The environmental and social impacts of urban runoff on eutrophic lake ecosystems

The University of Wisconsin, Madison
Geography 565 Research Project
Tuesday December 13, 2010

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**Research Question:**

How does urban stormwater runoff affect the Lake Mendota ecosystem, fish populations, and subsistence anglers? How are stormwater contributions identified and dealt with on campus?

**Abstract**

Unraveling the issue of urban runoff is a daunting task to bring into focus because of difficulties identifying runoff sources and developing cost-effective solutions. The need to find solutions stems from issues of eutrophication that jeopardizes lake ecosystems and fish populations. The contributions come from sources ranging from residencies to businesses, and actors ranging from individuals to organizations. As the urban landscape expands, understanding surface and stormwater runoff is a necessity for responsible development and should take into account the resulting impacts on fish and the people who rely on them for sustenance.
Introduction

Lake Mendota, the largest of the Yahara Lake chain, the city water source and sustenance for Madison, represents decades of water management policies. These policies have been focused on runoff from the rural and urban Madison area, focusing primarily on urban stormwater runoff from the Isthmus of downtown Madison.

This goal of this project is to find a correlation between the increase in Madison's urban landscape and its relationship to the health of Lake Mendota and its fish populations. The health of the lake and fish populations are important as they provide sustenance for recreational fishers around the area. People’s livelihoods rely upon the fish in the lake; when the fish aren’t healthy because of the over-polluted lake, they tend to suffer. The paper brings together many major topics that could easily be one single research project. Keeping this in mind, the linear progression of steps that occur has to be well understood in order to establish a connection between the information. This can be seen in a flow chart (Figure 1) to dismiss any confusion.

The urban landscape, in relation to this project, is seen as any sort of developed land in and around a city center. In the case of Madison, downtown is the major portion of the urbanized area but dense residential areas surrounding downtown will be considered developed because they pose as big of a threat to urban runoff. It is important to understand that urban runoff does not include any sort of sewage system or treated water. Stormwater is the primary focus for urban runoff because it acts as an untreated water source that inevitably flows into lake systems.

Water policies have changed to counteract the increased amount of direct water runoff into Lake Mendota. Surface drainage systems will be analyzed to understand Madison’s structural policies around the city. The runoff quality of the water is important when considering its impact on the lake itself. Huge amounts of contaminants are dragged into the lake from many
different sources such as construction areas, lawn fertilizers and rooftops. There is an extensive
array literature on stormwater chemistry research around Madison, which is useful in trying to
understand the primary pollutants. Phosphorus is the expected major factor, which is considered
the main limiting nutrient in blue-green algae eutrophication in many lakes.

These algae blooms are a distasteful addition to the resource quality of Lake Mendota and
are expected to have numerous effects on the fish populations. The ecosystem of Lake Mendota
is clearly not as stable as it originally was and cannot continue to lose its usefulness to the people
who rely upon a stable population of fish. Even if the fish aren’t decreasing in number, the
number of toxins and unhealthy contaminants inside them could be increasing. This is a major
cause for concern when there are people eating the fish every day.

Much of the University of Wisconsin, Maison campus is located along the shore of Lake
Mendota near downtown and is undoubtedly a primary source of contaminated urban runoff.
Landscape observations and interviews will lead us to draw conclusions as to what can be done
on campus to counteract stormwater runoff. The surrounding inhabitants that all rely upon the
lake directly effect the cleanliness of Lake Mendota. Focusing efforts on campus is a more
realistic goal that can still have large positive effects on the lake’s health.
Literature Review

Lake Mendota has always been a highlight of the Madison area. However, Mendota's unhealthy state was only noticed because of its unattractive appearance. Considering how quickly the urban landscape has evolved in the Madison area, there is little doubt that urban stormwater pollution is having affects on the healthiness of the lake. According to the city of Madison census and state populations estimations, the area of Madison increased from 4.9 square miles in 1850 to almost 70 square miles by the year 2000 (Dave Larson, 2000). This rapid urbanization has greatly increased the amount of surface water making its way into Lake Mendota.

The changing appearance of the lake was first recognized in the 1880’s, during which time the limnology department at the University of Wisconsin was founded. Hydrology, climate and precipitation, populations, soil erosion and transformation lead the debate on the connection of the human impact on lake ecosystems. Over a century of water quality studies have been conducted on Lake Mendota in order to understand the connection between eutrophication and pollution runoff. One of the primary contributors to the eutrophication process is agricultural non-point runoff that comes into Mendota from the Yahara River (Benson, 2006). While this provides a large portion of the pollution, the focus of this research is to determine how urban land development and use has lasting impacts on the lake. The change from diverse grasses and plant coverage to a smoother surface and coverings, such as streets and asphalt associated with urban development, alters the infiltration rates of precipitation to the ground (Ellis, 2010). Documented data show surface changes in these areas and possible effects. Possible, because for scientists to accurately measure true impacts with an ecosystem time line it would take thousands
of years to understand the full ability of the ecosystem to adapt to the changes (Turner, et. al., 1990).

One of the primary contributors to the eutrophication process is agricultural non-point runoff that comes into Mendota from the Yahara River (Benson, 2006). While this provides a large portion of the pollution, the focus of this research is to determine how urban land development and use has lasting impacts on the lake. The chief concern in urban areas is found to be construction-site sediment runoff (Wegener, 2001). Improper barriers and catchments allow nutrient rich sediment to rush off into the lakes through storm drains and little has been done in the past to curtail this issue. On the City of Madison website, one is able to locate all of the permit information for construction sites of a certain size or larger in the entire Madison area that have been reviewed by the Department of Public Works. Currently, three large construction sites on campus are listed: the Chazen Art Museum (Larry D. Nelson, 2009) expansion, the Exploration Center (Larry D. Nelson, 2008) on engineering campus and the new Union South (Larry D. Nelson, 2009) near Camp Randall. The construction permits are outfitted with a universal soil erosion equation that can be implemented with any construction site relative to their location. All three of the sites state the total amount of soil loss due to erosion in tons/acre of land. The three construction sites show formidable amounts of soil loss that will make their way into the surrounding lakes. Union South and the Exploration center are close to the watershed border for Mendota and Monona so their particulate runoff could affect both lakes.

Construction is not the only contributing factor in pollution runoff. Streets, houses, apartments, neighborhoods and businesses all contribute to the collection of the runoff. By changing the ground cover with roads, sidewalks and buildings has altered the permeability of the land surface. Many studies exist that quantify runoff pollution in urban residential areas of
Madison that show the massive impact single family households can have on the health of non-point pollution entering the lakes. These will be discussed further on. Because of the diversity of pollution point and non-point sources, local and state policies have to stretch many boundaries. All bases have to be covered for stormwater runoff sanitation to be effective for returning Lake Mendota back to its healthy state.

Recently the Department of Natural Resources passed their updated runoff rules to the state assembly and senate. These rules aim to keep down the input of suspended solids and nutrient rich runoff from point and non-point polluters. By definition point pollution refers to “end of pipe” (storm drain) contributions while non-point comes from surface runoff into the lake. Development of land affects the water in both fashions; through improper construction practices and also permanently by changing the face of surface runoff (Dane County Land Information Office, 2000 & State Highway Commission of Wisconsin, 1937). The rules proposed were passed by the Agricultural, Environment, and Natural Resources committees in the State Senate and Assembly showing that concern for the lakes has become a political priority.

With the recent passage of the DNR’s runoff rules there was a compromise sought between the numerous stakeholders of this issue. Agriculturalists, developers, manufacturers, environmentalists, and municipalities were involved to reach a compromise on how to reduce runoff pollution. Rather than impose a system of bricks and mortar by creating or expanding water treatment facilities, the rules allow for an adaptive management process. Through this process buffer zones that offer natural vegetative filtration are a more cost effective and lasting solution than building and maintaining treatment facilities to reduce the nonpoint runoff into the lake. For construction and developers limits are set at 5 tons of sediment per acre per year and
require a storm water discharge permit, which is aimed to bring down the cost of water treatment.

The City of Madison has as part of its annual budget a portion of funds for not only for the maintenance for the system, to keep it unclogged and working, but also for updating and applying new construction phases for the system. It certainly seems to be easier to deal with and affect the ground water runoff in rural surroundings than the city. Urban developments such as gutters, storm drains, retention ponds and collection system all provide for the belief of control of the runoff; these run throughout the city and surrounding suburbs. The organization of runoff from residential and industrial areas needs to be reevaluated to attempt to reduce the rate of collection and discharge of the surface water. The implementation of techniques to create a more permeable ground cover in the urban environment has started. With rain gardens, rain barrels and terracing yards can change the rate over time of surface runoff into the storm system in residential neighborhoods (Mueller, G. D. and Thompson, A. M.; 2009).

As reported by Wisconsin DNR, non-point pollution can be directly connected to the volume of storm drain outlet discharge. The concentration of debris discharged from the urban storm water system is releasing increased amounts of contaminants in a much more restricted area becomes these non-point sources. This volume of discharge has increased the erosion and compositions of soils in the discharge areas. The collection and redirecting of surface drainage both in urban and rural areas account for this volume increase (Harder, 1994).

By understanding how the land uses and developmental structures around Lake Mendota contribute to surface runoff will help create a plan to utilize methods to reduce the quantity and increase the quality of the water. Retaining the water before it reaches lakes allows time for sediment and nutrients to settle. It is important that policymakers and conservationists determine
the nutrient with the highest potential to harm lake ecosystems so resources and funds can be focused and begin to have positive effects. Much scientific research around the Madison area points towards phosphorus as being the most important factor when concerned with urban runoff and lake contamination.

A newsletter devoted to stormwater runoff in Madison collects information from scientific research completed by Dr. G. Fred Lee and his associates (Anne Lee, G. Fred Lee; 2007). The research entailed the collection of urban water samples and testing them for nitrogen and phosphorus that make their way into the lake. It ends the research with a conclusion stating a specific type of algal growth-promoting phosphorus, soluble ortho phosphorus, which should be a focus for conservationists. Although it is nice to pinpoint a specific type of phosphorus to contain, I think our project is much more general in the respect of management programs. Ideally we would want chemical fortifications before runoff made its way into the lake, but a more feasible application of conservation in Madison and the campus area would involve stopping all types of phosphorus as sediment from the storm systems.

To get a different sense of phosphorus levels throughout Madison and on campus, William F. Cohen and G. Fred Lee (1976) presents findings with several test locations. The locations were chosen for high, medium and low-density residential areas, a campus area and a construction site. With the collected runoff water, samples were tested for different forms of organic and inorganic phosphorus. Much of the literature is extremely scientific and tough to understand without a good organic chemistry background. The details presented are too extensive for our project, which is going to focus more on the general runoff and presenting a barrier before it enters into Lake Mendota. In the conclusion section they finish by saying their information could be calculated to determine a total phosphorus load from urban runoff but they
do not bother to do so. Unfortunately, this final number would have probably been the most useful of all their information.

A project, by R. T. Bannerman, D. W. Owens, R. B. Dodds and N. J. Hornewer (1993) studies surrounding residential and industrial areas of Madison for Stormwater runoff contaminants, which will be useful for understanding the general public’s affect on stormwater runoff. This project looked at many different chemical factors that came from many sources that we do not have time to test or observe. Most importantly, it recorded levels of total and dissolved phosphorus from all of its tested areas. The significance of their findings shows the highest levels of total and dissolved phosphorus in residential areas. Residential areas, especially in lawns because of fertilizers can be equated to the campus area. The campus area uses fertilizers in their green space and obviously includes streets, roofs and driveways. This paper presents the information in a seemingly non-biased manner with its raw data. In the conclusion they do provide some future insight into how development of runoff technology can help. They seem to calculate that by fixing only two of the major input sources of contaminants will bring levels below what is considered critical for lake runoff. This is good to see, though it may be optimistic, since campus provides only a small fraction of the Mendota watershed. It shows efforts on campus would not be worthless relative to the lake size.

Most of the literature involving stormwater chemistry, especially those listed above, presents statistical-heavy information that can get jumbled when all thrown together. This is especially true for readers without an extensive water biology and chemistry background. The goal is to sort out the useful information pertaining to our project without losing key information from the article. All of the articles address phosphorus in runoff, which seems to be the biggest
contaminant from stormwater runoff; therefore the research will focus on phosphorus as the main cause of overly eutrophic lakes.

To establish a strong connection between the phosphorus and the health of fish populations, one must understand the correlation between phosphorus and algae blooms. Richard C. Lathrop explains the effect eutrophication has had in the Madison chain of lakes, in causing vast amounts of blue-green algae bloom growth (2007). Following Madison’s eradication of direct wastewater inputs into Lake Monona in 1936, and the diversion of effluents into Lake Mendota in 1971, Lathrop notes that the persistent algae blooms have been spurred by agriculture and urban non-point runoff. He gives an excellent overview on how algae has been historically caused and the affects changing land use has had on runoff, but stops short of any effects these algae blooms may have on humans. This was not the primary focus of the paper, but he gives the reader no real cause for concern in the prevention of algae formation.

Further research shows that there can be a real cause for concern for increased algae blooms in lakes. A scientific article by H. W. Paerl, et. al. (2001) presents specific types of toxins created by algae that can make their way into the food chain and have negative effects on fish populations. There is also reason to be concerned because of blue-green algae’s ability to totally block out light from getting through to other producers in the food chain. This, along with the creation of hypoxic conditions can have disastrous effects on lake food chains and ecosystems. The Wisconsin DNR covers health concerns with eating fish from lakes with high abundances of blue-green algae (2009).

It is also important to gather just whom the contaminated fish are affecting. Many local scholars address the lack of local cultural knowledge and understanding demonstrated by institutional scientific experts when developing risk assessment policies and procedures to
protect sustenance anglers from harmful affects of contaminated fish consumption. Jim Powell, et al. (2010) argue that more information on race and class fish consumption would provide for more culturally appropriate education, from language-specific warning signs to public awareness programs that address disproportionately affected minorities. They admit that there is no concrete solution to defending against anglers consuming fish with dangerous levels of toxins, but lay out guidelines for reaching out to local health agencies and elected officials to create change.

A good portion of this article by Jim Powell et al. is dedicated to accomplishments or projects created and implemented by Madison Environmental Justice Organization, some which have ultimately failed. A particular fish-consumption warning sign project, which was pushed by the organization in earlier publications, has proven to be mostly ineffective, and other projects have had the same fate (Powell & Powell 2008). On one hand, this horn-blowing about all the things the organization has done could be seen as a group simply looking for attention, but on the other hand, learning about how and why these projects have been unsuccessful could prove valuable in moving forward with further solutions and also spread the issue into the public sphere. The latter of these two assumptions is probably the more appropriate reason for their including of past efforts with anglers.

Making these major connections between what is causing the pollution that contaminates the fish, and which subsequently harms the humans that consume these fish, is vital in understanding what can be done to make effective change both on campus on beyond. It is also critical to collect data on the people who consume harmful amounts of fish, so we may better concentrate public outreach to impacted communities.
Methods

Interviews

John Magnuson – University of Wisconsin, Limnology Department

In order to understand what has motivated changes in legislation concerning runoff pollution John J. Magnuson Emeritus Professor of Limnology was sought for an interview. As co-author of Long-Term Dynamics of Lakes in the Landscape Magnuson was able to offer insight as to how society’s perspective of lake management has changed along with the landscape. He also was extremely helpful in telling us about campus projects that are happening to combat the amount of runoff into the lake. In a chapter specifically on Lake Mendota, Magnuson’s book points out that with 15,000 lakes in Wisconsin and a water centered tourism industry it’s no wonder that economic impact plays a major role in the effort to keep Wisconsin waterways clean (Benson, 2006). Beyond tourism another economic aspect must be examined and that is of course the cost/benefit analysis of possible solutions.

John Reimer - Department of Public Works, City of Madison

To understand the current procedures implemented in the City of Madison an interview with the Department of Public Works that oversees the storm sewer system, will give an official perception of the circumstances surrounding the effort of runoff control into Lake Mendota and Monona to improve water quality and the local fisheries.

Madison Construction Workers

The construction workers that they were required to the City to clean out the drain screens following a rain event. The drain had the landscape fabric mesh/cloth to capture as much
sediment as possible. Even with this extra effort to collect and contain debris still allowed some to drain into the storm sewer system.

Candy Schrank – Toxicologist, Wisconsin Department of Natural Resources (Email)

In order to establish a strong connection between phosphorus affecting algae populations and their effect on fish populations, we turned to some people who work for the DNR who understand fish toxicology and ecosystems that have negative effects on their populations. Candy provided us with very useful information and with other scientific articles that are present in our secondary findings.

Maria Powell, PhD - Executive Director – Madison Environmental Justice Organization

Dr. Powell has conducted extensive research on the sustenance-angler population in Madison. We met with her to receive documents covering this research and to gain insight on approaching these anglers as an outsider. She has experience interviewing anglers and prepared tips for us to avoid offending or upsetting the anglers. She also has a wealth of knowledge of past developments concerning the protection of urban sustenance anglers. She is experienced in handling pressing issues in the environmental justice movement such as combating degrading runoff leading to the pollution of Lake Monona, Lake Mendota, and their aquatic species.

Interviews with Anglers

In order to gain a better understanding of how the depleted fisheries directly affect members of the community who use them as a source of sustenance, we resolved to interview shoreline fishermen and women on the shores of downtown Madison’s lakes. The health of the
sustenance fishing community is of the utmost importance to us, because unlike other recreational and economic uses of the lake, the livelihood of these anglers and their families is highly dependent on the cleanliness and productivity of the lakes. Interviewing these men and women turned out to be rewarding for our research project as we formed informal relationships with some of the fishers, allowing us to acquire insight on their experience, which others rarely hear. Cognizant of the fact that many of Madison’s sustenance anglers speak Hmong, Spanish, and other foreign languages, we decided to interview only those who could effectively communicate in English. We recognized that this would jeopardize our results by eliminating a large and culturally diverse sample of sustenance anglers, but considering time and language resource limitations, we found it necessary in order to obtain enough interviews to formulate clear results.

Landscape Observations

In order to better understand the effect that campus has on Lake Mendota, landscape observations were made along the lakeshore to determine the location of as many storm drains as possible. The locations were mapped over the Mendota watershed layer along with construction sites on campus to give a better perspective of the Universities non-point sources. (Figure 2).
Results

For more than a century now Lake Mendota has been the focus of extensive monitoring and experimentation with both cleanup of pollutants and prevention of detrimental contributions (Magnuson, 2006). The issues of urbanization that pose the biggest threat to water quality is the process of changing the landscape through development and the resulting landscapes susceptibility to surface runoff. The city of Madison is entirely aware of the runoff effects and works on preventing and limiting the amount of untreated stormwater from entering the lake. Their primary concern is of the wellness of the people of Madison, which is partially a product of the healthiness and safety of the Yahara Lakes and their ecosystems (City of Madison, 2007). The way in which runoff impacts lake ecosystems and fish populations will be shown as a condition of varying concern. Two different approaches to how fish are affected are through a chemical reaction causing hypoxia as well as blue-green algae presence which impairs primary production and as a result the lakes food chain.

The watershed basin, approximately 9,566 acres, drains into Lake Mendota and accounts for 25 percent of the 38,247 acres in the city of Madison (Figure 5). Combining this with the Lake Monona drainage watershed of 8,017 acres the two equate to 46 percent of the land surface in Madison (John Reimer, 2010). This gives us a view of the scale of the problem. Runoff into lake Mendota, as stated previously, comes from many more places than just urban areas. 70 percent of the pollution into Lake Mendota comes from agricultural practices while the other 30 percent is urban influenced (John Magnuson, 2010). Lake Monona’s pollution, on the other hand, comes from more than 50 percent urban contributions. To continue focusing on Lake Mendota, though both would be ideal, will inevitably contribute to the health of Lake Monona downstream.
The Madison area urbanized very rapidly because of the downtown area being squeezed into the isthmus. The buffer of land was therefore, originally quite small between development and the water. Typically water will have time to seep into the ground and filter before the feeding nutrients move into the lake. It is easy to misunderstand the concept of a buffer between city and lake because it may seem as solely the shoreline of the lake from preventing water flowing in directly. John Magnuson describes this concept as too narrow, “Many people see buffer strip as only the shoreline of the stream or lake... well those are all interrupted by tributaries or storm sewers and so the management of the buffer strip is actually not just the shoreline, it’s the whole area of [Madison]... Every house, business and park in Madison is on the storm sewer drainage system. At one time when you didn’t have the storm sewers, the water would seep in and get to the lake, but now the whole town is as if it is on the shoreline.” (John Magnuson, 2010).

The City of Madison Engineering office oversees the storm water system throughout the city. The storm system is designed to control urban flooding and improve water quality through BMP (Best Management Practices). Each watershed has in place vast infrastructure of piping varying in sizes needed to carry the surface water load. Lake Mendota has 131 output sources and Lake Monona has 202 outfall basins or pipe sizes 36 inches or greater.

The city of Madison has many ordinances and rules set to help reduce the amount of pollution going into stormwater. More street sweeping and leave pickup keeps nutrients from being carried out during heavy rains while leaves are decomposing (Figure 7). It was never made an ordinance due to the complexity of regulation but leaf disposal “is a major issue” (John Magnuson, 2010). This isn’t enough in itself though. There are other smaller ordinances that add up. These include practices such as, picking up dog feces and placing labels on storm sewers to dissuade people from dumping toxic chemicals that can be harmful to the lakes (John Magnuson,
2010). With a focus on reducing the TSS (Total Suspended Solids) Madison evaluates the installation of underground collection basins as a big step in reducing debris flows (John Reimer, 2010). Operational maintenance within the system for both urban and residential areas is addressed in the same manner.

The city of Madison funds many projects that aim to reduce the amount of sediment reaching the lakes. One of the most successful projects involves catchment basins or detention ponds that hold erosion runoff before it enters into the lake and gives time for the sediment-filled water to settle into the catchment. Yearly reports show the level of total phosphorus in lake Mendota versus the total phosphorus found in detention ponds. The detention ponds tend to have much higher levels of total phosphorus around 100-200 m/l but is highly variable. Lake Mendota’s total phosphorus levels are much more stable over time, around 50-70 m/l. This shows that they achieve their goal of disallowing high phosphorus concentrations into the lakes (City of Madison, 2008 Clean Lakes Report) (Figure 3). The variability in the detention ponds is seen in a much closer time frame than the stable P levels of Mendota. Measurements this close together could be showing high P levels during periods of high rainfall and low P levels during low periods of rainfall.

Throughout Madison, much scientific research has been completed and compiled concerning urban stormwater runoff. An important thing to consider when concerned with stormwater is the chemical (nutrient) composition of the water making its ways into lakes, especially lake Mendota. Nitrogen and phosphorus present themselves as the major influential nutrients that conservationists should be concerned with in nearly every study (John Magnuson, 2010). Phosphorus is particularly important because of its known associations with positive algal growth in freshwater lakes.
Runoff has taken center stage in recent policy actions due to public outcry of the blue-green algae problem in highly eutrophic lakes (Wisconsin DNR). Citizens of the state that use the waters for recreation or sustenance have experienced a negative impact due to the input of nutrient rich sediment. When toxic algal blooms are at their peak in the late summer, beaches get closed due to the risk of health issues associated with coming into contact with the blooms. Pets have died due to ingestion of these toxic waters, but there is a greater effect that blue-green algae has had on the lake ecosystem.

Two organisms, blue-green algae and cyanobacteria, are largely abundant in lake ecosystems and present the possibility of negatively affecting fish populations. The phosphorus loading into Lake Mendota is largely a reason why blue-green algae (BGA) blooms are so frequent and unattractive. It has been observed that the BGA episodes that are so widespread can have major direct and indirect impacts on organisms such as freshwater clams (Prepas E.E., et. al. 1996) and more importantly, fish populations. The direct effects are those that contaminate the fish with harmful toxins (Paerl HW, et. al. 2001). These toxins are especially abundant in the livers of the fish and are known as hepatoxins (Schrank, 2010). These toxins are especially concerning because they can eventually build up and become harmful to humans when consumed. Other organic compounds produced by BGA are harmful to phytoplankton and zooplankton and can have adverse effects up the food chain (Paerl HW, et. al. 2001). A second form of harmful organisms that rely upon the nutrient loading into lakes are cyanobacteria. These photosynthetic prokaryotes produce similar toxins as BGA and others harmful to vertebrates known as cyanotoxins (Wiegand C. and Pflugmacher S., 2005) that have been known to produce massive fish mortality rates in lakes (Rodger H. D. et. al., 1994).
Under extreme eutrophic conditions fish may suffer from hypoxia due to lack of oxygen in the waters. These hypoxic conditions are a result of a chemical reaction with decomposing BGA. When BGA dies they create a sestan fall that eventually penetrates through the the thermocline of the lake and continues to decompose. The process of decomposition uses up oxygen supplies in the lower colder waters until fall. During fall months the lake cools and the thermocline breaks down which allows a remixing of surface and deep waters. The oxygen that is lost through the decomposing sestan fall would otherwise serve respiratory functions of cold water fish. Prior to the break down of the thermocline cold water fish like the lake herring and the sculp must venture out of colder waters to continue respiratory functions. As a result these fish may perish in warmer surface waters leading to fish kills. These hypoxic conditions have put fish like the lake herring and the sculp on the brink of extinction in Lake Mendota due to excessive amounts of phosphorus which allow blue-green algal growth (John Magnuson, 2010).

Blue-green algae, as opposed to other forms of algae, do not represent major parts of food chains in lake ecosystems, but they can still affect it in indirect ways. Lake ecosystems and food chains, similar to terrestrial, are hugely reliant upon primary producers converting sunlight into usable energy. BGA blooms in eutrophic lakes can get so abundant to the point where they reduce the amount of light penetration into the lake (Wisconsin DNR). The reduced light source can have effects on the photosynthetic algae that many primary consumers such as zooplankton rely upon for food. This can prove detrimental to the populations of fish who rely upon zooplankton and similarly larger fish and secondary consumers.

Runoff’s effects on lake ecosystems are evident in fish populations, which provide a large source of sustenance for many fishers around both Lake Mendota and Monona. The health of the fish can directly affect the health of consumers if they have harmful toxins built from algal and
cyanobacteria intrusion. Population sizes can be affected, which reduces the amount of fish available for consumption that can in turn, affect the health of anglers who rely on fish populations to stay fed.

As local fisheries in close proximity to Madison’s urban nucleus decline in quality or quantity due to the increased presence of algae growth and toxin drainage, anglers using the lake as a source of food are often left out of the picture. They do not receive imperative information that may influence their practices. It is evident that there is a significant disparity between the level of knowledge regarding the harmful effects of fish consumption among sustenance anglers and the recommended limitations and warnings issued by the Wisconsin DNR.

The logistical challenges of preventing damaging urban runoff into Madison’s lakes and the environmental justice issues it subsequently creates have not been readily accessible to the public thus far. The interviews that have been conducted by our group as well as those conducted by previous organizations have allowed us to provide insight into the lives of those who are affected the most by the deteriorating conditions of local urban fisheries. After participating in several interviews with sustenance anglers, a few major patterns emerged that have allowed us to pinpoint major issues faced by the English-speaking fishing community in Madison.

A large percentage of the anglers we spoke with were unaware of the risks associated with consuming too much fish from the lakes, and a lack of knowledge was displayed regarding the problems which local fisheries are faced with (Figure 6d & 6f). Amongst this majority, two overarching trends were indicated in the level of desired knowledge regarding the fish populations they depend on. There was a tendency among some anglers towards a lack of desire to obtain information pertaining to the risks they may be facing, possibly due to anxiety of what
they might find. Almost every angler we spoke with had been fishing on Lake Mendota or Monona for at least two years, and some as many as sixty (Figure 6b). A few joked that if there were damage to be done, it was now irreversible. One fisherman named Lance Davenport claimed to have been fishing Mendota and Monona for 62 years, and although he was well aware of the consumption warnings, said that to stop eating self-caught fish would put an end to the way of life he has been accustomed to since a young boy (Interview, Nov. 2010).

Some anglers who claimed to have little knowledge of how the fish populations are affected reflected an eagerness to learn more about the resource they use on a monthly, weekly, and even daily basis (Figure 6c). When posed with the question, “What have you heard about the health risks associated with eating fish from Mendota and Monona?”, some anglers became anxious and asked what information they were missing out on. This represents a lack of community outreach by officials in sharing with anglers the negative effects that the accumulation of toxins in the fish can have on the human body.

The interviews showed that a large percentage of shoreline anglers consume nearly all of the fish they catch (Figure 6a). Many were surprised that anyone would ask the question, “How much of the fish that you catch do you eat?”, as they simply assumed it would be foolish to waste good food if one had put in the effort to catch it. Others found the idea of catch-and-release to be foolish, and said that they almost always consumed each and every fish that they were able to successfully reel in. The majority of anglers noted that they fish the lakes an average of three to fives times a week, revealing that a large portion of their diet is made up of fish caught in Madison. These anglers, who consume all or most of the fish they catch, are primarily catching panfish, usually bluegill and crappie (Figure 6i). It is worrisome that the diet of these anglers is composed of multiple meals of bluegill or crappie per week or even per day, as the DNR
recommends limiting consumption of these species to one meal per week (WI DNR). People prefer cooking the fish in a variety of ways, but deep-frying, pan-frying, and baking the fish were the prevalent responses (Figure 6e). Some anglers said they leave the skin on the fish, which can hold concentrated levels of dangerous toxins (WI DNR).

Much to our surprise, many people who regularly acquire fish from Madison do not live in Madison or even its surrounding region (Figure 6h). People seeking better fishing conditions frequently make daily trips from the Milwaukee area, the Rockford, Ill area, as well as smaller urban areas in the southern portion of Wisconsin. Many noticed and had heard through fellow anglers that the Madison lakes are cleaner and fish are healthier in Mendota and Monona than their respective hometowns. It may be true that the lakes are cleaner than bodies of water in surrounding regions, but as our research has shown, Madison is not a safe haven from polluted waters and contaminated fish. As mentioned earlier, Madison’s location on an isthmus may make the city even more prone to urban runoff problems.

By speaking with local environmental activists, it is clear that the current challenge in keeping anglers safe lays in the communication of warnings and postings concerning fish consumption to them in an effective manner. The activists maintained that the focus, however, should also consistently remain on the ways we can reduce detrimental urban runoff that are slowly ruining the fisheries. Once a healthy, nutritious, and free source of food, the fisheries must now be warned against rather than promoted. This is especially frustrating to environmental justice advocates who know that sustenance anglers drawn away from the lake may resort to inexpensive and unhealthy processed foods in order to feed their families. Of particular interest in an interview with Dr. Maria Powell of the Madison Environmental Justice Organization was her response to a question asking how activists suggest alternatively feeding
the anglers who they warn from consuming significant amounts of local fish. Unlike Mr. Davenport who is convinced that pollution is an unavoidable aspect of modern ecosystems and must be accepted at moderate levels, Powell insisted that adequate steps should be taken to reduce harmful runoff generators in order to eventually return Madison’s fisheries back to a healthy, flourishing resource (Interviews, Nov 2010).

Although some of the anglers confessed wanting access to more information regarding the dangers of eating Madison fish, they are reasonably unenthusiastic about being told they can no longer safely depend on the free food source. Even with ample notification of the hazards associated with eating fish from Madison’s lakes, many of the anglers cannot afford to obtain food from elsewhere and will continue to consume the fish. The anglers who purposely avoid seeking fish consumption warnings for fear of what they might find is a prime example showing that the only fundamental way to create change is to reduce input of pollution into the natural resource they can no longer safely utilize.

Establishing a healthy connection between the lake ecosystem and anglers health can be worked on from the campus level. Considering the campus area isn’t regulated by the City of Madison, it is continually seen as having “…a reputation for being a bad actor.” (Magnuson, 2010). Considering how much research is conducted all around the campus, there is no reason why we should be perceived as a weak link in the chain of protecting the lakes that provide the community with so much information and sustenance.

Keeping Magnuson’s theory of an extended buffer, we performed landscape observations along the shoreline and on campus to understand how campus is having negative effects on the lake. Many of our photos show sediment from construction flowing into storm drains without prior sanitation (Figure 4a). There are also completely full storm drains that are simply holding
leaves like they were a teabag and allowing the nutrients to seep into the lake (Figure 4b). At a construction site outside of the Wisconsin State Historical Society, there is a form of erosion and sediment leaching prevention. There seems to be a machine pumping standing water into a porous bag that captures sediment and allows water to run through. Unfortunately there are many holes along the entire bag (Figure 4e). Along the waterfront there are storm drains consistently pouring into Lake Mendota from the storm sewer system in the Mendota watershed (Figure 4c & 4d). These exit points as well as the Mendota watershed are put together on a map with construction sites overlayed for an understanding of the sources of pollution on campus and their direction into the lake (Figure 2). The major construction projects on campus that affect Mendota are the addition to the Chazen Art Museum, the work in front of Science Hall and the Wisconsin State Historical Society, and the reconstruction of the Ecology Building on Linden avenue. Also, the recent completion of the Educational Science building can be considered a recent construction activity that has affected the lake.

As has been said before, the sediment from construction is one of the most important factors in stormwater runoff through the addition of phosphorus into lakes. In order to prevent sediment eroding with storms the Wisconsin DNR requires a number of permits and prevention methods. Besides their requirement of a legal permit that involves an inspector to visit the construction site multiple times, they list off many different means of physical erosion prevention. These are listed on their site and each has its own research and implementation strategy with it. The Chazen Art Museum construction near Library Mall is almost as close to the lake one can get for such a large construction project. The permit includes tables for the “Universal Soil Loss Equation for Construction Sites” that is used to estimate the total amount of sediment lost due to erosion at construction sites. According to the permit the Chazen Museum
of Art construction project estimates that 8.3 tons of soil per acre will be lost due to erosion (Larry D. Nelson, 2009). The construction area is about two acres in area, producing a total of 16.6 tons of soil lost. This amount of sediment will eventually make its way into Lake Mendota and be a huge source of phosphorus for algae populations that will, over time have effects on the food chain and fish populations.

The Muir Woods area provides as an extremely effective natural buffer to erosion runoff from upper campus that fails to make it into the drainage system. The exit points along the campus waterfront would be the best places to begin a water runoff program specifically targeting stormwater erosion. But, as Mr. Magnuson alluded to, the waterfront is not the only place to focus efforts for cleaning the lakes. Magnuson had much to say about the past and present campus projects that affect the lake and its ecosystem. There are green roof projects going up around campus including the new addition to the Educational Science Building on Bascom Hill (Figure 2). Sedimentation ponds detain water and hold it for absorbing sediment before it makes its way into the lakes like the one near parking lot 34 (Figure 2). There is another one down by the Bay fields near the University Hospital to prevent harmful nutrients into the wetlands area of Mendota. The campus is also experimenting with permeable surfaces to implement into parking lots and roads to allow for the permeation of water into the water table before draining straight into the lakes.

Considering how many things can have negative effects on stormwater draining into Lake Mendota, the opposite is also true. John Magnuson says, “There are so many of these little [projects]...people who look for a grand thing and fix it, well, the grand thing that fixes it is all of the little things.” The best way to continue working towards a healthier lake is, “Continuous pressure, at least on campus, for more green roofs, more infiltration facilities, stopping the
erosion of lakeshore path,” and other small projects. These small projects are apparent throughout the entire campus area. One of such is a small length of storm drains at the end of a downhill sidewalk. The sidewalk ends at lakeshore path, which is unpaved and holds much sediment that is prone to erosion. The drain is solely placed so water running down the sidewalk either runs off into the grass to be absorbed or into the storm drain and into the lake (Figure 4-f). Another such project is on Muir Knoll, which overlooks Lake Mendota. The paths leading down to lakeshore path are very steep and prone to erosion, so runoff barriers were positioned at the top of the lookout. These barriers are simply cylindrical absorbing obstacles that slow down the flow of water and allow it to infiltrate the ground (Figure 2). It’s the little projects like these that add up in helping prevent the lake from being polluted with sediment.

Not only is a great resource, Lake Mendota, in jeopardy but so is the healthiness of many people relying upon the sustenance the lake provides. One fisherwoman reflected the sentiment among some of her fellow anglers when asked her if she had ever gotten sick or noticed any health problems from eating fish. She cleverly responded by saying, “Child, if I don’t eat food, I get sick.” When posed with the same question, another angler humorously noted that it is, “Good for (his) health to go out fishing and see all the pretty women run past on the bike trail.” It is apparent that partaking in the activity of fishing is a positive experience for the anglers, as they are able to obtain a free source of food while enjoying their time spent outdoors amongst friends.

It is important to keep the anglers in our community safe, and at this point and time, it is evident that the need for increased outreach and education regarding fish consumption warnings are necessary. To solve the larger problem, however, strategies to reduce fish contamination and depopulation should be thoroughly examined, and the root of the problem must be addressed.
Action must be taken at every step in the chain for this urban-to-lake contamination crisis to be cured.
Conclusion

In order to understand the problem of pollution in urban runoff we sought to answer the question: *How does urban stormwater runoff affect the Lake Mendota ecosystem, fish populations, and subsistence anglers?*

Our research has concluded that urban runoff has carried phosphorus into the lake and has stimulated excessive blue-green algae growth. Such growth has limiting effects on zooplankton and phytoplankton, it has the potential to block out light from primary producers, and reduces oxygen levels in the process of decomposition jeopardizing some fish populations. As lake ecosystems continue to undergo adaptations to the increased BGA growth, fish with sustained exposure to toxins may affect consumers.

In order to define the scope of the issue in a given area we asked: *How are stormwater contributions identified and dealt with on campus?*

Construction projects are dealt with in a fairly straightforward permit and inspection process. Issues of construction runoff are mitigated to the best extent possible by utilizing catchments with marginal results for preventing erosion. Aside from construction projects the campus has put in retention ponds to filter water, built green roofs, experimented with permeable surfaces, and worked to preserve Muir woods.

What we can gather from this research is that there is a need to respond to the issue of eutrophication in Madison lakes. The increase in nutrients has reduced stability in the lakes food chain and ecosystems. Within the scope of the watershed preventative measures can help reduce the strain on lake ecosystems. Individuals and businesses within the watershed should be
conscious to how they contribute to runoff pollution. Construction projects should continue to employ current catchment practices in a responsible fashion. Storm systems need to have a means of alleviation as the urban footprint within the watershed grows. Developing land utilizing permeable surfaces could reduce the amount of runoff into lakes as well. The diversity of effective projects is promising but comes slowly as investment in such practices is slow moving.
Future Research

The different approaches to handling runoff pollution are constantly evolving as the scope of contributions expands. Not every project gets implemented in the form of legislation though. For example the city can only urge people to participate in leaf pick-up efforts. Further research could be tailored to examine how individuals respond to recommendations by authorities. Since all the little things contribute to the aggregate problem, identifying how and why citizens understand and comply with such authoritative requests could shed some light on how projects should be tailored in the future.

Urban contributions into Lake Mendota may not be as significant as agricultural ones. However, the urban contributions into Lake Monona are much greater (Magnuson, 2010) than agricultural. With the agricultural inputs being fairly straightforward, i.e. erosion of heavily fertilized croplands, it seems rather prudent to mitigate those identified problems while identifying the urban issues with a little more detail. Urban contributions are a result of the aggregate practices of lawn fertilization, gardening, pet waste disposal, construction sedimentation, shoreline erosion, drainage issues, retention filtration, and surface permeability. For a community to properly address this issue it needs to become more aware of the wide range of issues, which play a role in urban runoff. To understand and quantify the effectiveness of implementing these practices would take extensive time and resources but could ensure that development can continue without posing a risk to the surrounding lakes.
Works Cited


--------. 2009. Erosion Control and Stormwater Management Permit: Union South. Madison Department of Public Works, Wisconsin Department of Natural Resources.


Schrank, Candy S. Wisconsin Department of Natural Resources. Information gathered via email. 2010.


Figure 1: The linear progression of data this paper looks at can be visualized through this flow chart. Any of these steps could be an entire project but our goal was to establish a solid connection between the different types of occurrences and data.
Figure 2: Original Map
Figure 3: Phosphorus graphs of levels in Lake Mendota and certain detention ponds around Madison. The graphs are from the City of Madison 2008 Water Report.
Figure 4: Original photos taken during landscape observations. Photos A and B are of two different storm drains that have sediment flowing into them. B is overflowing with water because of the leaf bag hanging underneath acting as a tea bag and seeping nutrients into the system. C and D are drains into Lake Mendota. E shows a type of sediment bag used at a construction site. F is a downhill sidewalk with a perpendicular drain at the end before water could cause erosion.
**Figure 5:** Map showing the boundaries of the separate watersheds. Lake Mendota’s is surrounding the lake and covers the north side of downtown as well as huge amounts of residential areas. This is overlain with major storm drains.
Figure 6: Graphs quantifying angler interview data
Figure 7: Original photo taken by Steven Roanhaus of leaf collection in Madison, Wisconsin. 11/3/2010