Do artificial water hazards on golf courses have as much biodiversity as natural wetlands?

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Abstract

The number of natural wetlands in Wisconsin is decreasing due to increased development; however, by government definition, man-made residential ponds and golf course water hazards are considered wetland equivalents. If this is the case, we would expect that these artificial wetlands would have similar communities of aquatic life relative to natural wetlands. Three golf courses that contained both natural and anthropogenic water hazards were chosen for study. The aquatic macroinvertebrate community was sampled over a period of two months. Based on the Shannon index of biodiversity, natural wetlands tended to have a more diverse macroinvertebrate community relative to the artificial wetlands. However, artificial wetlands may develop characteristics of natural wetlands with age. Adjacent land use may also be a contributing factor to the diversity of artificial wetlands. Although the government definition of wetlands may be misleading, carefully designed artificial wetlands may provide some of the functions of natural wetlands.

Literature Review

Wetlands

Wetlands occupy the interphase between uplands and adjacent water areas (Lyon 1993). There are many types of wetlands, all sharing three features: hydric soils, wetland hydrology, and hydrophytic vegetation. In 1978, Wetlands in Wisconsin were defined by the State Legislature as "an area where water is at, near, or above the land surface long enough to be capable of supporting aquatic or hydrophytic (water-loving) vegetation and which has soils indicative of wet conditions (WI DNR 2005)." Although wetlands now occupy less than five percent of the land in the lower forty-eight states, they are home to thirty-one percent of our plant species (EPA 2002 as cited by U.S. Fish and Wildlife Service). More than one-third of threatened and endangered species live only in wetlands, with an additional twenty percent using them at some point in their lifetime (EPA 2006).

In addition to providing high levels of biodiversity, wetlands are extremely important because they function by filtering water, preventing floods and erosion, and providing food, and recreational opportunities for wildlife watchers, anglers, hunters, and boaters (WI DNR 2005). In 1980, fifty-five million people spent ten billion observing and photographing waterfowl and other wildlife species (Salzman 2003). Coastal wetlands, including coral reefs, mud flats and mangroves also protect shorelines from damaging storms by blocking high winds and heavy surf from bays, estuaries, and shorelines with their roots that grow from their binding soil (Sayre 1996). Wetlands also help stabilize temperature and humidity. For example, in summer they may cool off the surrounding air or in winter warm it up (Sayre 1996). Studies indicate that wetlands retain eighty percent of the phosphorus and eighty-nine percent of the nitrogen found in runoff (Salzman 2003). According to the EPA (2002), an acre of wetland can store between one and one half million gallons of floodwater, enough to fill thirty Olympic size swimming pools. A Wisconsin study found that watersheds consisting of thirty percent or more wetlands had sixty to ninety percent lower flood-water levels compared to watersheds with no wetlands (Salzman 2003). Finally, fisheries in wetlands are extremely important around the world. Of the fish we harvest, about two-thirds of the fish and shellfish harvested off the Atlantic and Gulf coasts of the United States depend on coastal wetlands for their survival (Sayre 1996).

The most important wetland type in Wisconsin is the marsh. Marshes are usually dominated by emergent aquatic plants, such as cattails and reeds. The largest freshwater cattail marsh in the United States is the Horicon Marsh in central Wisconsin (WI DNR 2007). In marshes, the water level is always above the mud surface, even during the dry season (Moore 2006). However, marshes are rarely ever deeper than seven feet. Freshwater marshes are very common at the mouths of rivers and form in areas with mineral soil that drains very slowly. Marshes are created when emergent plants that are rooted in the basal mud invade shallow waters, but they may also develop when floating mats of stems and roots invade (Moore 2006). Birds such as herons can hunt fish and amphibians among the tall cattails while being protected from their own enemies. Since marshes receive water from both precipitation and groundwater they are rheotrophic (Moore 2006). The amount of productivity seems to be related to the supply of nutrients and the rheotrophic wetlands are higher in productivity than the ombrotrophic wetlands, since ombrotrophic ones only receive water and nutrient inputs solely from atmospheric precipitation. Cattail marshes, which are rheotrophic, have the second highest primary productivity values of any wetland, with a net primary productivity between 1.32 and 6.60 pounds per square yard per year in dry weight (Weller 1994).

For wetlands to be most beneficial, they should be connected to other habitats so that wildlife has corridors for migration (USGA 2003). For example, protecting only the wetland and developing all around it reduces or eliminates the ability of frogs and salamanders to reproduce because many species of frogs and salamanders move between wooded uplands, where they spend much of the year and where they breed (Woolbright 2003).

Wetland Loss

Wetlands are under threat because floodplain soils are rich in nutrients and people attempt to recover them for agriculture or improved transport. Nineteen states have already lost more than 50% of their wetland areas (California tops all at 91%). Nine states that were historically rich in wetlands have lost more than five million acres of wetlands (Florida has the most: 7,413,160 acres). Losses have been greatest in states with extensive agriculture in drained wetlands (California, Ohio, Missouri, Iowa, Indiana, and Illinois; Dahl 1990). Wisconsin has gone from having 9.8 million acres of wetlands before European settlement down to 5.3 million acres, a loss of approximately forty-six percent (Weller 1994).

Humans have influenced the chemical degradation of wetlands in a variety of ways including: increased air and water pollutants, construction runoff, drainage, mining, and the releasing of toxic chemicals to the air. The Summitville Mine in Colorado, for example, has been mined by soaked ore with gallons of cyanide, that later seeped into local water systems (National Wildlife Federation 2003). According to the General Accounting Office in the Summitville Mine in Colorado, fifty billion tons of mine waste had been generated, 14,400 sites needed to have extensive work done in preventing surface water contamination, and five thousand miles of streams were affected by acid drainage (NWF 2003). Another example of wetland chemical damage is the Florida Everglades, which get pollutants from croplands (National Audubon Society 2003). Since they help flood control and provide water storage for urban centers they are now in extreme danger and very crucial (National Audubon Society 2003).

Finally humans are destroying wetlands by either physically removing plants and animals or introducing new species. For example, in parts of the southeastern United States by illegally harvesting and stealing endangered pitcher plants from national parks. In northern Europe and Canada peat moss is being mined, which is causing loads of damage to bogs (Sayre 1996). In Florida, a fast-growing, non-native plant, water hyacinth, is clogging up waterways and displacing native wetland plants (Sayre 1996). During the last fifteen years, because of all the damage humans are doing to wetlands, the continental duck population has declined from about forty-five million to thirty-one million, a decline of over thirty-one percent (EPA 2002). Nature has also caused plenty of disasters to wetlands. Some of the causes include: erosion, rising sea levels, droughts, and storms (EPA "Status and Trends").

Wetland Recovery

The declining status of the nation's wetland resources has led to a strong need for mitigation and policies have begun to be put in place to minimize the impact on native wetlands. (Zedler 1996). For example, the United States "no-net-loss" policy for wetlands, endorsed by President Clinton in 1993, states that damages to protected habitats are to be avoided, but if unavoidable, they must be mitigated by replacement or enhancement of the resource elsewhere. The agencies that implement it are the Army Corps of Engineers and the Environmental Protection Agency which both indicate that damages to functions shall be mitigated. This means that the compensatory wetland must equal or exceed the performance of the damaged site (Zedler 1996). However, in practice, this is difficult since anthropogenic wetlands are often isolated from other natural corridors, and it is difficult to replace the complexity of a natural ecosystem (Zedler 1996).

An important ecological issue when creating an artificial wetland in place of a natural one is whether the new one should give priority to restoring the functions previously provided, or attempt to replace resources that are currently being lost (Zedler 1996). In other words, should decisions be based on relative abundance of existing and historic habitat types, the opportunities that exist, or the likelihood of achieving restoration goals? If sustaining biodiversity is a goal, mitigation decisions must take into account the present and historic condition of the landscape, not just the impact and mitigation sites (Zedler 1996).

Golf course wetlands

Most recently, many golf courses have been establishing wetlands on their sites. As of 2006, there were 15,990 golf facilities in the United States, and 11,608 of which were open to the public (NGF 2007). The total average acreage of an eighteen hole golf course is one-hundred and fifty acres (GCSAA 2007). With one hundred acres being maintained turfgrass. Of the remaining fifty acres, about eleven acres (seven percent) are water bodies (GCSAA 2007). In the United States there are an estimated 161, 183 acres of water bodies. According to the Golf Course Superintendent Association of America, seventy percent of water bodies are ponds and lakes, while only twelve percent are wetlands (GCSAA 2007). This would suggest that the average golf course has only one acre of wetland and in the United States there would be just under 20,000 acres of wetlands on golf courses in the United States. Most golf course wetlands tend to be marshes, and they are the easiest to create, though, there is sufficient maintenance to keep them from turning into a forested swamp (Moore 2006). Mitigation projects of freshwater marshes take about fifteen to twenty years to develop (Mitsch 1996). However, on April 17, 2006, the Bush Administration announced that the nation is no longer losing wetlands if these golf course water hazards are considered wetlands (Department of Interior 2006 as cited by Clemens 2006).

The community, from Ducks Unlimited to the Theodore Roosevelt Conservation Partnership, reacted quickly and not favorably (Marshall 2006). They argued that artificial wetlands are not equivalent to natural wetlands, because sharp-edged water bodies like water hazards, farm ponds, and even reservoirs offer very little for wildlife (Marshall 2006). This is because abrupt edges are less suitable for emergent plants and, therefore, less attractive to swimming waterbirds (Weller 1994). Even more important, these can rarely achieve the fifty-fifty cover-to-water ratio that seems ideal for most waterbirds.

Invertebrates as a Bioindicator of Wetland Health

One way that humans can monitor whether artificial golf course wetlands are acceptable replacements for natural wetlands is to monitor indicator species. Macroinvertebrates are great for this because some are more sensitive to pollution than others. Macroinvertebrates have short and long life cycles and they integrate stresses to wetlands often within a one-year time frame (EPA 2002). Macroinvertebrates are also a great indicator because many depend on diverse wetland vegetation, and some depend on particular types of vegetation for reproduction (EPA 2002).

There are several invertebrates found in wetlands based on water chemistry, temperature, water depth and fluctuation, and oxygen levels. Invertebrates are one of the most common creatures in wetlands and are an important food for waterfowl and fish. Invertebrates come anywhere in size from microscopic, like most protozoans, to ten centimeters or more, like crayfish. Most invertebrates have complex life cycles with multiple life stages that may be found in different sections of the wetland or even outside the wetland. As with other animals in wetlands, one of the major problems facing wetland invertebrates is when the water becomes stagnant and there is little mixing of oxygen from the air. This causes little oxygen to enter the water, and hardly any to enter the soil and species that can be found in these conditions, typically include bloodworms. When present in high numbers, they are considered indicators of very poor water quality (EPA 2007). Another common species that indicates poor water quality is the pouch snail. When pouch snails are present, they generally indicate nutrient enriched conditions (EPA 2007). However, snails and other mollusks can be abundant organisms in most marshes and are the main diet for many vertebrates (Weller 1994).

Second, there are several species that are moderately sensitive to pollution. The larger dragonflies and damselflies are common sights of the marsh and they are moderately sensitive to pollution. Scuds, which are scavengers of both plant and animal material, are widely variable, although usually not found in severely polluted waters. Sometimes they can be found in moderately polluted waters, although some species are very sensitive and are used as important indicators for water quality (EPA 2007).

Next are the mayflies which display a varied tolerance to pollution, but are generally considered cleaner water benthos (EPA 2007). Mayflies occur in deeper marshes and leave their abundant cases floating on the surface as they fly away; their swimming larvae are abundant and rich food sources (Weller 1994). Other important macroinvertebrates are true bugs, caddisflies and crustaceans. The true bugs (Hemiptera) include water striders and backswimmers with prominent eyes and enlarged, oar like legs. The may be found on the marsh bottom and come to the surface “belly up” for air, which is then carried with them externally. Early in the summer, marshes can produce masses of moth like caddis flies. Many of their larvae build cases of bits of vegetation, other organic materials, or sand.

Crustaceans, though, are the most prominent of the invertebrates. They can be encountered even in food-poor marshes. Many of these are tiny drifting or free-swimming forms, known as plankton; include the water fleas such as daphnia and the copepods such as cyclops. All are vital to the efficiency of food chains. Besides the food invertebrates provide and their conversion of plant materials to animal protein, the most important role that invertebrates play in the ecosystem is that they break down plant material to a size and structure where bacteria and aquatic fungi can further process these products.

To help our everyday problems associated with development, it is better to put an artificial wetland in than none at all. However, I expect that they are not an equivalent substitute. I predict that the artificial wetlands would have a lower biodiversity of macroinvertebrates than natural wetlands since they will have had less time for succession.

Methods

Sampling

To test whether or not artificial water hazards on golf courses have comparable biodiversity to natural wetlands, one natural and one man-made pond was sampled at three different golf courses. At the northwest, southwest, southeast, and northeast sections of each of the ponds, one Ekman dredge and one scoop net was collected. The samples were put into labeled buckets. Within the next four days, the species were sorted into different weighing boats after being looked through a microscope.

<u>Species Richness</u>

The species richness was also recorded, which included zooplankton (copepods and ostracods). Species richness is how many different species were present in a given pond.

<u>Shannon Diversity Index</u>

Then, the biodiversity was measured using the Shannon Diversity Index. The Shannon Diversity index equals the Σ (p_i*ln p_i), where p_i refers to the decimal proporation of individuals of a species to the total number of individuals overall. All of the organisms in a given pond, from the four corners collected, were summed into one chart, so that a single index was calculated for each pond. The Shannon Diversity Index assumes that the diversity or information in a sample or community can be measured in a similar way or the information contained within a message or code (Kent 1997). The index makes the assumptions that individuals are randomly sampled from an "infinitely large" population and that the species from a community are included in the sample.

Study Areas

The first site was the Big Mo Course at Rainbow Springs in Mukwonago, Wisconsin. Rainbow Springs was built in 1962 and the Mukwonago River runs through it. The first pond analyzed was a natural pond with a few trees along the edge of it. A picture of it is shown in Appendix A. The second pond was a man-made pond around ½ an acre, except it did not have as many large trees around the perimeter.

The second course was Brighton Dale Golf Links in Kenosha, Wisconsin. This course was built in 1971. The natural wetland selected was about eight acres, has an island in the center, and is shown in Appendix B. It has an abundance of cattails around the outer and inner edges. The artificial wetland is about half the size, but still fairly large with an island in the center as well.

Finally, the third site was the Bull at Pinehurst Farms. This course opened in 2000 and the Onion River runs through it. The natural wetland selected has two golf holes bordering it. It is shown Appendix C. The artificial wetland also has a split fairway from the same hole bordering it on two sides.

Results

Overall, the natural wetlands had a greater biodiversity of macroinvertebrates than the artificial wetlands (Figure 1). The wetland with the highest diversity index was the artificial wetland sampled at Rainbow Springs. The artificial wetland at Rainbow Springs, constructed in 1962, actually had the highest biotic index of all the wetlands at 1.998. The next highest was the natural one at Rainbow Springs with an index of 1.989. However, natural wetlands had a higher average biodiversity index than the artificial wetlands (Figure 2). After taking the averages of the three natural and the three artificial wetlands, natural wetlands had an average biotic index of 1.698 and artificial wetlands had an average index of 1.161.

After running a t-test, the difference between natural and artificial wetlands is not significant. The confidence interval was only 66.4% (Warner 2003).

The natural wetlands also had a greater species richness than artificial wetlands (Figure 3). The wetland with the most species was the natural wetland at Rainbow Springs with 16 different species.

The most abundant species in each of the ponds are shown in Table 1. They included: mayflies, bloodworms, scuds, caddisfly #1, pouch snails, and backswimmers. The species that had the greatest abundance of all was the mayfly in the artificial wetland at the Bull at Pinehurst Farms where it comprised of 88% of all the species population.

Backswimmers and scuds were both only present in the natural and artificial wetland at Rainbow Springs and the natural one at Brighton Dale Golf Links. They are shown in Table 2 (in white and light green). Damselflies were present mostly in the natural wetlands, and not the artificial ones. Bloodworms were found in all the wetlands except the natural one at Rainbow Springs. Orb snails were only cited at Rainbow Springs.

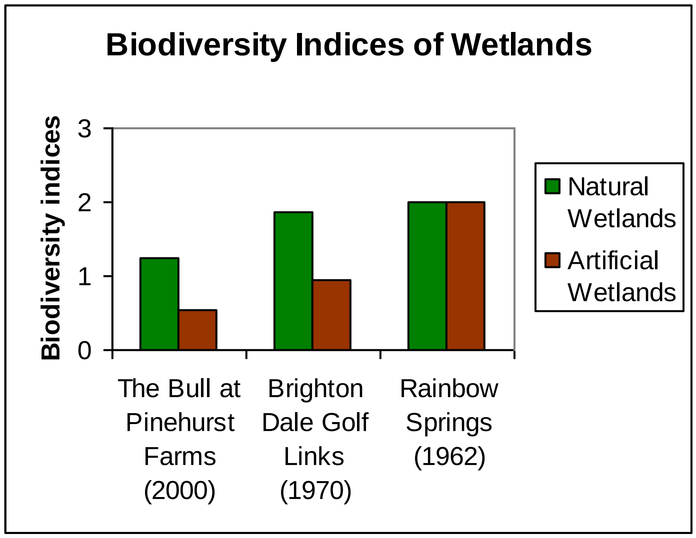


Figure 1. Biodiversity indices of wetlands sampled. The sites are in order from youngest (left) to oldest (right). The actual values are shown in the Appendix's A through C at the end.

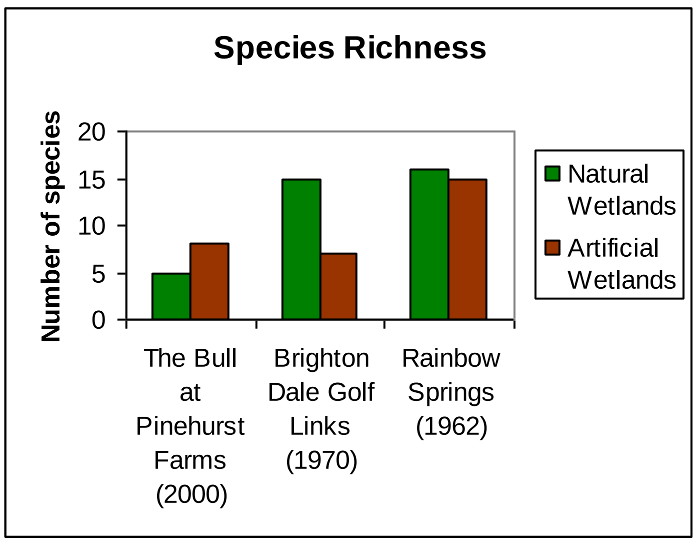


Figure 2. Species richness of wetlands sampled. The sites are in order from youngest (left) to oldest (right).

Table 1. Most abundant species in each pond. The ones in bold that are italicized are very sensitive to pollution. The regular bold ones are semi-tolerant to pollution, while the rest are pollution tolerant.

Site	Natural wetland	Percent of all species	Anthropogenic wetland	Percent of all species
Rainbow Springs	**Backswimmers** (59 of 188)	31%	**Scuds** (68 of 261)	26%
Brighton Dale Golf Links	**Caddisfly #1** (116/282)	41%	Bloodworms (39/67)	58%
The Bull at Pinehurst Farms	Pouch snails (25/52)	48%	***Mayflies*** (309/351)	88%

Table 2. This table lists species that were the most abundant in all the wetlands. The species listed came from taking the four most abundant species in each of the six ponds and listing them. As is shown in the table below, many of them were abundant in more than one pond. Then the percentage from each pond was listed even if there was none.

Species	The Bull at Pinehurst Farms (natural)	Brighton Dale Golf Links (natural)	Rainbow Springs (natural)	The Bull at Pinehurst Farms (artificial)	Brighton Dale Golf Links (artificial)	Rainbow Springs (artificial)
Backswimmers	0	6.0	31.4	0	0	8.0
Bloodworms	13.5	5.7	0	4.6	58.2	11.9
Caddisflies	0	41.1	0	0	0	0
Damselflies	17.3	9.2	5.30	4.30	3.0	0
Dragonflies	0	0	5.9	0	3.0	3.8
Mayflies	21.2	0	3.7	88.0	34.3	13.0
Orb snails	0	0	21.3	0	0	23.0
Pouch snails	48.1	0	.5	0	0	0
Scuds	0	17.0	13.8	0	0	26.1
Others	0	21.0	18.1	2.2	1.5	14.2

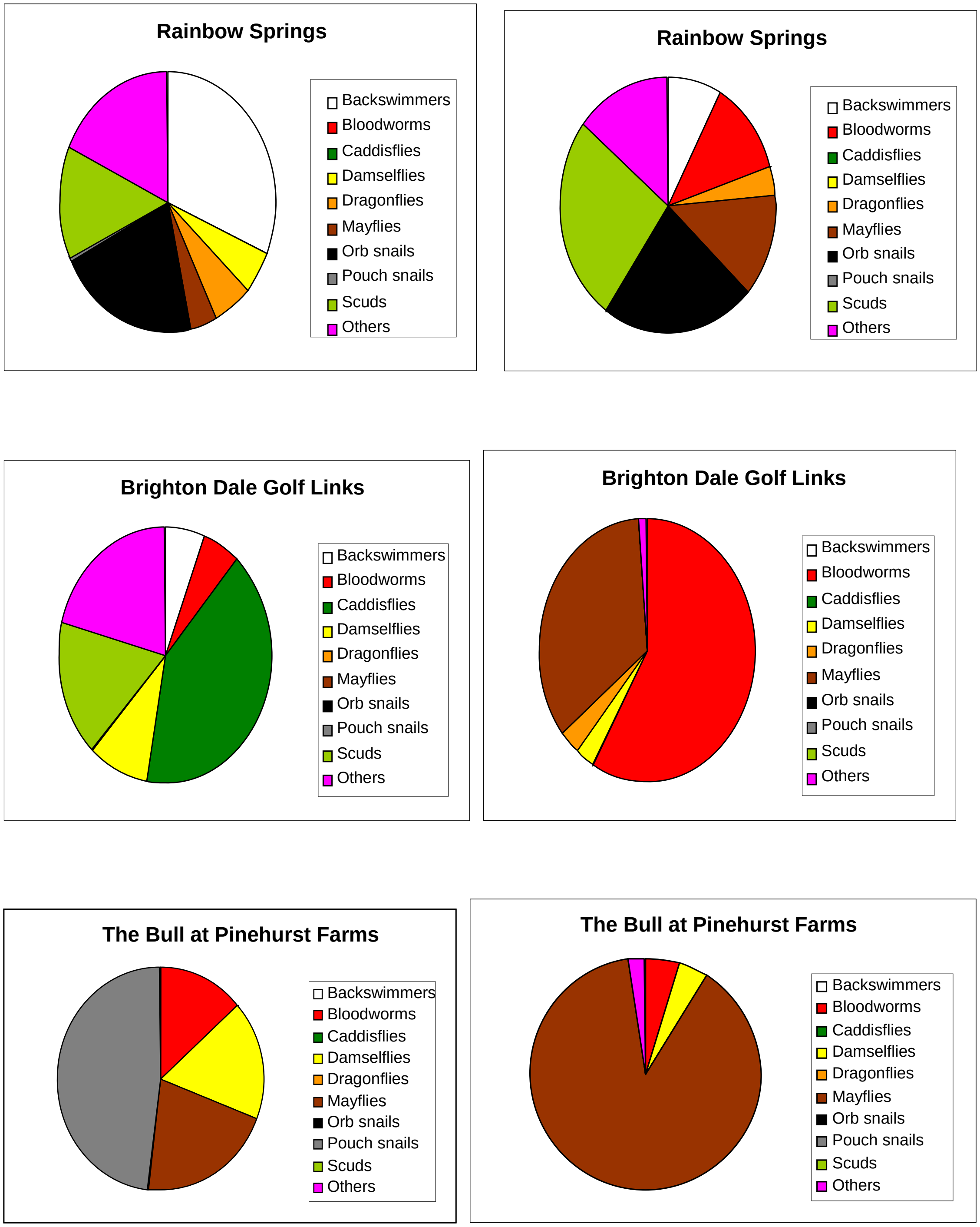


Figure 3. Shows the relative proportion of the ten most common species at the three sites. The ones on the left represent the natural wetlands and the ones on the right represent the artificial ones at each site.

Discussion

Natural wetlands had a higher average biodiversity than the artificial wetlands suggesting that these two types of wetlands are not equivalent. The only artificial wetland that had a higher biotic index than of any of the natural wetlands was the one sampled at Rainbow Springs, which is the oldest site with the longest time for other plants and macroinvertebrates to colonize and become established in the system. The artificial wetland also has other wetlands and creeks that attach to it and those attach to wooded areas. This allows wildlife species that are not likely to cross an open turf-dominated area, frequently occupied by humans, to more likely use the area. Frogs, for example, can reproduce if there is an adjacent forest or woodland, because many species of frogs move between wooded uplands, where they spend much of the year and where they breed (Woolbright 2003).

The next oldest of the other two artificial wetlands, the one at Brighton Dale Golf Links, had a higher biotic index than the artificial wetland at The Bull at Pinehurst farms. This is likely due to the fact that the one at the Bull was constructed in 2000 whereas the one at Brighton Dale was constructed thirty years earlier. They are both similar in size, although the one at Brighton Dale has a grassy island in the center. The one at the Bull at Pinehurst Farms in Sheboygan was about one foot below normal because of the dry weather in the summer and fall of 2007.

There were a few species that were only found in the wetlands with higher biotic indices which were the two at Rainbow Springs and the natural one at Brighton Dale. One of them was orb snails which were only present in the two wetlands at Rainbow Springs. According to the Wisconsin DNR, orb snails live in clean, quiet waters (Wade 2004). Backswimmers and scuds were only present in two of the natural wetlands and one artificial wetland. However, the three ponds they were present in were the ones with the highest species richness and biodiversity indices. Damselflies were found mainly in the natural wetlands, although there were also some in two of the artificial wetlands. According to the EPA's *Biological Indicators of Health* (September 2007), scuds and damselfies are moderately tolerant benthos. This explains why scuds and damselflies are found mainly in natural wetlands, although the highest percentage of scuds was 26.1% in an artificial one at Rainbow Springs.

Mayflies, according to the EPA, are sensitive benthos. However, Figures 4 and 5 show that mayflies (brown) were found mainly in the artificial wetlands. At the Bull at Pinehurst Farms, they comprised approximately 88% of the population (shown in Table 1) in the artificial wetland. This is probably due to all the nutrients from the golf hole, bordering approximately sixty percent of the hole, running off into the pond and creating algae blooms, which mayflies feed on. Consequently, the natural wetland with the most mayflies was at the Bull at Pinehurst Farms.

The less sensitive invertebrates were mostly found in the artificial wetlands. For example, bloodworms were the dominant species in the artificial pond at Brighton Dale, and they were present in the other three lower diverse wetlands. They are aquatic *Diptera* which are generally found in soft mud bottoms, and when present in high numbers are considered indicators of very poor water quality (EPA 2007). The chemical that makes them red helps them get oxygen when they are in the benthos. The chemical is hemoglobin, just like in our blood. Their dominance in the artificial wetlands is illustrated in Figure 4, where they are shown in the right column in the color red. Figure 4 shows how they were also present in the two of the natural wetlands but not as dominant.

Pouch snails, which made up about half the sample in the natural wetland at the Bull at Pinehurst Farms, generally indicate nutrient enriched conditions and poor water quality (EPA 2007). The natural wetland they were found in has two golf holes bordering about one-half of the wetland. This may lead to loads of nutrients, not filtered yet, entering the wetland.

As expected, the natural wetlands had a higher biodiversity index and a higher species richness average. The largest natural wetland, the wetland at Brighton Dale, would supposedly have the highest species richness. It ended up having one less species than the natural one at Rainbow Springs, however. Another unique result was the natural wetland at the Bull at Pinehurst Farms had fewer species (a lower species richness) than did the man-made one at the Bull, although its biodiversity index was still greater. This may be due to the fact that the man-made one is slightly larger. The larger the wetland area, the greater its ability to sustain a diversity of species (Libby 2004). The exception to this rule is vernal pools, which, by definition, are small, seasonal wetlands. These small wetlands are extremely valuable to amphibians because of their small size and lack of fish predators. Many reptiles and amphibians use seasonal wetlands for breeding (Gibbons 2001 as cited by Libby 2004).

The artificial wetlands, however, were not significantly different. I would have had a much lower standard deviation if I had taken four samples from each pond consisting of one Ekman and one dip net and then taken the average Shannon index of the four samples.

I chose biological assessment over traditional chemical measures. Although chemical measures of water quality are useful to help determine sources of wetlands contamination, they do not provide information about acute or long-term impacts on aquatic life and wildlife. Chemical water samples serve as a "snapshot in time", since chemical concentrations measured may be highly variable from day to day depending on such factors as the timing of discharges, amount of recent precipitation and water flow patterns (Bureau of Land & Water Quality 2005). Therefore, water samples alone might be misleading and fail to detect sporadic contaminants that may have entered and can damage wetland ecosystems. Also, chemical sampling is not useful to evaluate certain types of wetland impacts, such as the presence of invasive species.

Information about wetland plant and animal communities is especially valuable as an indication of both water quality and overall wetland health. Unlike physical and chemical measures, biological communities integrate the environmental stress over time, since the types and numbers of organisms present reflect the quality of their surroundings. Biological assessment provides a direct, objective measure of wetland condition and can be used to evaluate impacts from a variety of human activities. There are several potential uses of wetland bioassessment. They can help detecting ecological damage to wetlands, identifying sources and causes of wetland degradation, measure the success of wetland protection activities and restoration projects, study ecological links between wetlands and other water bodies, improve wetland management and regulatory tools, and track wetland condition over time (Bureau of Land & Water Quality 2005).

Historically, wetlands have been viewed as something to eliminate in the development of a golf course. Therefore, golf courses wetlands, lakes, and streams overall have been changed from thriving habitats into manicured “water features.” This is important since it takes away vegetated buffer areas which are areas around the edge of a water body specifically maintained with plants that will reduce storm water flow and potential pollution from runoff. The plants in a vegetated buffer take up nutrients, trap sediments, reduce erosion, and slow down water as it moves from the land into a pond. For most wetlands, a minimum of twenty-five feet should be used as a buffer width (Libby 2004). In the past, course superintendents had received little or no training on how to manage them, other than how to eliminate plants and wildlife (Libby 2004).

Another problem with golf course wetlands are that high levels of fertilizers can cause eutrophication and pesticides can impact wildlife. This is evident even in the natural wetlands on golf courses. The biodiversity samples of four natural wetlands, which were not on any golf courses, sampled in my aquatic ecology class, all had diversity indices greater than all the golf course wetlands, except for one which had an index of 1.994 (the highest golf course one was 1.998). They are shown in Figure 12 under Appendix F. The species richness in all of the “wild” wetlands was twenty-two or greater, whereas the greatest richness for any golf course wetland was sixteen. This shows that it is best for a natural wetland to be left as it currently is.

An interesting observation was that caddisflies, which are moderately tolerant, composed of two-fifths of the population in the natural wetland at Brighton Dale. However, they were not found in any other wetland sampled. According to Wade (2004), some species of caddisflies build homes of leaves or twigs; others use tiny stones, and some are free-living. Some caddisflies live in temporary stagnant ponds while other types will only live in swift streams. All caddisflies, however, eat plants and some catch tiny bits of plants by building a net to trap food as it drifts past (Wade 2004). At the natural wetland at Brighton Dale, there are woods at one end, there are cattails all the edge and near the middle. In between the cattails, the water is deep and not as stagnant. The ecology and limnology of the wetland seems to suit the needs of caddisflies.

In order for us to keep high levels of biodiversity in our wetlands, we definitely need to keep our natural wetlands, whether or not we add artificial wetlands. It is better to construct an artificial wetland than none at all because of all the wetlands already lost, but one of the many drawbacks to artificial wetlands is their high construction costs.

The average cost of a created wetland, for example, is forty-thousand per acre, not including the cost of the land (MI DEQ 2007). Therefore, focusing on wetland protection by avoiding land alteration in and near existing wetlands is not only better for a community's environmental health, it is better for the budget as well.

Most studies suggest that there is much room for improvement in the building of wetlands. Maguire in 1985 (cited by Mitsch 1996) used area, vegetative cover, and implementation of permit conditions to estimate migration success in Virginia and found that only fifty percent of twenty-three mitigation wetlands were "successful." In most unsuccessful cases, the mitigation project had been implemented. Another study done by Reimold and Cobler in 1985 (cited by Mitsch 1996) conducted for the U.S. EPA gave similar results. Glubiak et al. (1986) and Quammen (1986) (cited by Mitsch 1996) both suggested the need for better management of mitigation wetlands. Additionally Glubiak et al. (1986) predicted that while the protection of wetlands through a permit process – Section 404 of the Clean Water Act enacted by the U.S. Congress in 1972 – was somewhat effective, it would not prevent wetland area losses as effectively as it should.

In 1991, Erwin (cited by Mitsch 1996), found that of forty mitigation projects in south Florida involving wetland creation and restoration, only about half of the required 430 hectares of wetlands had been constructed and that twenty-four of the forty projects were judged as incomplete or failed. The most significant problems with the created wetlands were improper water levels and hydroperiod. Hydroperiod means the cyclical changes in the amount or stage of water in an aqueous habitat.

Erwin (1991 as cited by Mitsch 1996) pointed out that several Florida wetlands were considered failures in his Florida study because they lacked suitable hydrology. In so-called "on-site mitigation," wetlands are developed in watersheds near the wetlands being drained or lost; their success is often problematic because of the usual proximity of the mitigation project to a human-altered landscape and the accompanying changes in hydrologic conditions. In these settings, created and restored wetlands can lead to greater water level fluctuations compared to those in more natural settings. Unpredictable and rapidly fluctuating hydrology can lead to washouts, scouring, planting failure, and macroinvertebrate emigration, leading to decreased biodiversity and even loss of water quality function.

More recently, however, stricter government regulations, changes in the attitude within the golf industry, and both criticism from and collaboration with the environmental community have led the golf industry in taking a closer perspective on its status of environmental issues. The main question facing the golf communities today is how to move the industry forward in a way that not only does no harm, but that may actually have some benefits in terms of integrating environmental attributes, including fully functioning wetlands, into golf course design and management. One of the best ways to do this is to keep maintain natural wetlands and but when creating new wetlands, establish corridors with natural areas and establish buffers around all wetlands.

Appendix A

Rainbow Springs Data

Weather: Mostly Cloudy, 75 degrees Fahrenheit, and winds WSW around 10 mph (September 25, 2007)

Mostly cloudy, 65 degrees Fahrenheit, and winds S around 10 mph (October 16, 2007).

Figure 4. Shown above is a natural pond between the 11th and 17th holes at Rainbow Springs Golf Course in Mukwonago, Wisconsin.

Shannon biodiversity index for the natural wetland shown in Figure 4.

	# of species	Proportion of total species	In p_i	-(p_i In p_i)
Ostracods	Present			
Copepods	Present			
Backswimmers	59	0.314	-1.159	-0.364
Tadpoles	1	0.005	-5.236	-0.028
Leeches	2	0.011	-4.543	-0.048
Orb snails	40	0.213	-1.548	-0.329
Giant water bugs	1	0.005	-5.236	-0.028
Dragonfly larvae	11	0.059	-2.839	-0.166
Crawling water beetle	1	0.005	-5.236	-0.028
Water mites	9	0.048	-3.039	-0.145
Bloodworms	18	0.096	-2.346	-0.225
Damselfly nymph	10	0.053	-2.934	-0.156
Scuds	26	0.138	-1.978	-0.274
Water scavenging beetle	2	0.011	-4.543	-0.048
Pouch snail	1	0.005	-5.236	-0.028
Mayfly nymph	7	0.037	-3.291	-0.123
Total	188	1.000		1.989

Figure 5. A man-made pond at Rainbow Springs.

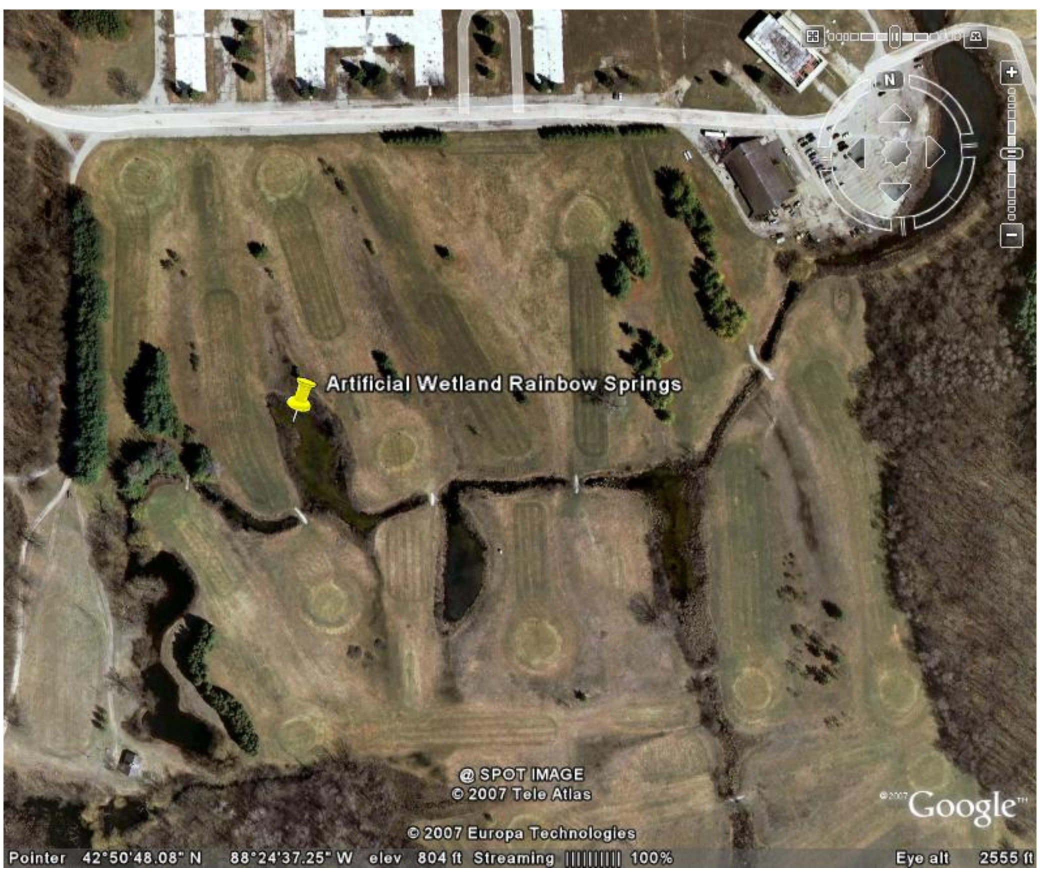


Figure 6. This map shows how the artificial wetland at Rainbow Springs has a several wetlands all interconnected be creeks. There are woods at the ends of the corridor.

Shannon biodiversity index of the man-made pond shown in Figure 5 at Rainbow.

	# of species	Proportion of total species	In p_i	-(p_i In p_i)
Bloodworms	31	0.119	-2.131	-0.253
Mayfly nymph	34	0.130	-2.038	-0.266
Damselfly nymph	24	0.092	-2.386	-0.219
Ostracods	present			
Copepods	present			
Aquatic Sowbogs	2	0.008	-4.871	-0.037
Dragonfly larvae	10	0.038	-3.262	-0.125
Waterscavenging beetle	3	0.011	-4.466	-0.051
Backswimmers	21	0.080	-2.520	-0.203
Water mites	3	0.011	-4.466	-0.051
Orb snails	60	0.230	-1.470	-0.338
Leeches	3	0.011	-4.466	-0.051
Scuds	68	0.261	-1.345	-0.350
Tadpoles	1	0.004	-5.565	-0.021
Crayfish	1	0.004	-5.565	-0.021
Total	261			1.998

Appendix B

Brighton Dale Golf Links Data

Weather: Mostly Cloudy with fog, 60 degrees Fahrenheit, and winds S around 10 mph (October 2, 2007)

Turning sunny, 50 degrees Fahrenheit and winds out of the NW around 15 mph (October 31, 2007)

Figure 7. A large natural wetland at Brighton Dale Golf Links in Kenosha county.

Shannon biodiversity for the natural wetland shown in Figure 7

	# of species	Proportion of total species	In p_i	-(p_i In p_i)
Ostracods	present			
Caddisfly #1	116	0.411	-0.888	-0.365
Caddisfly #2	1	0.004	-5.642	-0.020
Dragonfly larva	4	0.014	-4.256	-0.060
Bloodworms	16	0.057	-2.869	-0.163
Damselfly nymph	26	0.092	-2.384	-0.220
Water mites	26	0.092	-2.384	-0.220
Scuds	48	0.170	-1.771	-0.301
Mayfly	20	0.071	-2.646	-0.188
Backswimmer	17	0.060	-2.809	-0.169
Gilled snails	2	0.007	-4.949	-0.035
Green sunfishes	2	0.007	-4.949	-0.035
Tadpoles	2	0.007	-4.949	-0.035
Catfish	1	0.004	-5.642	-0.020
Fingernail Clams	1	0.004	-5.642	-0.020
Total	282			1.852

Figure 8. A man-made pond at Brighton Dale Golf Links.

Shannon biodiversity for the pond shown in Figure 8.

	# of species	Proportion of total species	In p_i	p_i In p_i
Dragonfly larvae	2	0.030	-3.512	-0.105
Bloodworms	39	0.582	-0.541	-0.315
Ostracods	present			0.000
Mayfly nymph	23	0.343	-1.069	-0.367
Copepods	present			0.000
Damselfly nymph	2	0.030	-3.512	-0.105
Threadworm	1	0.015	-4.205	-0.063
Total	67			0.954

Appendix C

The Bull at Pinehurst Farms

Weather: Partly Clouds, 55 degrees Fahrenheit, and winds W around 20 mph (October 17, 2007).

Figure 9. A large natural wetland at The Bull at Pinehurst Farms in Sheboygan County. Photo Courtesy of The Bull at Pinehurst Farms (www.golfthebull.com)

Shannon biodiversity for the natural wetland shown in Figure 9

	# of species	Proportion of total species	In p_i	$-(p_i \text{ In } p_i)$
Ostracods	present			
Mayfly nymph	11	0.212	-1.553	-0.329
Bloodworms	7	0.135	-2.005	-0.270
Damselfly nymph	9	0.173	-1.754	-0.304
Pouch snails	25	0.481	-0.732	-0.352
Total	52			1.254

Figure 10. A man-made pond at The Bull at Pinehurst Farms.

Shannon biodiversity for the pond shown in Figure 10.

	# of species	Proportion of total species	In p_i	p_i In p_i
Damselfly nymph	15	0.043	-3.153	-0.135
Bloodworms	16	0.046	-3.088	-0.141
Ostracods	present			
Mayfly nymph	309	0.088	-0.127	-0.112
Copepods	present			
Water mite	4	0.011	-4.474	-0.051
Midgefly larvae	4	0.011	-4.474	-0.051
Water scavenging beetle	3	0.009	4.762	-0.041
Total	351			0.530

Appendix D

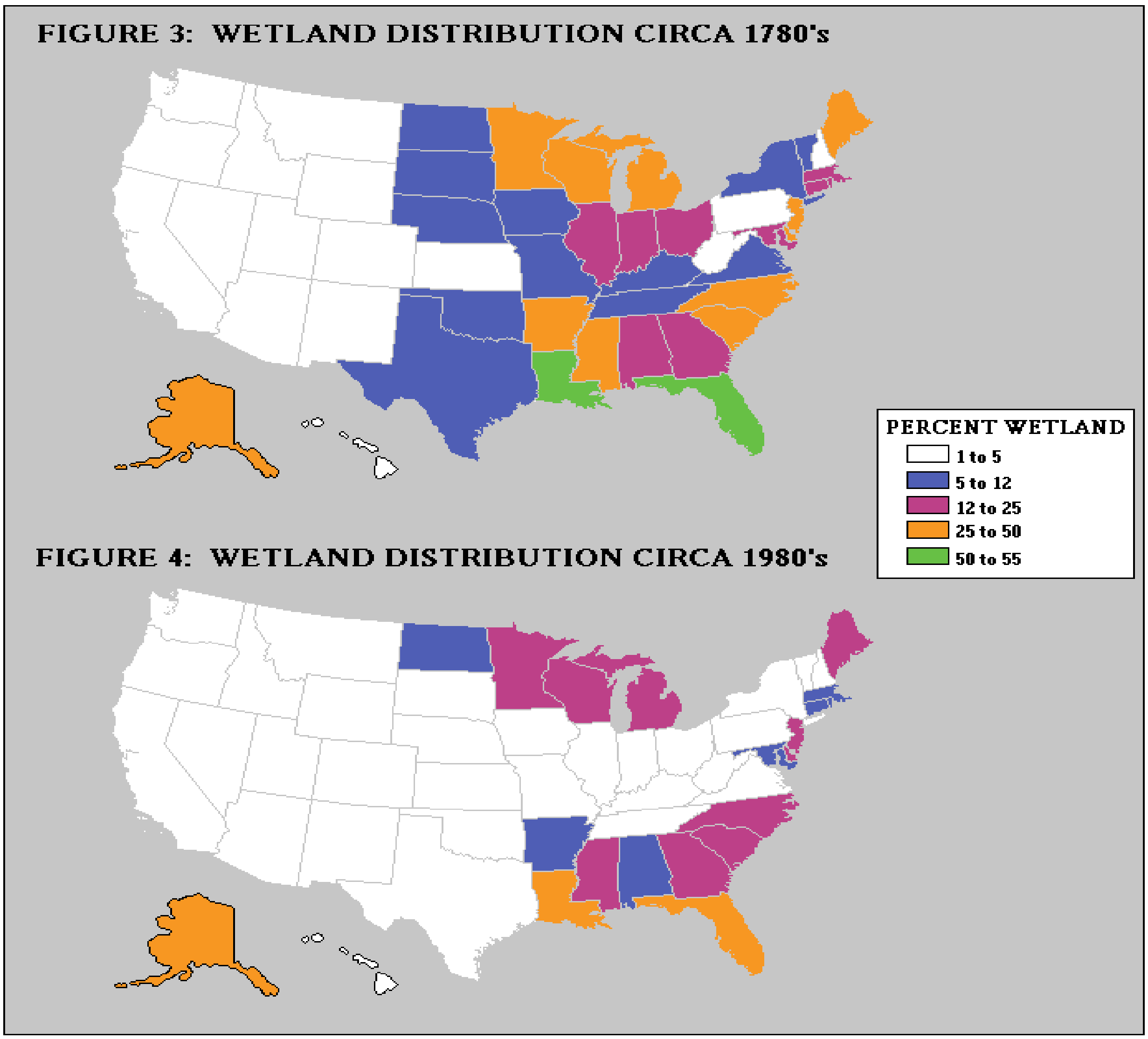


Figure 11. Change in Percent of Wetlands in each state. (Dahl 1990)

Appendix E

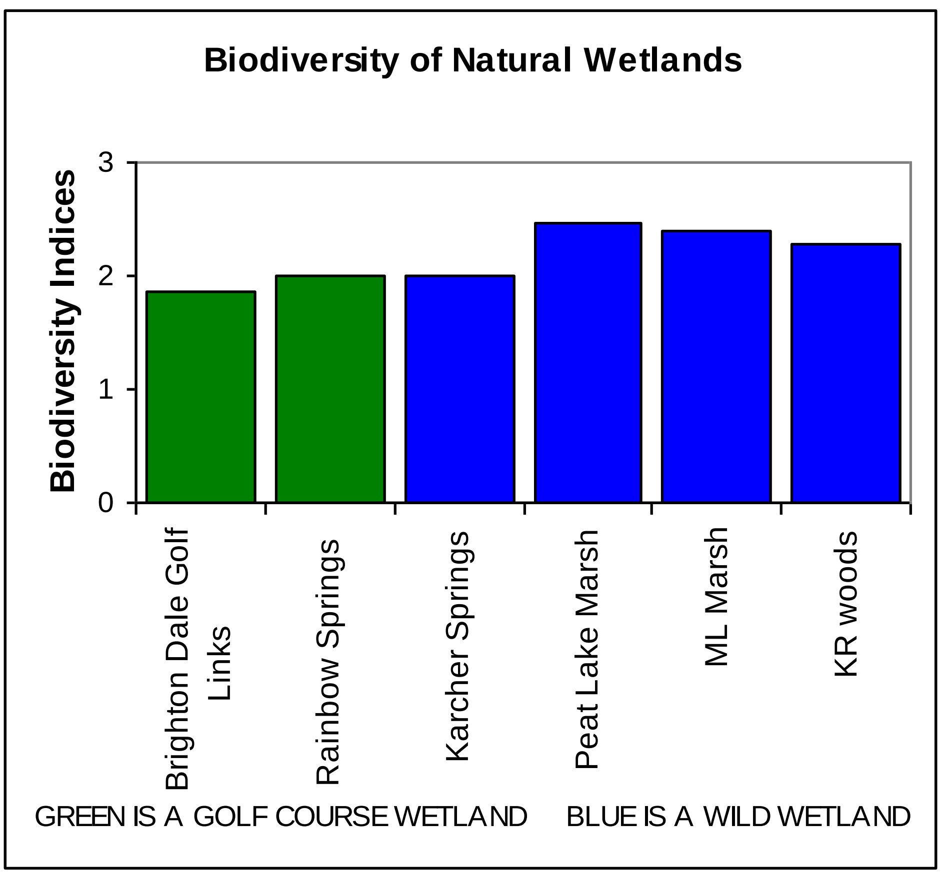
Survey

	Rainbow Springs	Brighton Dale	The Bull at Pinehurst Farms
Are no-mow areas or shoreline plantings incorporated around wetlands to slow and filter runoff and provide habitat?	Yes	Yes	Yes
Where more extensive shoreline plantings cannot be incorporated, is the mowing height raised around wetland borders to create a grassy buffer?	Yes	Yes	Yes
Are no-spray or limited spray practices and mechanical controls employed around wetlands?	Yes	Yes	Yes
Is a comprehensive integrated pest management (IPM) program in place to keep turfgrass vigorous and healthy and minimize the need for chemical control measures?	Yes	Yes	Yes
When aquatic weed maintenance is required, are physical solutions employed first (e.g. hand and mechanical weed removal)?	N/A	No	No
Are maintenance companies selected that comply with the course’s request for environmentally sensitive best management practices?	Yes	No	No
Are maintenance staff trained and familiar with management strategies protecting wetland areas?	Yes	No	No
Are signs used to call attention to wetland boundaries and educate golfers about the importance of these areas?	No	No	No
Are carts kept out of wetland areas?	Yes	Yes	Yes

Appendix F

Site	Shannon Biodiversity Index	Species Richness
KR Woods	2.279	26
Karcher Springs	1.994	30
Peat Lake Marsh	2.476	22
ML	2.403	25

Figure 12. Shows the biotic indices and species richness for four natural wetlands sampled in an aquatic ecology class I took (Fall 2007). However, I was not the only one to collect and sort the samples. The graph illustrates the results. It is important to note that golf course natural wetlands do not have the biodiversity levels of wild natural wetlands.



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