<=t) one-tail	0.13	
t Critical one-tail	1.894578605	
P(T<=t) two-tail	0.26	
t Critical two-tail	2.364624252	

In Figure 9 the mean phosphate values at West Skokie and Dixon are compared and Dixon's mean phosphate is greater than W. Skokie mean phosphate but not statistically significant since p=0.26, as seen on Table 5. The standard error at Dixon is greater than the SE at W. Skokie. Phosphate level in general ran about 1.0 ppm most of the time at both wetlands, but increased to 5.0 ppm at Dixon after the largest rainfall of 5 inches, see raw data appendix. Table 5 shows the results of the t-test comparing the mean phosphate levels at Dixon to the mean phosphate levels at West Skokie.

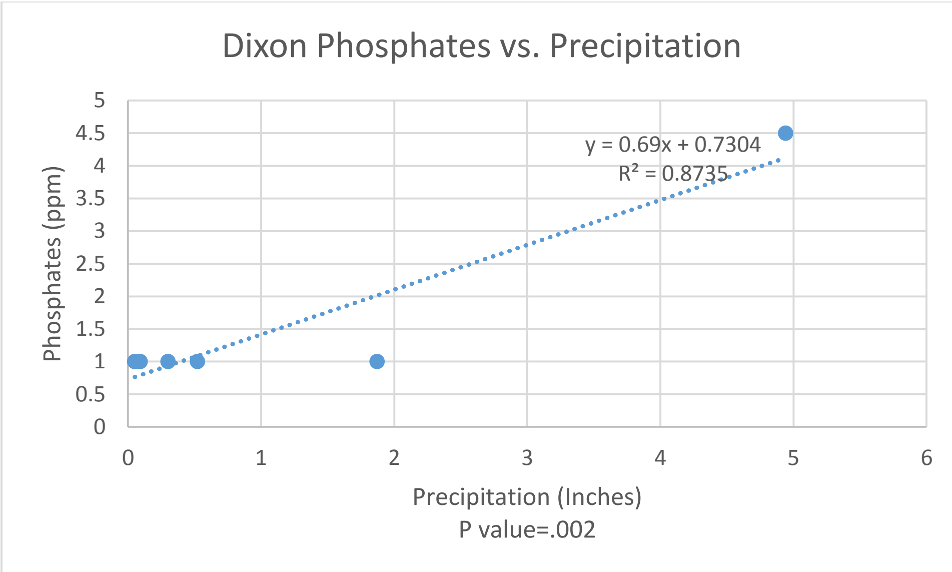


Figure 10: Dixon Phosphates vs. Amount of Precipitation

Table 6: Dixon Regression Analysis: Phosphate vs. Precipitation

SUMMARY OUTPUT Dixon

Regression Statistics	
Multiple R	0.934628639
R Square	0.87
Adjusted R Square	0.848236832
Standard Error	0.515349924
Observations	7

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	9.17207228	9.172072	34.53528	0.002025543
Residual	5	1.32792772	0.265586		
Total	6	10.5			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*
Intercept b	0.73	0.234715378	3.111816	0.03	0.12703594
Precipitation (inches)m	0.69	0.116779601	5.876673	0.002	0.386083995

In Table 6 the Dixon Regression Analysis of Phosphate vs. Precipitation shows an R^2 of 0.87, meaning that 87% of the variation in phosphate values can be explained by precipitation. The P-value=0.002 is statistically significant and the slope of the line is not zero. Figure 10 shows a positive slope=0.69, which means that phosphates went up with increasing amounts of precipitation.

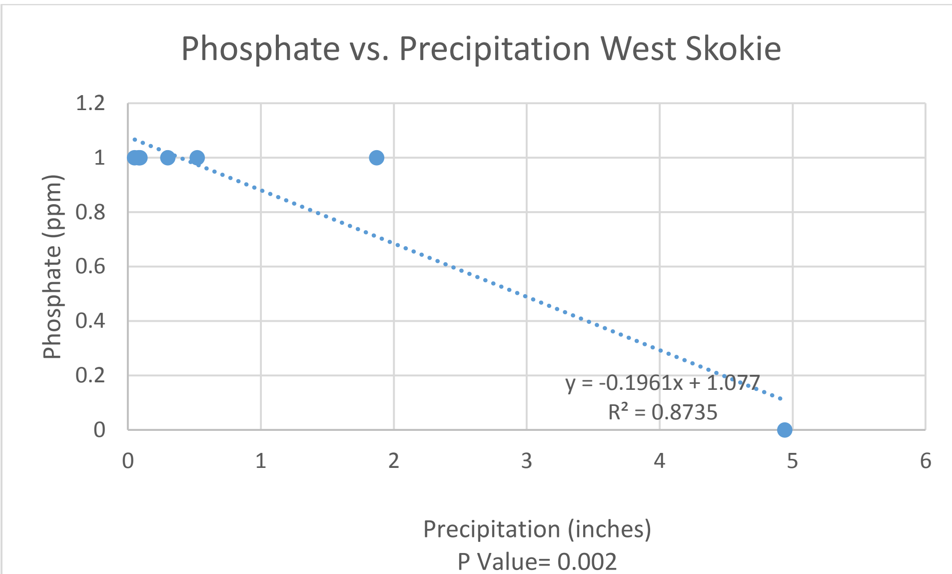


Figure 11: Phosphates vs. Precipitation West Skokie

Table 7 : West Skokie Phosphate vs. Rainfall Regression Analysis

SUMMARY OUTPUT	West Skokie			
Regression Statistics				
Multiple R	0.934628639			
R Square	0.873530693			
Adjusted R Square	0.848236832			
Standard Error	0.147242835			
Observations	7			
ANOVA				
	df	*SS*	*MS*	*F*
Regression	1	0.748740594	0.748740594	34.53528434
Residual	5	0.108402263	0.021680453	
Total	6	0.857142857		
	Coefficients	*Standard Error*	*t Stat*	*P-value*
Intercept	1.077031135	0.067061537	16.06034084	1.70474E-05
Precipitation (inches)	-0.196078719	0.0333656	-5.876672897	0.002025543

In Table 7 the regression analysis West Skokie phosphate levels and rainfall show a R^2 of 0.87 meaning that 87% of the variation in phosphate values can be explained by precipitation. P-value= 0.002 showing that it is unlikely that the slope of the graph will be zero. The slope is negative 0.19 the P levels decrease with increasing precipitation. Figure 11 shows the negative linear relationship between P levels and precipitation with a slope of -0.19. In general the phosphate levels were 1.0 ppm except after the largest rainfall of 5 inches the phosphate level was zero.

Table 8. Wetland Macroinvertebrates at 1 ft. depth

Date	**West Skokie** Wetland	**Dixon** Wetland
10/25/2014	15 Bithyniid snails	2 Planorbid snails, 4 Bithyniid snails
11/8/2014	9 Bithyniid snails, 1 fingernail clam, 1 nonred aquatic earthworm	6 Bithyniid, 4 Panorbid Snails, 1 Aquatic Earthworm

Table 8 is the raw data results of the Dixon and West Skokie wetlands, and shows that the majority of the macroinvertebrates found in the samples were scrapers which could indicate a hypereutrophic environment. Of note these macro invertebrate samples were taken in October and November at the end of the growing season.

Table 9. Relative Frequency of Bithyniid Snails and Planorbid Snails (# of samples that the species occurred in)

West Skokie		Dixon
Bithyniid Snail	100%	100%
Planorbid Snail	0%	100%

In Table 9, 100% of the samples at West Skokie and Dixon had Bithyniid snails and 100 % of the Dixon samples had Planorbid snails.

Table 10: Proportion of Bithyniid Snails and Planorbid Snails (n species/ total # of species)

		West Skokie	Dixon
Bithyniid Snail	10/25	15/15= 100%	4/6=60%
	11/8	9/11=81%	6/11=54%
Planorbid Snail	10/25	0%	2/6=33%
	11/8	0%	4/11=36%

Table 10 shows that the proportion of Bithyniid snails was 81-100% at W. Skokie and 54-60 % at Dixon, showing a large proportion of these grazers. The proportion of Planorbid snails was 0% at W. Skokie and 33% at Dixon.

DISCUSSION:

The results support the hypothesis that rainfall runoff can affect wetland pH levels. The pH decreased an unhealthy level of 5.0 with increasing rainfall at W. Skokie, but not at Dixon. This difference in results could be from the recently added large lawn which is adjacent to the West Skokie wetland. The Dixon wetland is surrounded by restored and virgin prairie and there are no visible lawns from the wetland, although there are suburban lawns about 10 minutes away by foot. The West Skokie wetland may get more volume of acidic lawn runoff since it is exposed to more lawn area where the ground doesn't absorb rainfall as well as the prairie surrounding the Dixon wetland. Lawn fertilizer has phosphoric acid which could contribute to decreasing the pH. The macroinvertebrate sampling showed primarily only Bithyniid snails, which typically can survive in pH= 5.0. A pH of 5.0 is harmful to wetland benthic bacteria, some eggs and larvae, mayflies, some clams and snails, and mollusks (Robertson-Bryant, Inc. 2004). However the fact that the pH averages of the wetlands were not statistically different argues against the lawn at West Skokie having an effect on the pH of the wetland. Of note, the West Skokie had a pH reading of 9 which is also considered borderline harmful since it is too alkaline. The fact that the pH fluctuated so much at West Skokie is concerning and may indicated excessive runoff. The Dixon pH=8.0 is within the optimal range of 6.5-8.0, which is consistent with healthy wetland pH values (US EPA 2012). Skokie Valley River testing at the Deerpath test station in Lake Forest, IL, located several blocks away from the Dixon wetlands tested in this study, showed pH= 7.65, so this is fairly consistent with Dixon's pH (Flood 2014). These pH results support the hypothesis that rainfall runoff can affect the pH of nearby wetlands.

The results support hypothesis that rainfall runoff can affect phosphate levels. Phosphate levels were elevated at both wetlands and were at an unhealthy levels > 0.7 ppm (Kalec et al 1995). The test kit defined healthy phosphate at <0.1ppm, but the lowest level of phosphate that the test could pick up was 1.0 ppm. It could be that some of the 1.0 ppm phosphate readings were false readings since the test describes different shades of light blue as either 1.0 or trace, and was difficult to interpret at times**.** At the Dixon wetland the phosphate stayed at 1.0 ppm throughout the study period except after the largest rainfall of 4.94 inches when the phosphate measured 4.5 ppm. This PO4 level is similar to the elevated PO4 levels found in lawn runoff in study done by Garn in 2002. It would be interesting to have water temperature measurements since more soluble phosphate is released from wetland sediment as the water temperature increases and this value was obtained at the end of August when the water could be warm (Smil 2000).

At the West Skokie wetland the phosphate levels stayed at 1.0 ppm except after the largest rainfall of 4.94 inches when the phosphate level read as no trace which may have been affected by the fact that the pH decreased to 5.0 that same sample day**.** In acidic hydric soils decreasing the pH of the water causes soluble phosphate to precipitate with ferric ions and aluminum ions (Reddy et al 2005). More water samples are needed to understand if phosphate levels were affected by rainfall runoff since most of the readings were at 1.0 ppm at both wetlands. However the statistical tests indicate that there is a relationship between phosphate levels and amount of precipitation supporting the hypothesis that rainfall runoff can affect the phosphate levels of wetlands.

The nitrate levels at both wetlands were within a healthy range of less than or equal to 1.0ppm. Healthy wetlands tend to have nitrate levels of less than or equal to 2.0 ppm.The nitrate test kit used in this study tests for levels between 2 to 10 ppm with trace amounts being recorded as 1.0 ppm. Only 4 water samples from each wetland were tested because the kit was not available on other test days. At the West Skokie wetland after the largest rainfall of 4.94 inches, both nitrates and phosphates were not detected but the pH had decreased to 5.0 on the same sampling day which may have affected the solubility to the nitrates.

The most numerous macroinvertebrate found at both wetlands was the Bithyniid snail. The Bithyniid snail is considered facultative or somewhat tolerant of pollution, and if it is found in large numbers it can indicate polluted water from nutrient rich (Voshell Jr., 2015) fertilizer runoff. The presence of mainly these macroinvertebrates at both wetlands is indicative of hypereutrophic water with increased amounts of algae that these scrapers like. This would go along with the abnormally high phosphate levels found at both wetlands.

The Planorbid snails were only found at Dixon. The Planorbid snail is considered facultative to somewhat tolerant of pollution, and because it has hemoglobin in its blood it is also able to live in water with low dissolved oxygen content (Voshell, Jr., 2002). The presence of Planorbid snails at Dixon but not at West Skokie could indicate lower dissolved oxygen content at Dixon wetland which can be found in small, shallow warm water, but the water was not warm when these macroinvertebrate samples were obtained. These snails are collectors or filter feeders which could indicate nutrient rich water.

Only one aquatic earthworm was found at each wetland, and one aquatic fingernail clam which can both tolerate some amount of pollution. When red aquatic earthworms are present in large numbers it can indicate pollution, however this was not the case in this study.

Based on the small number of different macro invertebrate species found it seems that sampling should be done earlier in the year before it gets too cold, so that higher concentrations of diversity among the macro-invertebrates could be possible. The grazer type of invertebrates found are consistent with the elevated phosphate levels found at both wetlands and probable hypereutrophic states. According to the IOWATER Volunteer Water Quality Monitoring Key the Planorbid and the Bithynid snails are designated as semi-tolerant to pollution, which would go along with the elevated phosphate levels and some abnormal pH levels in the study waters.

Some weakness in this study include the small amount of water samples used in this study, and the fact that there was not a wide range of precipitation that occurred on the sampling days, i.e. it was relatively dry. There was difficulty in reading trace amounts versus 1.0 ppm with the phosphate test kit and not knowing what trace amounts means as far as ppm is concerned. The macroinvertebrate collections should have been done during the late spring to early fall, instead of the late fall when some macroinvertebrates are normally not present even if they are present during the summer months. So the macroinvertebrate data in this study is really not a complete picture.

Further studies of these wetlands should include more pH, nitrate, and phosphate water sampling with ideally more sampling days that are rainy, and macroinvertebrate sampling from late spring to early fall. Water temperature measurements could be recorded on all sampling days to help with interpreting solubility changes of phosphate and nitrate. It would also be interesting to get trends on the local amphibian populations as another bioindicator of wetland health.

Monitoring the health of these wetlands is important for making decisions on how to keep the wetland water healthy by various interventions such as changing the drainage patterns going into the wetlands, limiting nearby lawn development, and planting various plants that help absorb the runoff.

In summary these results support the hypothesis that rainfall runoff can effect phosphate and pH levels in wetlands. Water chemistry tests at both wetlands demonstrated unhealthy mean phosphate levels and a relationship between precipitation and phosphate levels. The pH at West Skokie did demonstrate a statistically significant decrease in pH with increasing rainfall and supports the hypothesis that possible lawn runoff can decrease pH in wetlands. The macroinvertebrate populations were consistent with hypereutrophic water which would be consistent with the elevated phosphate levels found at both wetlands.

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APPENDIX A: RAW DATA

The nitrate level appeared to be stable at 1.0 ppm after all of the rainfalls except the comparatively small rainfall of 0.3 inches at which time there were no traces of nitrate. There was no available nitrate testing kit on 10/14/2014, 3/22/15, and 3/27/15 so n/a is marked in the nitrate column for those dates.

Table I. East Dixon Wetland Water pH, Nitrate, Phosphate and Precipitation

Dixon	Date	Precipitation (in)	pH	Nitrate	Phosphate
	8/5/2014	0.3 inches	8	none	1.0 ppm
	8/22/2014	4.94 inches	8	1.0 ppm	4.5 ppm
	9/6/2014	.52 inches	8	1.0 ppm	1.0 ppm
	10/4/2014	0.05 inches	8	1.0 ppm	1.0 ppm
	10/14/2014	1.87 inches	7	n/a	1.0 ppm
	3/22/2015	0.08 inches	8	n/a	1.0 ppm
	3/27/2015	0.09 inches	8	n/a	1.0 ppm

After the most significant rainfall of 4.94 inches there were no traces of nitrate. However, nitrate was present at 1.0 ppm during all other collection dates when the nitrate testing kit was available for use.

Table II. West Skokie Wetland Water pH, Phosphate, Nitrate, and Precipitation

West Skokie	Date	Precipitation (in)	pH	Nitrate	Phosphate
	8/5/2014	0.3 inches	9	1.0 ppm	1.0 ppm
	8/22/2014	**4.94 inches**	**5**	**no traces**	**no traces**
	9/6/2014	.52 inches	5	1.0 ppm	1.0 ppm
	10/4/2014	0.05 inches	8	1.0 ppm	1.0 ppm
	10/14/2014	1.87 inches	6	n/a	1.0 ppm
	3/22/2015	0.08 inches	8	n/a	1.0 ppm
	3/27/2015	0.09 inches	7	n/a	1.0 ppm