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Comparison of Odonata Populations in Natural and Constructed Emergent Wetlands in the Bluegrass Region of Kentucky

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ABSTRACT. With the degradation and destruction of many natural wetlands in Kentucky, there are high incentives to look at the remaining natural wetlands and the new artificial wetlands that are beginning to become prevalent among biologists. Wetlands are important to dragonfly populations just as dragonflies are vital to wetland function. In my study I looked at the fluctuation in Odonata (dragonfly and damselfly) populations at ten artificial wetlands and ten natural wetlands in the Inner Bluegrass region of Kentucky. In my study the dragonfly populations were monitored based on Shannon and Simpson's diversity, Species richness, and number of individual and species numbers. The wetlands were also compared on a season to season basis and the health of the wetlands were considered using a rapid assessment method. My research found that the artificial wetlands, though they scored low on the rapid assessment method, scored high in all categories except for species richness in the fall season of data collection. This study can be important in discovering the differences between natural and artificial wetlands, since Odonates are such an important biological indicator of wetland health and function. This could be vital in increasing the health of remaining natural wetlands and new artificial wetlands that are being created to supplement the lack of many of Kentucky's natural wetlands.

KEYWORDS. *Odonata,* Wetlands, Diversity, Richness, Undergraduate Research.

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INTRODUCTION

Wetlands are important to dragonfly populations just as dragonflies are vital to wetland function. Wetlands provide valuable hydrological functions and provide valuable niches for many small species of animals, including dragonflies (Biebighauser 2011). Yet we still know relatively little about the response of dragonflies to wetland conservation. Kentucky's wetlands are in dire need of help. Research has shown that in the past forty years Kentucky has lost up to 80% of its own natural wetlands (Brown & Richter 2012). This lack of wetlands is alarming because wetlands provide important habitat for small mammals, insects, amphibians, and migratory waterfowl. Localized wetlands often have small, isolated populations resulting in populations being vulnerable to destruction and extinction by chance through demographic events, inbreeding, natural events or even disease (Gibbs 1993). These factors, coupled with the fact that many wetlands were filled in with soil for agricultural reasons resulted in the decrease of wetlands and wetland flora and fauna today (Jones 2005). In fact many of the world's endangered organisms are wetland species, making the preservation of wetlands even more important to protect these individuals and the ecosystem that they live in (Gibbs 1993).

Yet many people would still wonder about the reasoning for studying Odonates. What do they do that makes them so special? How would they be beneficial to humanity? Dragonflies and damselflies are important assets to any kind of ecosystem. Not only do they add to the predator and prey equation that is common in every ecosystem, but what they prey on specifically can be very important in any setting. Odonates are intense predators of mosquitoes in all of their forms (Martinez & Castro 2007). As intense predators of mosquito larvae in their own larval form and predators of the adults in their adult form, Odonates can be used as controlling agents for mosquitoes and other types of midges that humans find so annoying. As a vector of diseases such as West Nile Virus and Malaria, the control of mosquitoes around populated areas is crucial to prevent the spread of disease.

Their presence as mosquito controllers could become even more important here in the coming years. There has been a sudden decline in bats, which are the main predator of mosquitoes, due to White Nose Syndrome. Since discovered a few years ago, White Nose Syndrome has been the reason for the destruction of millions of bats (Blehert et al 2009). The sudden lack of this predator will likely result in the increase in the mosquito population. Which will increase the value of Odonates as a predator species.

Besides being a predator and prey species, odonates are vital to aquatic ecosystems. *Odonates* are often associated with the quality of a wetland or water source.

Providing a valuable step in the aquatic food chain, they are affected through wetland function through water quality, hydrological patterns, and vegetation structures (Mabry and Dettman 2010). Due to their heavy dependence on water quality, almost any type of water pollution can affect dragonfly population size, reproductive rates, and overall health. In tandem with this association, dragonflies are also connected with vegetation structures and have specified vegetation requirements, such as submerged vegetative debris in the water to ovulate upon. Thus they are dependent on vegetation as a critical asset when they choose a place to lay eggs. As to hydrological patterns, odonates need standing water at least from ovulation time to nymph emergence. For several species time can vary depending on latitude and the species in question. This would indicate that the wetland or water source that their parents chose as a breeding spot would be filled with at least a few inches of water year round. Leaving one with the assumption that for a dragonfly to find a successful place to breed they would typically find something that did not dry up too quickly. This would mean that dragonflies typically are vital to detect a wetland that could have water pollution, aquatic vegetation, and is full of water long enough for nymph emergence. Due to the distribution patterns of larvae and adults, conservation judgments are often based on the adult species present at a wetland. Through this, they are the basis for evaluating restored wetlands as habitat (Mabry and Dettman 2010).

Territoriality also plays an intense role in dragonfly habitat choice and behavior. Dragonfly males are typically territorial to other males, these males are typically of the same species of dragonfly. As per their reproductive behavior, most female dragonflies must choose between a lentic and a lotic water site in which to deposit her eggs. Once the site is chosen, the female typically flies out to the water when she is ready to mate and is pulled into tandem by a male dragonfly. Most of the brightly colored dragonflies and damselflies that are seen out near water are typically male. The females, like most birds, are usually a duller color and only really come down to the water to breed. Odonates are usually sexually dimorphic, meaning that a male and female of the same species will look different in coloration and sometimes body size. The male then pulls her into to his territory within the water area. Surrounding males will then constantly attempt to but in between the happy couple during ovipositation. If they wish to pass on their genes with this female, it is essential that they are the last male that she mates with before laying her eggs. It is essential because sperm from the last male to mate with a female fertilizes 60-100% of the eggs she lays. The male that has just copulated with her will guard his acquisition so that it is his genetic material that is used. Sometimes in the mad rush that follows females can be harmed by her many amours suitors (Marden 1989). Thus it is common for male dragonflies to chase off any other males of the same species to ensure that their genetic material is used and passed on. The less competition around, means the more females that a male can mate with successfully. After coitus with one female, the male will then tend his territory and breed with any other females of his species that enter his area. As such, he will continue to chase off any other rival males in the area. Though males typically guard perches due to territorial reasons, they can also use perching sites to catch and/or eat prey as well. Perching is vital to dragonflies because it provides a way to regulate body temperature. Dragonflies alter their perching postures to adjust the amount of sunlight hitting their bodies in order to preserve thoracic temperatures, through this *Odonates* can attain a certain degree of independence from encompassing air temperature variation. This variation of freedom is typically within the correct range essential for reproductive behavior (Pezalla, 1979). This influences habitat choice because it emphasizes the usage of perches as a vital habitat component as they are important in reproductive success.

Odonates could be the key to discovering many of the variations between natural and artificial wetlands. Being such an environmentally sensitive set of insects, dragonflies and damselflies are typically the first thing to disappear when a wetland is disturbed. As they affect such a wide range of variables, it is the accepted conclusion that they serve as useful biological indicators. Should water quality become disturbed by nearby cattle grazing the population would be affected. Should the surrounding vegetation be cut, removed, or burnt or perching sites destroyed or removed, then the population would be affected. By being such a sensitive set of organisms, the dragonfly and damselfly prove their worth to be studied by providing a comparative factor in which to compare natural and artificial emergent wetlands.

As discussed above, many of Kentucky's wetlands have been destroyed and there has been a new initiative to clean up many of the natural wetlands that are left in the state. Many of these wetlands are polluted and disturbed. Invasive species are a major concern as run off from roadways and siltation from nearby agricultural fields cloud and pollute the water. In public areas human activity can be a problem and so can landscaping and mowing. Through the initiative to clean up many of our natural wetlands, many biologists have begun to look at alternatives to supplement the natural wetlands that have been lost. As pointed out by Jon Kusler, there is no way to perfectly duplicate a natural wetland that has been destroyed (Kusler 1990).

Artificial wetlands have become quite popular for both wildlife conservatives and ecologists. Artificial wetlands are relative easy to make. Attention to soil composition and placement of the artificial wetland is very important to ensure that the wetland succeeds. Often, a bulldozer is used to create a hole large enough for the artificial wetlands and sometimes plastic is placed to keep the water in more sandy soiled places. These wetlands usually take a few years to become a true functioning wetland due to the vegetation structures and colonization of animals that must take place. Many of these wetlands have yet to be looked at in correlation to dragonfly populations and health. If there is a possible difference in natural and artificial wetland dragonfly populations, then perhaps the difference could be quantified and used to improve the artificial wetlands to make them more like their natural counterparts, even if they cannot be duplicated completely.

To gather proper data on the wetlands that are being assessed, one must first know what kind of wetland they are working with. An artificial wetland is much more likely to hold water permanently or semi-permanently than a natural wetland, whose hydrology differs. Sadly, there is not much data about constructed wetlands. As a relatively new concept in the idea of wetland restoration, there has been research into making artificial wetlands, but many artificial wetlands need years to mature and gain the things that make it into a proper wetland. Things such as vegetation communities and hydrological functions take a little time to work themselves out. Due to this, and the fact that many wetland functions are very easy to destroy but hard to put back together has resulted in a. astounding lack of data for wetland restoration (Zedler 2000), which includes the making and working of artificial wetlands. The Kentucky Rapid Assessment Method of KY-

WRAM is a new method of wetland data collection. A collective effort by multiple Kentucky agencies and Eastern Kentucky University, the assessment is a new way that wetland data is being collected. By assessing the wetland based on various criteria, the KY-WRAM can assess the basic health of a wetland, adding to the data that is missing for many of the wetlands across Kentucky.

Objectives- My objective in this research is to measure the Odonata populations at various natural and artificial emergent wetlands and to compare these populations to biotic and abiotic variables such as water quality, vegetation types, wetland condition, territoriality, and perching availability. I believe that if the wetlands being studied prove to be healthy then the dragonfly and damselfly populations at the individual wetlands will be high in species richness and diversity, while the wetlands that are less healthy will have a low species richness and diversity.

METHODS

Study Design

In this study, I plan to collect data on the population size of Odonates in twenty different wetlands in the Bluegrass Region of Kentucky. Ten of these wetlands will be natural emergent wetlands and ten will be constructed emergent wetlands. Along with Odonata populations, other variables gathered will be territoriality, perching availability, and a wetland quality survey (Kentucky Wetland Rapid Assessment Method; hereafter: KY-WRAM) which includes a vegetation survey, hydrology information, and an overall judgment on the wetland condition. All of this data will be gathered during three different sampling periods: spring (May-June), summer (July-Aug), and fall (Sept-Oct).

To gain the Odonata population data for each wetland I will walk around the perimeter of each wetland rustling the vegetation to flush any roosting dragonflies. After the initial walk around the perimeter, I will sit in a central location for thirty minutes to count dragonflies using the space around the water source. Doing this, it is planned to identify species in the field on the wing using binoculars. A butterfly net will be used to catch individuals that cannot be identified with binoculars, so that later they can be identified using a field guide. Many of the species that are netted will then be collected and preserved to go into my voucher collection. To reduce double counting, the maximum number of each individual seen within any four minutes of sampling will be considered different individuals. This protocol will be repeated for all of the sites in each of the three seasons. Dragonflies typically use small woody branches or tall vertical emergent stems for perches. The number of available perches around the wetland will be counted. Any perches within a foot of the shore line will be counted. The data gathered from the KY-WRAM will act as an overall assessment for the wetland condition. The KY-WRAM includes metrics measuring wetland size and distribution, land use, hydrology, vegetation, and habitat features (KDOW 2013). Quantifying these variables, the wetlands will be rated on a scale of 1 - 99. As for the territoriality survey, the main goal is to determine how many males of a species are using the wetland and how territorial they are. It is assumed that if a male is in a territory, he will then be territorial with another male of the same species. I will record the number of territory disputes per dragonfly species. Based on the number of disputes the male population residing there will be ranked on a scale of 1 (not very territorial) to 4 (very territorial) for its species.

Statistical Analysis

In this study, I plan to report the population mean and the species richness of each wetland for every season. This, along with the KY-WRAM number, the perching data, the wetland depth and size data, and the territoriality data will all be considered. Using an Analysis of variance (ANOVA) model and a Regression Analysis, I will evaluate the differences and similarities between the natural wetland data and the artificial wetland data. I will also be looking at the wetlands in reference of Shannon-Weaver Diversity, Simpson’s Diversity, Species Richness, and various t-tests that compare the wetlands by season (spring, summer, fall) and by wetland type (Artificial and Natural). With these statistical analysis, I will determine if the data gathered is significant or if the data was not significant enough to be considered useful.

Area of study

My study area will be wetlands within Madison County and Fayette County, both are located in the Bluegrass Region in Kentucky. Located in the center of the state, the Bluegrass Region is a rolling plateau, with underlying limestone. Many of the emergent wetlands in the region are marshes and wet meadows. Settled first due to the fertile soil composition, many of its natural wetlands have been filled to be used as agricultural fields. (Kleber 1992). Much of the land was once open savannah woodlands containing bur oak, blue ash, and understory river cane and grasses. The effects of wetland loss in the Bluegrass Region has resulted in a loss of habitat for native species, a decline in water quality, and increased flooding (Jones 2005). In addition to the few remaining natural wetlands, numerous wetlands have been constructed across the region. One of the special places that will be studied in this study is the Taylor Fork Ecological Area. Located within the Richmond city limits, it is a recent acquisition of EKU and is a 60 acre plot of land that is being managed by Eastern Kentucky University. It is essentially an outdoor classroom that allows for many of the students, Wildlife Students especially get hands on experience on the Taylor Fork grounds. Some of the other constructed wetlands in this study have been made by schools such as Glen Marshal Elementary School and Kirksville Elementary to serve as outdoor classrooms. Though many of these wetlands have been made with the intention of being used as outdoor classrooms, there has not been much data at all being collected from them just yet. And they effect on the hydrology and populations around them have not been recorded either.

RESULTS

My data collection ran over a six month period of time, from May2013-October2013. Over that period of time, I surveyed each of my twenty wetlands three times, equaling a number of 60 different surveys. Over my data collection season, I saw a total of 1275 Odonates at my wetlands. Overall there were 883 dragonflies out of the dragonflies seen there were 19 species. Out of the data collected there were also 392 damselflies species recorded with 13 species. According to the United States Geological survey, many of the dragonflies and damselflies that were gathered for this research project were actually new species records for Madison County Kentucky.

Natural Wetlands compared to Artificial Wetlands

Out of my twenty wetlands, there were really only two different types that I am taking into account in this study. 10 of my wetlands are natural, and 10 of them are artificial. In the natural wetlands, there was a total number of 645 odonates recorded over the 6 month period. In the artificial wetlands there was a total number of 1030 odonates recorded over the time period. There could be quite a few reasons as to why the numbers differ so much but one difference would be the hydrology of the wetland types. Also discussed by (cite here), Artificial wetlands typically tend to hold water for longer than natural wetlands. Where the natural wetlands tend to flood and then drain at different times of the year, artificial wetlands hold onto the water for longer, sometimes year round.

When compared together in by the KY-WRAM a rapid assessment method for evaluating wetlands the natural wetlands I used on average scored 51.8 out of 99. When compared to the artificial wetlands, which averaged a score of 46.3 out of 99. Despite the difference, when compared with a two tailed t-test, the difference in points was not statistically significant (T= 1.1832, P = 0.252123). This means that though the number looks different, statistically it is actually not significant enough to make a difference in the overall function of the wetlands. A regression analysis, which was used to estimate relationships between variables was also performed. The slope of the line of best fit suggests that the relationships between the two variables is not as strong as originally thought. The R-value, which is low [R-value= 0.058] suggests the same as the slope of the line of best fit. This is typically an indication the variability of the data cannot be explained by the Regression Analysis. Despite this, the P-value seems to be significantly significant [P-value= 0.044]

Finally, the wetlands were compared biased on the average number of dragonflies per each type of wetland. On average the artificial wetlands surveyed had 34.3 odonates per artificial wetland. Which numerically is roughly 14 more odonates per wetland than the average number for the natural wetland. The average number for the natural wetlands equaled out to 20.4 wetlands per natural wetland. When compared with a two-tailed t-test, the numbers were found to not be statistically significant (T=1.478844, P= 0.235724). Meaning that the average number of dragonflies was not significant enough to make a difference on the tow wetland types.

The wetlands were also compared on the basis of odonate species averages. On average artificial wetlands had 19.3 species overall, where natural species had an average of 15.6 species. When compared using a two tailed t-test, the difference in the average number of species was found to be statistically significant (T=4.91935, P=0.016093). With the P-value equaling to be less than 0.05. Thus the difference in dragonfly and damselfly species that were found at the wetlands were different enough to stand out from the data. Meaning that the number of species that were present at separate type of wetlands are different enough to make some sort of distinction between the two types.

Differences between the Seasons

There were three main data gathering sessions, spring (May-June), summer (July-Aug), and fall (Sept-Oct). In these three sampling sessions, there were twenty wetlands per session that were being looked at and assessed biased on the dragonfly populations present in the wetland. I only assessed wetlands with the KY-WRAM rapid assessment method once. The primary purpose of sampling in different seasons was to compare Odonate populations at the wetlands.

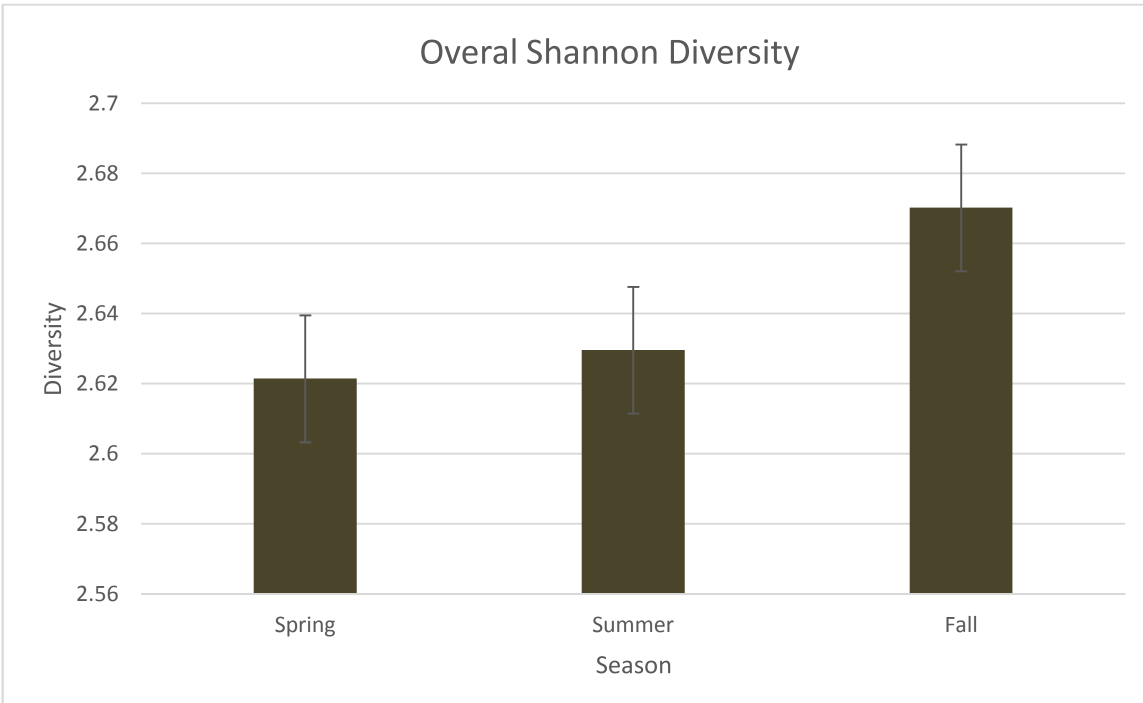
The data gathered from the three sampling sessions was mainly processed by running it through two different Diversity Indexes. A diversity index is used to measure species diversity in a given community. They separate themselves from species richness indexes by taking into consideration the relative abundance of species that are present in the community. The Shannon diversity index, which is the first index that I used, takes into account both abundance and the evenness of the present species in the community.

When compared by the Shannon Diversity index, the wetlands do not really differ all that much, with a 0.05 point difference in diversity [Figure 1]. This figure is a mixture of both the natural wetlands and the artificial wetlands. When separated by both wetland type and season, the differences between the wetland Shannon diversity is much more apparent. After separation, there is a much larger difference between the wetlands. With the artificial wetlands being much higher than the natural wetlands in Shannon Diversity. With the differences for spring being separated by 0.394, summer by 0.330, and fall being 0.277, [Figure 2.] Overall the spring artificial wetlands had the highest amount of Shannon Diversity. The separation of the two wetlands types obviously makes a large difference in how the data can be viewed.

The other diversity index that was used to assess the data in this experiment was Simpson's Diversity. Simpson's diversity is different from Shannon's diversity in that is measures the degree of concentration by separating individuals and classifying them by types. The Simpson's Diversity overall is actually different than the Shannon Diversity discussed above. With the spring and summer seasons really only being different in diversity by 0.026. Where the difference between summer and fall Simpson's diversity was 0.268 and the difference between spring and fall was 0.241, [Figure 3]. The fall season having the highest amount of diversity. These results were quite different from the Shannon Diversity results, likely because Shannon diversity looked at all of the odonates at one place, where Simpson's diversity looks at the amount of species at that same place. When separated up like the Shannon diversity data, the Simpson's diversity is also different when divided into natural and artificial wetland types. With differences for spring being 0.072, summer being 0.008, and fall being 0.037. All with the artificial wetlands having a higher amount of diversity. The fall artificial wetlands having the highest amount of Simpson's diversity overall.

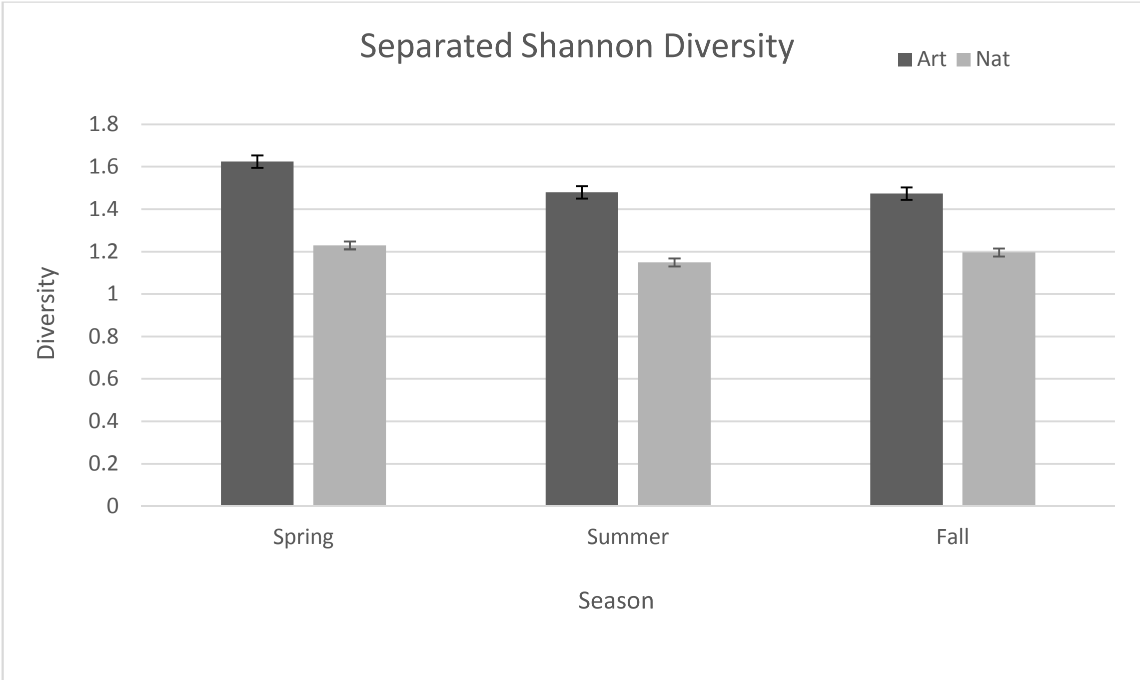
Species richness, which is a way to look at the different species at a wetland. This method is different in that it does not take into account species evenness. Overall, the species richness for the seasons did not fluctuate too heavily. With fluctuations from spring to summer being only 0.001503, from summer to fall being 0.045, and from spring to fall being 0.046 [Figure 5]. With spring having the most species richness. Once the data is then divided up between the two wetland types, it is more obvious just how close the species richness is for the different wetlands types and the three seasons. With the differences between springs being 0.063, summers being 0.031, and falls being -0.183 [Figure 6]. With the artificial wetlands being higher in species richness except for the fall data session. Overall the spring artificial wetlands had the highest species richness.

The final statistical analysis that has been used on the data gathered is an ANOVA. Analysis of Variance or ANOVA is a collection of models used to look at the differences between group means and the variation between the groups. It essentially generates 't-test' between more than two groups. The ANOVA that was preformed essentially looked at the variation between wetland surveys for all three season and took into considerations the two different wetland types. It then looked at the interactions between the average number of odonates and the number of species and looked at the variation between the types and the seasons. When compared using a two-way ANOVA, the data is found to be not statistically significant [P-value >0.07, F-value 11.1, DF 1].

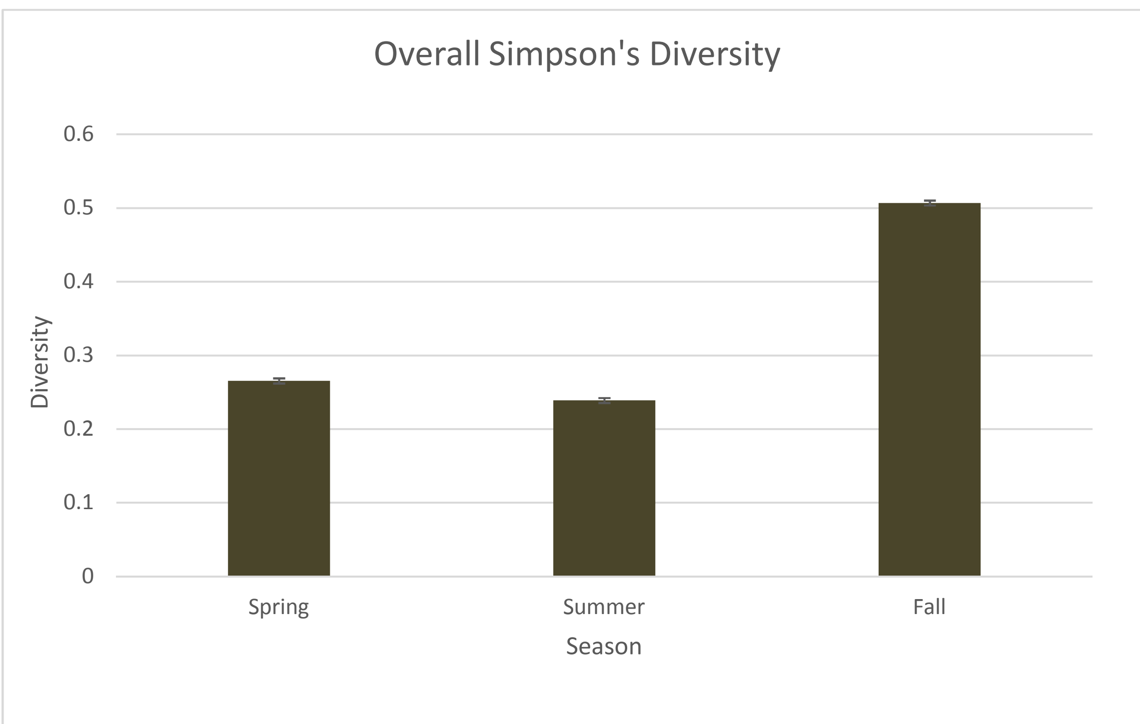


Meaning that there is no noticeable difference between the data.

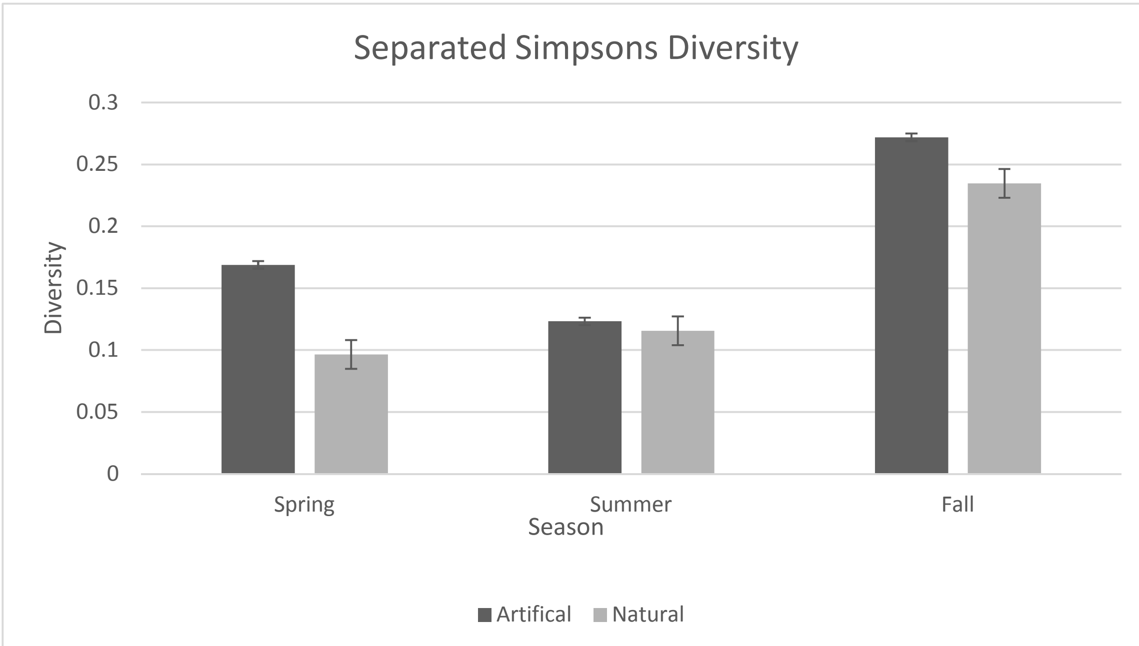
[Figure 1] Bar graph showing the overall Shannon Diversity between the seasons.



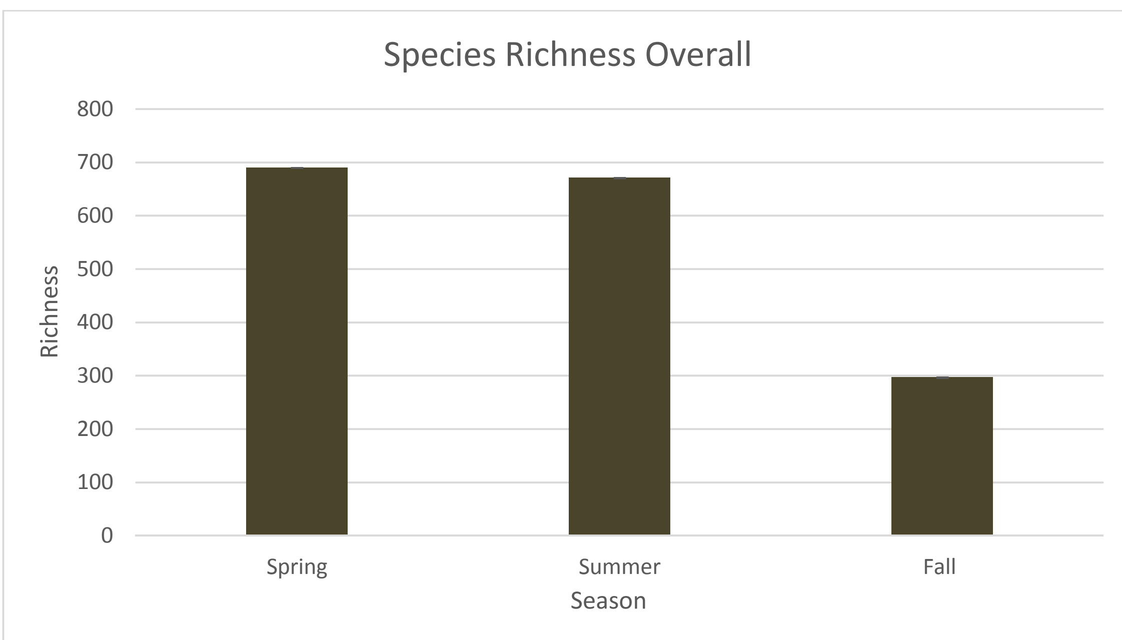
[Figure 2] Bar graph showing the separated Shannon Diversity between seasons and wetland types.



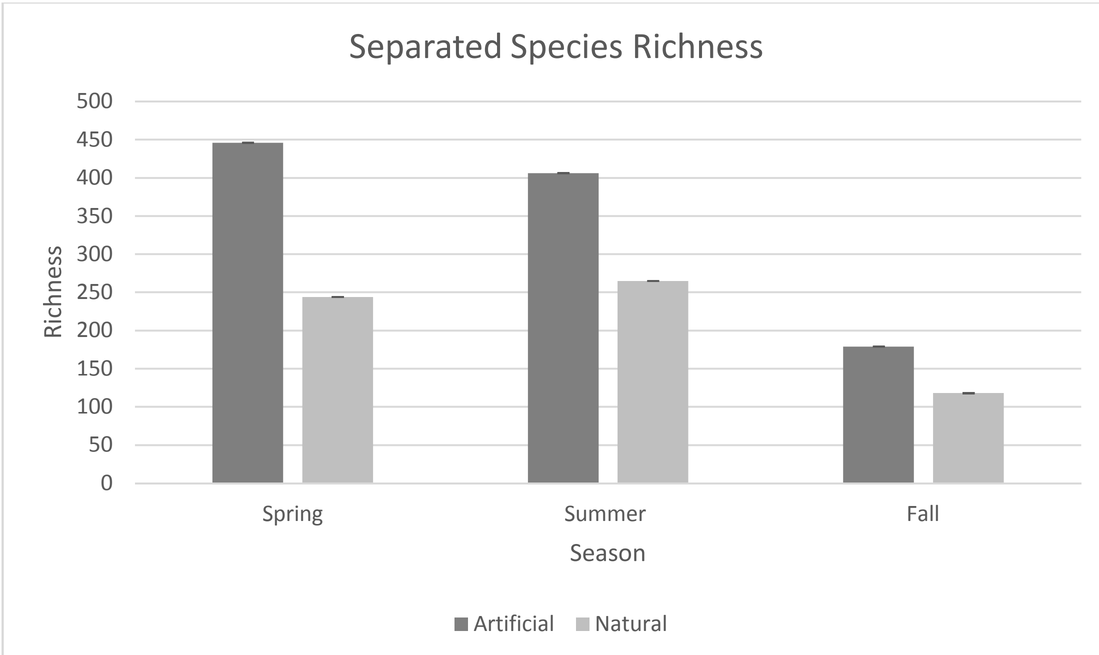
[Figure 3] Bar graph showing the overall Simpson's Diversity between the seasons.



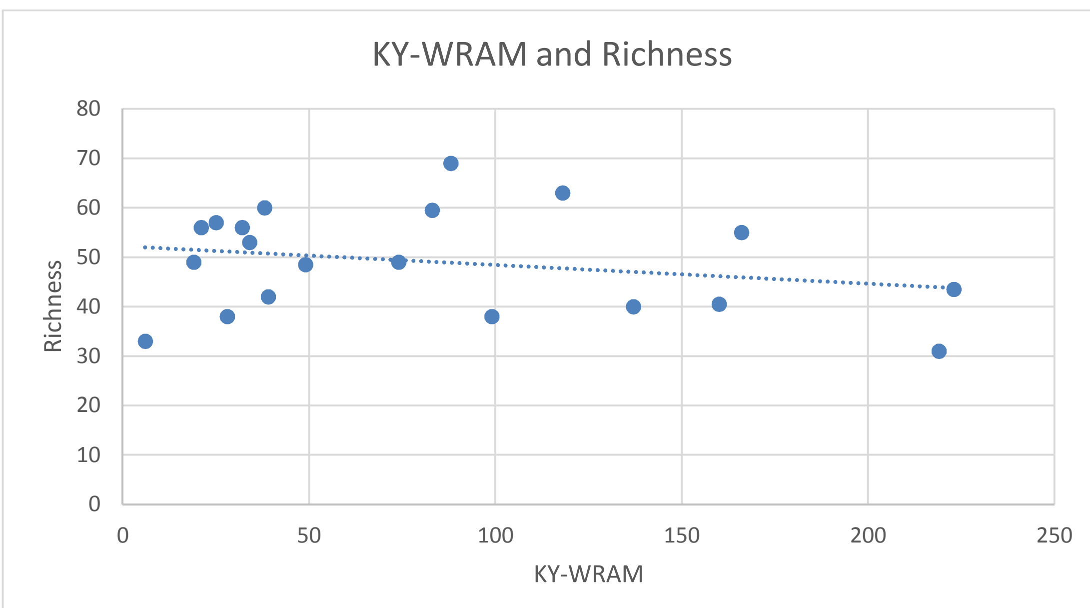
[Figure 4] Bar graph showing the Simpson's Diversity scores between seasons and wetland types.



[Figure 5] Bar graph showing the overall Species Richness between the seasons.



[Figure 6] Bar graph showing the Species Richness scores between seasons and wetland types.



[Figure 7] Scatterplot accompanied by a line of best fit showing relations between KY-WRAM and Species Richness.

DISCUSSION

Results Interpretation

The ANOVA confirmed that there was not a lot of variation between the types of wetlands and the three different data gathering sessions. While the species numbers and amounts seemed to fluctuate between the three data gathering sessions, it seemed that everything tended to balance out in the end population wise.

When I began this project, it was my original intent that to determine if there was any difference in the Odonate communities of a natural wetlands and artificial wetlands. Coupling these variables with the changing seasons and the shifting in Odonate populations as they emerged, bred, and died I expected to find many variables that were different though the season and the different wetland types. My original hypothesis was that there would be a major difference between the population numbers and the diversity of those numbers at the wetlands. I expected for the artificial wetlands to have a higher number of Odonates and a low amount of diversity, while I expected the natural wetlands to have a high level of diversity and a low population number. The data collected actually went against my original hypothesis. With the artificial wetlands having both more numbers and higher diversity.

Differences between Wetland Types

I believe that the reason for artificial wetlands having more numbers and higher diversity is because of the difference in hydrology of the artificial and natural wetlands. One of the key features that separates natural and artificial wetlands is the difference in hydrology. Most natural wetlands are on the edges of other aquatic habitats, where in periods of high water, or non-drought conditions, the wetland is semi-permanently flooded. This wetland can prove to be a good breeding ground for Odonates while the water is still there, but once it dries up it can become an ecological trap for the larvae that do not have the proper amount of water. Ecological traps are essentially places where an animal may breed or oviposit where it is unlikely their progeny may not survive. (Horvath et al 2007). Should these wetlands dry up, then many of the dragonfly larvae living in the water may die. Artificial wetlands tend to be filled with water for almost all of the year, they tend to retain at least two or three inches or water year round. Judging from the amount of dependence on year round water, I could find it believable that artificial wetlands, with their favorable hydrology would be better for both population numbers and diversity, since survival is more favorable.

Another noticeable difference between the two wetland types is the kinds of vegetative communities that are found around and in the wetlands. While visiting the various wetlands that were in my sampling groups, I noticed that the vegetation structures between the types were different. While at most of the artificial wetlands there was a noticeable amount of herbaceous vegetation. With plant families such as Juncaceae, Alismaceae, Cyperaceae, and Poaceae, there was a noticeable amount of vegetative species. Most of these were herbaceous and lacking woody components. These wetlands generally scored low on the amount of woody debris and snags that were in or near the wetlands as well. Only 30% of the artificial wetlands surveyed had that specific component. At most of the natural wetlands there was a noticed amount of woody and overhead species. With the families being present such as Oleaceae, Caprifoliaceae, and Salixaceae. These woody families among others were seen much more commonly along many of the natural wetlands. The natural wetlands also had a higher percent of snags and woody debris in the wetland, which was greater than 50%. Supported by Schindler in his paper addressing dragonfly association and habitat, one of the most critical variables that describe associations to habitat are quality and quantity of semi-aquatic plant communities (Schindler el al 2003). Suggesting that the dragonflies and damselflies present at the wetlands likely made more of an association and connection with the plant communities that held aquatic or herbaceous plants.

Territoriality

All of the wetlands surveyed exhibited some kind of territoriality. It seemed that wherever there were wetlands, there was some sort of territory or mating dispute going on. While it is true that there was more disputes at the artificial wetlands, there seemed to be more overall Odonates at the artificial wetlands. This of course meant less room, and more chances for territory disputes.

Diversity in Fall Wetlands

Another surprising thing that the data showed was the season which held the most diversity. At the beginning of the research, I expected that the summer season would hold the most diversity. I assumed that the summer season, being the point of high temperatures and the best time for activity for dragonflies, would have more species. The data showed that the fall season was actually the season of most diversity, having the highest amount of diversity in both Shannon Diversity and Simpson's diversity. I believe this is because until the fall season started, there was one important group of dragonflies that were still absent. Meadowhawks (Genus *Sympetrum*) are a small to medium sized species of dragonfly that are very common during the fall months. They are usually some of the shortest lived dragonflies when in their adult forms. Emerging in the late summer or early fall, adults are usually around and breeding in the early to mid-fall. With their small size and fall-like colors, the Meadowhawks are generally some of the last dragonflies left at a wetland, partially due to their small size (Dinkle 2000). Which allows them to hide from the first frosts much easier than many of the larger odonates. Unable to escape or hide from the early frosts that usually come with the fall, many of the larger dragonflies such as the Darners and Skimmers are unable to get out of the frost. If they unable to find shelter in the vegetation in or around the wetland, many of them perish. So there would be less large-medium odonates around, but the smaller sized odonates such as the Meadowhawks and many different smaller Damselflies, being of much slighter size could hide deeper in the vegetation which would protect them better from the frost that could kill them. This would give the fall season a higher diversity score because it had smaller, but more species of Odonates.

When originally starting, I expected for many of the wetlands to have an overall carrying capacity, or a certain number of dragonflies every season. It seemed to me that for some of them the capacity was very large. I believe that for some of the artificial wetlands there was a possible Population Overshoot. The theory of population overshoot is that each ecosystem has a carrying capacity, or a maximum number of individuals that can be sustained by the environment. Overshoot is when the population exceeds the carrying capacity, which results in a larger population than what can be held by the surrounding environment. This overshoot is then followed by a crash in population numbers because not all of the individuals can be sustained by the environment (Catton 1982). I suspect that many of the dragonflies seen at artificial wetlands in the spring were part of an overshoot. They seemed to go from a hundred or more, to half of that number in only two months. In theory, I believe that the data supports this at various artificial wetlands.

This looks to happen only in the artificial wetlands and I believe it is again due to the difference in hydrology. As mentioned, artificial wetlands tend to hold more water all year round. This extra water in the artificial wetlands could be the cause of the overshoot because it allows for more *Odonata* larvae to survive while they are living out the aquatic part of their lives. More than expected survive and emerge in the spring, which results in very high numbers. These individuals typically start mating not long after they mature, so there would be an excess of eggs being laid into the wetland before the crash that typically follows an overshoot happens. These eggs would then hatch into larvae that would survive and contribute to the overshoot the year following. Creating a cycle of overshoot and crash that would continue for as long as the wetland persisted.

KY-WRAM

In my project I used at the KY-WRAM or Kentucky Wetland Rapid Assessment Method, to determine the health of the 20 wetlands that I was surveying. This method, developed to be used in the Kentucky Division of Water’s (KDOW) 401 Water Quality

Certification Program and by other such regulatory agencies such as the US Army Corps of Engineers (USACE), USDA National Resources Conservation Service (NRCS), and Kentucky Department of Natural Resources (KDNR) (KDOW 2013). Created through the combined efforts of many agencies such as USFS, KDFWR, USFWS, EKU, and many more, the KY-WRAM was modeled off of the Ohio Rapid Assessment Method for Wetlands v. 5.0 which was developed by the Ohio Environmental Protection Agency. While there are differences in between some of the Kentucky land elements and Ohio elements, the KY-WARM was adapted to the Kentucky ecosystems. The assessment looks at the wetland classification, if it is critical habitat, its size and distribution, surrounding buffers and land use, hydrology, soil disturbance, vegetative components and micro topographic features. By assessing all of these features and how they affect the wetland that is there, the KY-WRAM can assess the health of that wetland. In my project it was essential to do a survey for the health of the 20 wetlands that I was using in my study.

One of my original hypothesis was that there would be more dragonflies at the artificial wetlands, and more diversity at the natural wetlands. This was decided partly because I expected the natural wetlands to have a higher KY-WRAM score. Meaning that since they were healthier, they would have better hydrological functions and more niches that needed to be filled. My hypothesis proved right in some respects and wrong in others. The artificial wetlands had a mean KY-WARM score of 46.3 out of 99 and the natural wetlands had a score of 51.8 out of 99. So the natural wetlands were healthier than the artificial wetlands, even though t-tests proved that the difference in number was not statistically significant. Despite this difference in the KY-WRAM scores, the diversity difference in the wetlands was not what I had originally thought. This leads me to believe that there is something different about the artificial wetland that matter to Odonates more so than wetland health.

Limitations to the Study

There was an adequate number of limitations to this study that need to be addressed. The first of which being animal interference in the wetlands and changes to the wetlands due to animal interference. During the time in between my summer and fall data gathering session, one of my artificial wetlands was altered due to beaver activity. The beaver *Castor canadensis*, is a North American fur bearer that has been important historically in the fur trade. Belonging the rodent family *Rodenia*, the beaver if known for building structures that dam up many lotic ecosystems so they can create their own homes. A keystone species in many aquatic ecosystems, the beaver can change the hydrology of a wetland quite readily (Hood & Bayley 2008).

This is what I discovered in the mid fall as I journeyed to one of my artificial wetlands to perform both a wetland count and a KY-WRAM assessment. The wetland's whole hydrology had been altered from what it had once been. The changes made to the wetland due to the disturbance probably altered the wetland in its KY-WRAM score by 5-10 points. This of course would have affected the whole artificial average. Where it had once been a large, wet area, covered with large amounts of *Carex, Salix,* and *Typha* much of the herbaceous and semi-aquatic vegetation that had been present was dead and gone. All of the small saplings that had been growing were cut down and only stubs remained. The *Odonata* numbers dropped at the wetland drastically, but that was probably due to the sudden lack of vegetation to hide in, due to the new channelization of the tiny stream that ran through the wetland. The changes done to the wetland will merely set back some processes, though the damming of a wetland has been known to increases its ability to handle drought due to the increased evaporation rates (Woo & Waddington 1990). Despite this disturbance, Beaver modifications to habitats have been known to increase the herbaceous plant species richness of a riparian zone in up to 25% of its original richness (Wright et al 2002). So it is very likely that though the beavers have disturbed the wetland for now, by next spring it very well could have bounced back and re-grown a lot of the aquatic vegetation. While I am not sure that the *Odonata* population will be back to what it once was in a few seasons, I expect for some of the larvae still living in the water to still survive.

Another animal that I had noticed in force at many of the wetlands were birds. I noticed more of a native bird population at many of my natural wetlands than at my artificial wetlands. Various species included the American Goldfinch (*Carduelis tristis*), Song Sparrows (*Melospiza melodia*), and Red-winged Blackbird (*Agelaius phoeniceus).* Though the mentioned species above were found at most of my wetlands, there were also other notable species at some of the other wetlands. These species included a Green Heron (*Butorides virescens*) and multiple Red-tailed Hawks (*Buteo jamaicensis*). Many of these species would gladly predate upon any Odonates that they could catch. I believe that the presence of these predators could have had a little to do with the numbers found at each of the wetlands, considering that many of them were more numerous at the natural wetlands where there were fewer numbers.

Weather

Weather is yet another factor that cannot be controlled when conducting a field experiment. The summer of 2013 was unusually damp, with 31.64 inches of rainfall from May to October. The average for that time is typically 23.64, so there were 8 extra inches of rain during the time that I was collecting data (Weatherdb 2013). This excess of rain very well could have affected the growth period and lead to there being more water at all of the wetlands. There was also a few early frosts this fall, and that very well could have led to early *Odonata* death before I was able to survey all of the wetlands for the fall season.

Possible Uses for this Study

This study is valuable in that it is adding more to the current amount of data that is being compiled for artificial wetlands. The idea is still relatively new, so any kind of data that can be complied about them is important. The dragonfly surveys and my voucher specimens were also good for adding to the database of *Odonata* information for Madison County. Per the United States Geological Survey, I have a total of 10 new species records for Madison County (USGS 2013). These new records include specimens for a Yellow-legged Meadowhawk (*Sympetrum vivinum*), Spot-winged Glider (*Pantala hymenaea*), Common Whitetail (*Libellula lydia*), Widdow Skimmer (*Libellula luctuosa*), Slaty Skimmer (*Libellula incesta*), Eastern Pondhawk (*Erythemis simplocicollis*), Halloween Pennant (*Celithemis eponina*), Marsh Bluet (*Enallagma erbium*), Citrine Forktail (*Ischnura hastata*), and Eastern Forktail (*Ischnura verticalis*).

This study could also raise interest in other agencies to make artificial wetlands in urban areas. As a typical colorful, large insect, dragonflies could be used by multiple agencies to draw interest in the urban settings. With the emergence of non-consumptive wildlife activities, the interest in simply watching bright animals such as birds, butterflies, and even dragonflies could be used to draw public interest into wildlife and wildlife agencies. The public, especially the public in urban areas, are more likely to be drawn to less intimidating animals, making dragonflies a perfect poster child for wildlife in urban areas. If artificial wetlands are doing so very well with their *Odonata* populations, then it is possible that an artificial wetlands could both function and bring much enjoyment to users in urban areas.

Future studies are always a concern, and I believe that there are plenty that could be drawn from this project. One, of course could be looking at a similar question, but to string it out over a few years instead of one year. Would the data be the same? Or were there certain factors about this study that lead to some data skewing? Are the populations stable in a year to year basis? Another could be to do a total vegetation count on the artificial wetlands and the natural wetlands. Would there be a noticeable difference in the wetlands plants, and what would that mean for the functions of the wetlands?

The management implications that can be drawn from this experiment are also quite important.. As of twelve years ago, 15% of North American *Odonata* species were at risk of becoming extinct (Dunkle 2000). Much of this is due to habitat reduction, disturbance, and destruction and many species that are endemic to North America only. These Dragonflies and Damselflies evolved specifically in the niche where they reside and they can be a very good subject of study for those interested in insects and evolution;

Odonata have been around since pre-historic times. They also tend to cover an important niche in many aquatic habitats by providing not only a source of prey for larger animals like birds and frogs, but they also predate upon nuisance insects such as mosquitos, which could pose a danger to human health. Finally fluctuations in *Odonata* population and diversity can provide an early warning system of sorts to warn against water pollution. Changes in water pH, eutrophication, and siltation can not only affect *Odonata* populations but other populations such as fish, mollusks, and zooplankton as well. By noticing a change in Odonates, a biologist can perhaps discover and stop whatever is causing the pollution before it affects the whole ecosystem. Making Odonates important the wetland health and protection.

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