ABSTRACT

Title of Document:	VEGETATION PATTERNS IN DEPRESSIONAL RESTORED, NATURAL REFERENCE, AND PRIOR-CONVERTED WETLANDS IN THE USA MID-ATLANTIC COASTAL PLAIN.
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Vegetation responds quickly to environmental changes, making it a useful tool for assessing the success of wetland restorations. Plant community composition was compared in 47 sites across the coastal plain of Maryland, Delaware, Virginia, and North Carolina, USA. Fifteen of the sites were isolated depressional wetlands (natural reference), 16 were farmed "prior-converted cropland" sites (ditched and drained former wetlands), and 17 were restored wetlands. Prior-converted sites were highly disturbed and dominated by non-wetland conventional row crops. Natural reference sites were dominated by native woody species and restored sites were dominated by herbaceous wetland species. Natural reference sites had lower Anthropogenic Activity Index scores, higher average coefficients of conservatism, and higher Floristic Quality Assessment Index scores than restored and prior-converted sites. Wetland restorations have succeeded in developing wetland plant communities, but have not developed plant communities that match natural reference wetlands. This is likely due to continued human disturbance, age, and a lack of proper propagules.

VEGETATION PATTERNS IN DEPRESSIONAL RESTORED, NATURAL REFERENCE, AND PRIOR-CONVERTED WETLANDS IN THE USA MID-ATLANTIC COASTAL PLAIN.

By

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Dedication

To my parents: Roger Yepsen and Alice Nass-Yepsen. To my dad for instilling in me a love of wetlands and nurturing my love of bizarre science. And to my mom for inspiring me to be strong, while cultivating a life of balance and tenderness.

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Chapter 1: General Introduction

Wetland Loss

The United States has lost more than 50% of its wetlands since European settlement (Dahl 1990). Wetlands provide valuable ecosystem services, including: flood water storage, removal of sediment and nutrients from water, regulation of greenhouse gasses, recreation, and habitat. They are home to one in three federally listed threatened or endangered plant and animal species (Dahl and Johnson 1991). Wetlands in the Mid-Atlantic Coastal Plain help to maintain water quality and aquatic habitats of the Chesapeake Bay, Albemarle Sound, and other large, highly productive estuarine ecosystems on the East Coast of the United States. (Tiner 1987; Chesapeake Bay Program 1998).

Depressions and Flats of the Mid-Atlantic Coastal Plain

Flats and depressions are non-tidal freshwater wetlands that dot the East Coast of the United States from New Jersey to Florida. There are multiple types of wetland depressions, one type being Delmarva Bays, which are shallow elliptical depressions with sandy rims thought to have been be created by wind blowouts in ponds 16,000-21,000 years ago (Stolt and Rabenhorst 1987, Brooks et al. 2011). Seasonal depressions in the Mid-Atlantic Coastal Plain often function as recharge wetlands in summer and discharge wetlands in winter and spring and many have only infrequent surface connections to other water bodies (Phillips and Shedlock 1993, Brooks et al. 2011). Their hydrology is driven mainly by precipitation, evapotranspiration, and ground water (Sharitz 2003). The hydrology of organic soil flats is similarly driven by precipitation and vertical fluctuations of water, but they have less relief and often have higher organic matter content in their soils (Brooks et al. 2011).

Under natural conditions, seasonal depressions and organic soil flats are forested in the Mid-Atlantic Coastal Plain, sometimes with herbaceous zones at the center. Maryland has lost 73% of its wetlands, Delaware 54%, North Carolina 49%, and Virginia 42% (Dahl 1990 and 2011). Wetland losses have mostly been due to conversion to agriculture, and more recently to urbanization. Many of the forested depressions and flats were logged, ditched, drained, and planted with conventional row crops (termed “prior-converted cropland” if converted prior to the 1985 Farm Bill). Restoration projects have been undertaken in some depressions and flats throughout the Mid-Atlantic Coastal Plain in an attempt to regain the services and functions provided by natural wetlands.

Restoration

Two important federal initiatives that are devoted to restoring depressional wetlands in Mid-Atlantic Coastal Plain are the Wetland Reserve Program (WRP) and the Conservation Reserve Program (CRP). The WRP and CRP are voluntary programs that provide financial incentives and technical assistance for landowners to protect, restore, and enhance wetlands on their land. The goal of WRP is “to achieve the greatest wetland functions and values, along with optimum wildlife habitat, on every acre enrolled in the program” (NRCS WRP website). WRP’s objectives are to “protect, restore, and enhance the functions and values of wetland ecosystems” (NRCS WRP website), to protect habitat for migratory birds and other wetland-dependent flora and fauna, protect and improve water quality, attenuate floodwater, recharge ground water, protect and improve aesthetics of open spaces, and contribute to education and scientific knowledge (USDA NRCS Manual Title 440 Wetland Reserve Program 2010). These are achieved by implementing a Wetland Reserve Plan of Operations that outlines how the land will be restored. Restoration is defined by WRP as "the rehabilitation of degraded or lost habitat in a manner such that – 1) The original vegetative plant community and hydrology are, to the extent practicable, reestablished; or 2) A community different from what likely existed prior to degradation of the site is established. The hydrology and native self-sustaining vegetation being established will substantially replace original habitat functions and values and does not involve more than 30 percent of the wetland restoration area" (USDA NRCS Manual Title 440 Wetland Reserve Program 2010). Alternative plant and animal communities can be established in part of the project area to improve the habitat functions and values of the site. The 2008 Farm Bill authorized WRP to enroll up to 3 million acres through the end of fiscal year 2012 either as cost share programs, 30-year easements, or permanent easements (USDA FY 2011 Budget Summary And Annual Performance Plan).

The USDA Farm Service Agency (FSA) uses CP23 to restore wetlands in the 100-year floodplains and CP23a to restore wetlands outside the floodplain. As of 2011 1.99 million acres of wetland had been restored through CRP in agricultural areas (USDA FY 2011 Budget Summary And Annual Performance Plan). CRP CP23 goals are to prevent degradation of wetland areas, increase sediment trapping efficiency, improve water quality, prevent erosion, and provide habitat for waterfowl and other wildlife (FSA Handbook). These services are typically provided by restoring the wetland according to the NRCS Wetland Restoration Practice Standard (Code 657), which defines wetland restoration as: “The return of a wetland and its functions to a close approximation of its original condition as it existed prior to disturbance on a former or degraded wetland site” (NRCS Practice Standard Code 657 2010). To the extent possible, the objective of the restoration is to have soil, hydrology, vegetation, and habitat match the conditions of the site found prior to human disturbance (NRCS Practice Standard Code 657 2010). Original conditions are determined from historical records or the use of an intact reference sites (NRCS Practice Standard Code 657 2010). Alternative communities are allowed in 30 % of the sites, but the other 70 % can be maintained as an herbaceous community so long as it is a precursor of what would naturally occur (personal communication, Steve Strano, NRCS). CRP contracts tend to be shorter than WRP contracts at 10 to 15 years.

Wetland ecosystems are complex and the specific suite of environmental factors needed to restore historic or reference conditions and functions can be difficult to determine (Zedler and Callaway 1999). Some of the more important environmental factors include: hydroperiod, soils, nutrient availability, competition, and plant propagules. Methods for the restoration of forested wetlands lag behind the relatively well developed emergent marsh restoration techniques, and forested sites take significantly longer to mature and stabilize than herbaceous sites (Clewell and Lea 1990, Mitsch and Gosselink 2007). Most wetland restorations take the form of ponds with a fringe of emergent marsh, regardless of what type of wetland they were historically (Kentula et al. 1992, Dahl 2005), although many newer restoration practices involve the creation of shallower macrotopography and microtopography which support the development of larger herbaceous wetland areas and less open water.

My research compared plant communities in seasonal depressions and organic soil flats along a wetland alteration gradient: semi-natural wetlands with native vegetation, prior-converted croplands, and restored wetlands. Relatively intact and undisturbed sites were used as natural reference sites to set a baseline for determining what the plant community of a wetland should look like "pre-disturbance" given the realities of current landscape conditions. Prior-converted cropland sites were originally flats or depressions, but are now drained and planted with conventional row crops. Restored wetlands, formerly prior-converted croplands, were impounded or excavated depressions restored through WRP, CRP, or other USDA programs.

Restoration Methods

Restoration methods for the sites surveyed for this research were compiled from restoration files, field notes, aerial photography, and soil profile observations. A combination of one or more of the following methods was used to promote wetland hydrology during restoration: excavation of a depression, soil compaction to form a perched water table, construction of a water retention berm, and/or ditch plugging. Excavation and compaction were more common in Maryland and Delaware and ditch plugging was more common in North Carolina (personal observation and Fenstermacher 2012). Excavated restorations generally created shallow round depressions with gentle slopes. Topsoil was removed without replacement at most of the excavated sites, leaving compacted soils with very low organic content (Fenstermacher 2012). Many sites had heterogeneous topography in the form of islands, rows of several small depressions, or finer scale microtopography. Some of the sites were planted with trees and most sites were planted with upland grass mixes on berms and buffers.

Goals

As part of the Wetlands Component of the Conservation Effects Assessment Project (CEAP) National Assessment objective to quantify the effects and effectiveness of USDA wetland conservation measures in agricultural lands, my study compared vegetation in depressional wetlands under three management states in the Mid-Atlantic Coastal Plain; semi-natural wetlands with native vegetation which were used as reference sites (natural reference), prior-converted cropland (formerly natural reference), and restored (formerly prior-converted). My goals were to:

1) Compare the character and quality of plant communities in natural reference, restored, and prior-converted depressional wetlands and assess whether restored wetlands are developing plant communities and functions similar to what would have been found pre-disturbance as evidenced by plant communities in natural reference sites. This is addressed in chapter 2 by describing plant community composition and structure as well as commonly used metrics of floristic quality designed to measure ecosystem integrity in wetlands.

2) Describe the degree to which each type of wetland is currently impacted by human disturbance. The degree of human disturbance was quantified using the Anthropogenic Activity Index; results from this are reported in chapter 2 and the implications are discussed in chapters 2 and 3.

3) Look at the roles played by seed dispersal and time-since-restoration in a restored

wetland’s transition from emergent marsh to forested wetland. This is addressed in chapter 3 by looking at the life history traits of the dominant species in natural reference sites and correlating plant community structure with environmental conditions and the time-since-restoration.

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Chapter 2: Plant Community Differences Between Natural Wetlands, Restored Wetlands, and Prior-converted Croplands

Abstract

As part of a multi-investigator project to assess the effectiveness of USDA-Natural Resources Conservation Service wetland conservation measures, I compared plant community composition in 47 sites across the Mid-Atlantic Coastal Plain in Maryland, Delaware, Virginia, and North Carolina, USA. Fifteen of the sites were depressional wetlands (natural reference), 16 were farmed “prior-converted cropland” sites (ditched and drained former wetlands), and 17 were restored depressional wetlands. Each site was visited during the 2011 growing season and vegetation was sampled in 100-square-meter plots. Differences were compared using the Shannon Evenness Index, species frequency and cover, coefficients of conservatism (based on tolerance of disturbance and fidelity to specific environmental conditions), USFWS Wetland Indicator Status (frequency a species is found in wetlands), species richness, origin (native or non-native), and cover by woody and herbaceous species. An Anthropogenic Activity Index (AAI) worksheet was completed at each site to assess the level of human disturbance, and two common floristic indices, the Floristic Quality Assessment Index (FQAI) and the Floristic Assessment Quotient for Wetlands (FAQWet), were used to compare qualitative differences between site types. There was little overlap in the species composition between the three site categories. Prior-converted sites were highly disturbed (high AAI), dominated by non-

wetland conventional row crops, and had low species diversity and evenness. Both natural reference and restored wetlands were dominated by native wetland plants and had similar evenness. Restored sites had the highest species diversity. Natural reference sites were dominated by woody species (75% cover by woody species and 13% by herbaceous) and restored sites were dominated by herbaceous cover (8% woody and 66% herbaceous). Species found in natural reference sites were less tolerant of disturbed conditions than those found in restored sites as indicated by average coefficients of conservatism. This is reflected in the AAI, which indicated that restored sites were four times more impacted by human disturbance than natural reference sites. Thus restored wetlands have succeeded in developing diverse native wetland plant communities, but so far they have not developed plant communities that match those found in natural wetlands.

Introduction

More than 50% of wetlands in the lower 48 United States were lost between the 1780s and the 1980s (Dahl 1990). In the Mid-Atlantic Coastal Region, Maryland lost 73% if its wetlands, Delaware 54%, North Carolina 49%, and Virginia 42%. Losses were largely due to conversion to agriculture and more recently to urbanization (Dahl 1990 and 2011). Federal programs have been implemented in the United States to protect and restore wetlands because they provide valuable ecosystem services, including: flood water storage, removal of sediment and nutrient from water, greenhouse gas regulation, support of native plant and animal biodiversity, and unique recreation opportunities. Wetlands in the Mid-Atlantic Coastal Plain are especially vital because they help to maintain water quality and aquatic habitat of the Chesapeake Bay, which is one of the largest and most productive estuarine ecosystems in the U.S. (Tiner 1987 and Chesapeake Bay Program 1998).

The Wetland Reserve Program (WRP) and Conservation Reserve Program (CRP)-Wetland Initiative (CP23) provide financial and technical assistance to landowners to protect, restore, and in some cases enhance wetlands on their land. Programmatic objectives include protecting wetlands, providing habitat for migratory birds and other wetland-dependent flora and fauna, protecting and improving water quality by trapping sediment and removing nutrients, attenuation of floodwater, recharging ground water, protecting and improving aesthetics of open spaces, and contributing to education and scientific knowledge. Services are provided by returning the soil, hydrology, and plants to as close to a historic pre-disturbance condition as possible.

However, wetland ecosystems are regionally distinct and complex and the steps required to return a degraded wetland to the functional equivalency of a natural wetland have not been agreed upon and require tailoring to each site (Zedler and Callaway 1999). Most wetland restorations take the form of ponds with a fringe of emergent marsh, regardless of what type of wetland they were historically (Kentula et al. 1992, Cole and Shafer 2002). On average the $500 million WRP budget and part of the $1.8 billion CRP budget are spent on wetland restorations yearly (American Planning Association 2010). The return on these investments can be difficult to determine due to the complexity of measuring ecosystem functions.

Biological indicators of ecosystem integrity have been developed into rapid field assessment methods (Fennessy et al. 1998, Lopez and Fennessy 2002, and Fennessy et al. 2004). These assessments can be used to describe overall ecosystem condition, suggest probable causes of poor conditions, identify human activities that contribute to degradation, monitor wetland restoration trajectories, and set and assess measureable goals (Galatowitsch et al. 1999 and Cronk and Fennessy 2001). Karr and Dudley (1981) define ecosystem integrity as: "the capability of supporting and maintaining a balanced, integrated, adaptive, community of organisms having species composition, diversity, and functional organization comparable to that of natural habitats of the region." Ecosystem integrity is thought to be inversely related to human disturbance because disturbances can change nutrient cycling, photosynthesis, hydrology, competition, predation, and more. Plants are one of the easiest and most frequently used factors for assessing the progress of a wetland restoration (Mitsch and Wilson 1996). Plants are adapted to normal natural variations in conditions and plant communities reflect the current state as well as historic conditions (Wilcox 1995, Bedford 1999, and Cronk and Fennessy 2001). As human disturbance increases, the proportion of weedy species tends to increase and given extreme disturbance plants tend to decrease in size of individuals, in cover, and in lifespan (Karr 1993). Some of the advantages of using plants as biological indicators include: they are present in most wetland ecosystems; they are relatively easy to identify; established methods for sampling exist; and their immobility creates a direct link between onsite environmental conditions and plant community characteristics (Cronk and Fennessy 2001). Because of these traits, plant communities provide a good way to compare the condition of wetlands along a human alteration gradient.

As part of an objective of the Wetlands Component of the Conservation Effects

Assessment Project (CEAP) National Assessment to quantify the effects and effectiveness of USDA wetland conservation efforts in agricultural lands, my study compared vegetation in depression and flat wetlands under different management practices in the Mid-Atlantic Coastal Plain. My goals were to: 1) compare wetland plant communities along a human alteration gradient including restored wetlands, natural reference wetlands, and prior-converted croplands; 2) describe the degree to which each type of wetland was impacted by human disturbance; 3) assess whether restored wetlands had developed wetland plant communities similar to what would have been found on site prior to human disturbance as indicated by the reference sites; and 4) determine the functional values gained by restoring a prior-converted cropland to a depressional wetland.

Methods

Study Sites

A total of 47 depressions and flats were chosen for study by the USDA in the Mid-Atlantic Coastal Plain regions of Delaware, Maryland, Virginia, and North Carolina. The sites consisted of 14 natural reference wetlands, 17 restored wetlands, and 16 prior-converted cropland sites. Sites were chosen to minimize natural differences and maximize anthropogenic differences (Figure 1, Lang et al. 2010). The natural reference sites were shallow forested depressions and flats that are seasonally flooded and infrequently connected to other wetlands via surface water. Natural reference sites are used to characterize the vegetation of depressions and flats under natural relatively undisturbed conditions. The prior-converted croplands were once depressions or flats like the natural reference sites, but in their current state they have been drained and are planted with row crops such as soybeans or corn (Figure 2). The restored wetlands were restored from prior-converted cropland condition and ranged in age from three to eleven years and in size from one to ten acres. Hydrology was restored either by plugging ditches (common in NC sites) or by excavation and compaction to create shallow perched water table depressions (common in MD, DE, and VA). Most restored sites had water retention berms and hummocks or islands for microtopography. Some of the restored sites were planted with trees and most were planted with upland grasses on berms and in buffer areas.

Figure 1: Sites were chosen in blocks of restored, natural reference, and prior-converted cropland sites to minimize the effect of local variation in environmental variables (Google Earth).

Figure 2: a) Typical natural reference wetland plant community, generally dominated by trees and shrubs. b) Typical restored wetland plant community, generally composed of grasses, sedges, and herbs. c) Typical prior-converted cropland vegetation, generally covered in conventional row crops.

Vegetation Survey

Vegetation surveys were conducted once in each of the 47 sites between late June and September 2011. The areas sampled in natural reference and restored wetlands were within the wetland boundary as roughly delineated by the change from wetland to upland plants. Ponded areas without vegetation were not sampled. Prior-converted sites were sampled within 25 paces of the wettest drained area. Given adequate area, three 10x10-m quadrats were randomly selected per plant community in each site. Plant communities were visually determined based on changes in dominant species. Where space allowed, quadrat location was selected using a randomly generated compass point and number of paces from the center of the wetland. If space was somewhat limited, quadrats were placed so that they were completely contained within the plant community, which sometimes meant changing the shape of the 100 square meters. When space was very limited, quadrats were placed so as not to be overlapping. Adequate sampling was ensured by sampling all plant communities and by surveying the site for any species not included in the quadrats. All dominant plants and 90% or more of the species in each site were included in the quadrats. Each species within the 100-square-meter area was assigned a percent cover class (Trace, 0-1, 1-2, 2-5, 5-10, 10-25, 25-50, 50–75, 75–95, or >95; class midpoints were used in data analysis) (Peet et al. 1998). Any plants that could not be identified to species in the field were collected, pressed, dried, and later keyed out in the lab using Radford et al. (1968), Brown and Brown (1972), Brown and Brown (1984), and Gleason and Cronquist (1991). Plant nomenclature is consistent with the USDA Plant Database (USDA, NRCS 2012).

Dominant Species

Dominant species in each type of site were chosen based on frequency (number of natural reference, restored, or prior-converted sites they were found in) and highest average percent cover. Percent cover of a species at each site was extrapolated from an average of cover in each quadrat, with 0% cover assigned in quadrats where the species was not found. These calculations were then used to determine the approximate cover of woody and herbaceous plants at each site.

Indices

Several vegetation indices commonly used to determine differences in wetland condition were used to compare the sites. The use of these indices enables objective quantitative comparison of wetlands with different plant community types. In order to describe plant community structure, the following were calculated for each site and then averaged to get the mean for each type of site: the Shannon Evenness Index, richness (number of species), average Wetland Indicator Status, average coefficients of conservatism, percentage of woody species, and origin (native or non-native).

The Floristic Quality Assessment Index (FQAI) was developed by Andreas and Lichvar (1995) to assign a repeatable quantitative value when assessing a wetland's "naturalness or presence of conservative species." It is based on coefficients of conservatism, which are ranks between zero and ten assigned regionally to individual wetland species based on their observed tolerance of disturbance and fidelity to specific conditions (Table 1; Andreas and Lichvar 1995, Lopez and Fennessy 2002, Ervin et al. 2006).

Table 1: Coefficients of conservatism (CC), which are ranks between zero and ten assigned regionally to individual wetland species based on their observed tolerance of disturbance and fidelity to specific conditions (Andreas and Lichvar 1995, Lopez and Fennessy 2002, Ervin et al. 2006). CCs for the Mid-Atlantic region were recently developed by researchers at Penn State and are still being tested (Chamberlain and Ingram, in review).

Coefficients of Conservatism	Basis of Rank
0	Non-native and opportunistic
1-3	Native species typical of disturbed sites
4-6	Native species that tolerate some disturbance even though they are generally associated with a specific plant community
7-8	Native species found in plant communities in the advanced successional stage that have undergone minor disturbance
9-10	Native species with high degrees of fidelity to a narrow range of synecological parameters

FQAI score for each site was calculated for each site as:

$$FQAI = \frac{R}{\sqrt{N}}$$

Where *R* is the sum of the Mid-Atlantic coefficients of conservatism for all species found at a site developed by Chamberlain and Ingram (in review) and *N* is the number of native plants identified to species in each site.

FQAI was adapted by Ervin et al. (2006) into the Floristic Assessment Quotient for Wetlands Index (FAQWet). FAQWet has the advantage of using regional USFWS Wetland Indicator Status classifications, which have been developed for all regions of the United States, rather than coefficients of conservatism, which have not. Wetland indicator status is assigned to plant species based on how frequently they are found in wetlands. The other way that the two indices differ is that the FAQWet equation places a heavier weight on non-native plant species than the FQAI. Both indices are influenced by species richness.

FAQWet score for each site was calculated as:

$$FAQWet = \frac{\sum WC}{\sqrt{S}} \times \frac{N}{S}$$

where *WC* is the wetness coefficient value assigned to each species of the site based on its regional wetland indicator status (Table 2), *S* is the species richness per site, and *N* is the number of native species at each site.

Table 2: Wetness coefficients based on Wetland Indicator Status categories (Hudson et al. 1997, Reed 1998, and Ervin et al. 2006)

Indicator Status	Probability of Occurrence in Wetlands	Wetness Coefficient
Obligate wetland (OBL)	>99%	+5
FACW+		+4
Facultative Wetland (FACW)	67-99%	+3
FACW-		+2
FAC+		+1
Facultative (FAC)	34-66%	0
FAC-		-1
FACU+		-2
Facultative Upland (FACU)	1-33%	-3
FACU-		-4
Upland (UPL)	<1%	-5

The Anthropogenic Activity Index (AAI) worksheet developed by Hudson (2005) was used to document the extent of continued human disturbance in each site (worksheet in Appendix 1). The AAI worksheet rates wetlands on a scale of 0-3 for five conditions: land use intensity in a 500-m buffer; intactness and effectiveness of a 50-m buffer; hydrologic alteration; habitat alteration; and habitat quality and microhabitat heterogeneity.

Statistical Analysis

Comparisons for statistical significance were made using analysis of variance (ANOVA) performed using the MIXED procedure in SAS version 9.2 (SAS Institute, Cary, NC). Significance was assigned for $P < 0.05$. Mean and standard error were calculated using MEANS procedure in SAS. Regressions were run using ProcReg in SAS and SigmaPlot (Systat Software, San Jose, CA) comparing AAI to FQAI and FAQWet scores to determine the floristic indicators' correlation with disturbed conditions.

Results

Plant Community Composition

Overall 204 species were found across the three site types – 71 in natural reference sites, 134 in restored sites, and 34 in prior-converted sites. Four species (*Hypericum mutilum, Phytolacca Americana*, *Diospyros virginiana*, and *Liquidambar styraciflua*) were found at all three types of sites. Restored sites had 17 species overlapping with natural sites and 20 species overlapping with prior-converted sites (see Appendix 2 for a full list of species found at each site). Species richness differed significantly between all three site types, with an average restored site containing almost 25 species, about 5 more species than a natural reference site and 15 more than a prior-converted site (Figure 3). In natural reference sites about 70% percent of the species were woody. This was 55% more than the restored sites and nearly 70% more than prior-converted sites (Figure 4). This is also reflected in the average cover of woody and herbaceous species (Figure 5). Natural sites had under 15% cover by herbaceous species and over 75% cover by woody species. This is in stark contrast to restored and prior-converted sites that had more than 65% cover by herbaceous species and less than 10% cover by woody species.

The dominant plant species in natural reference sites were all woody with the exception of two *Woodwardia* species (Figure 6). *Liquidambar styraciflua* (sweetgum), *Acer rubrum* (red maple), and *Clethra alnifolia* (coastal sweetpepperbush) were found in 90% or more of the natural reference sites. Of the species found in more than half of the sites, *A. rubrum* had the highest average percent cover (close to 30%), followed by *Nyssa biflora* (swamp tupelo, near 20%), and *L. styraciflua* (near 15%). *Smilax rotundifolia* (roundleaf greenbrier), *Eubotrys racemosa* (swamp doghobble), *Magnolia virginiana* (sweetbay), and *Ilex opaca* (American holly) were all found in 50-80% of natural references sites, but had low average percent cover (1-5% cover). *Woowardia virginica* (Virginia chainfern), *Morella cerifera* (wax myrtle), and *Pinus taeda* (loblolly pine) were dominant in the sites they were found in (around 10% average cover), but were only found in 20-25% of natural reference sites.

Restored plant communities were dominated by sedges, grasses, and herbs (Figure 6). Species found in roughly half of restored sites included *Juncus effusus* (common rush), *Ludwigia palustris* (marsh seedbox), *Echinochloa crus-galli* (barnyardgrass), *Bidens sp.* (beggarticks), and *L. styraciflua* (sweetgum). Species with average percent cover from 10-20% included *E. crus-galli, Xanthium strumarium* (rough cocklebur), *Scirpus purshianus* (weakstalk bulrush), *Phragmites australis* (common reed), and *Mollugo verticillata* (green carpetweed). *L. styraciflua* and *A. rubrum* are woody species found in both natural reference and restored sites, but averaged under 1% cover in restored sites.

Prior-converted cropland sites were dominated by conventional row crops of *Zea mays* (corn), *Glycine max* (soybean), *Gossypium hirsutum* (upland cotton), or *Sorghum bicolor* (sorghum). One of these four species was found in every site. *S. bicolor* had the highest average percent cover (around 80%), followed by *G. hirsutum* at 70%, and *Z. mays G. max* with cover around 45%. *Ipomoea* species (morning glory), *Solanum carolinense* (Carolina horsenettle), and *Phytolacca americana* (American pokeweed) were found in 40% or more sites, but generally had cover of less than 1% (Figure 6).

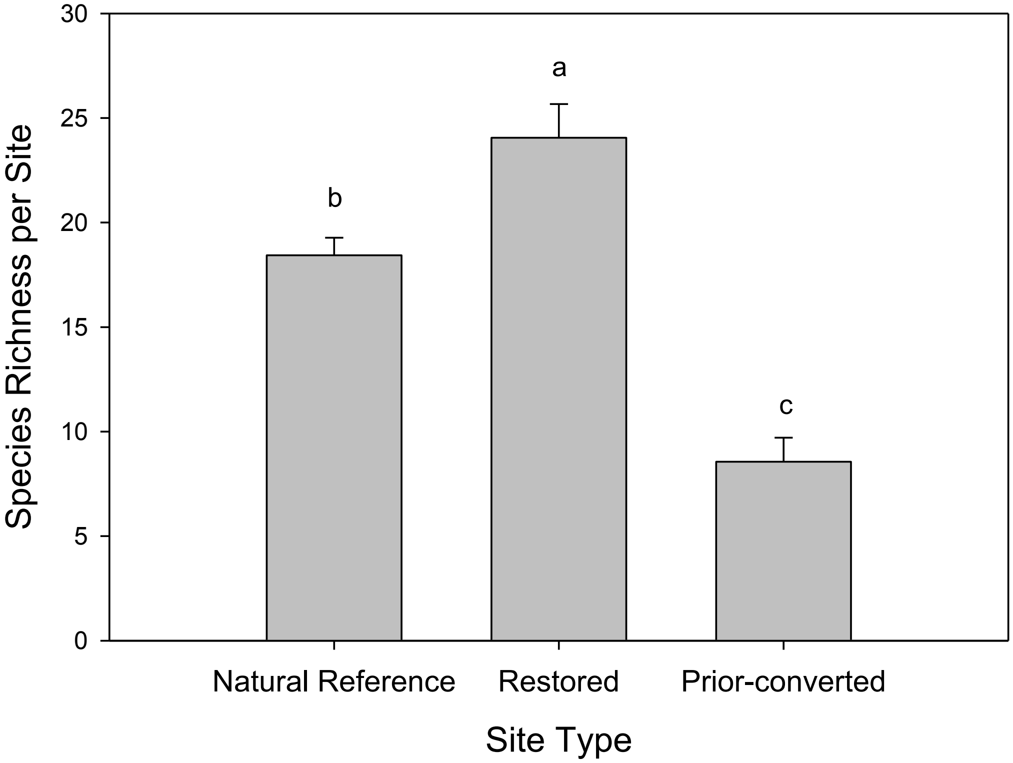


Figure 3: Plant species richness per site. Plotted values are mean + 1SE and means with different letters representing statistically significant differences (Tukey, $p < 0.05$).

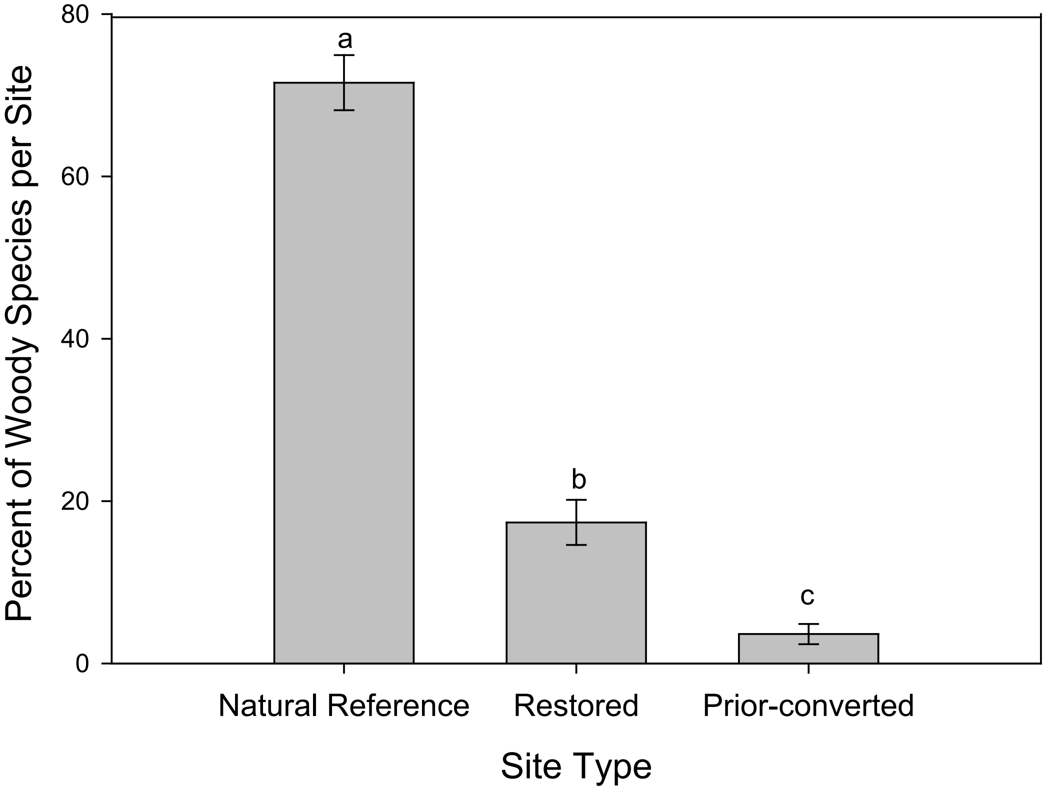


Figure 4: Percent of species characterized as "woody" per site. Plotted values are mean + 1SE and means with different letters representing statistically significant differences (Tukey, $p < 0.05$).

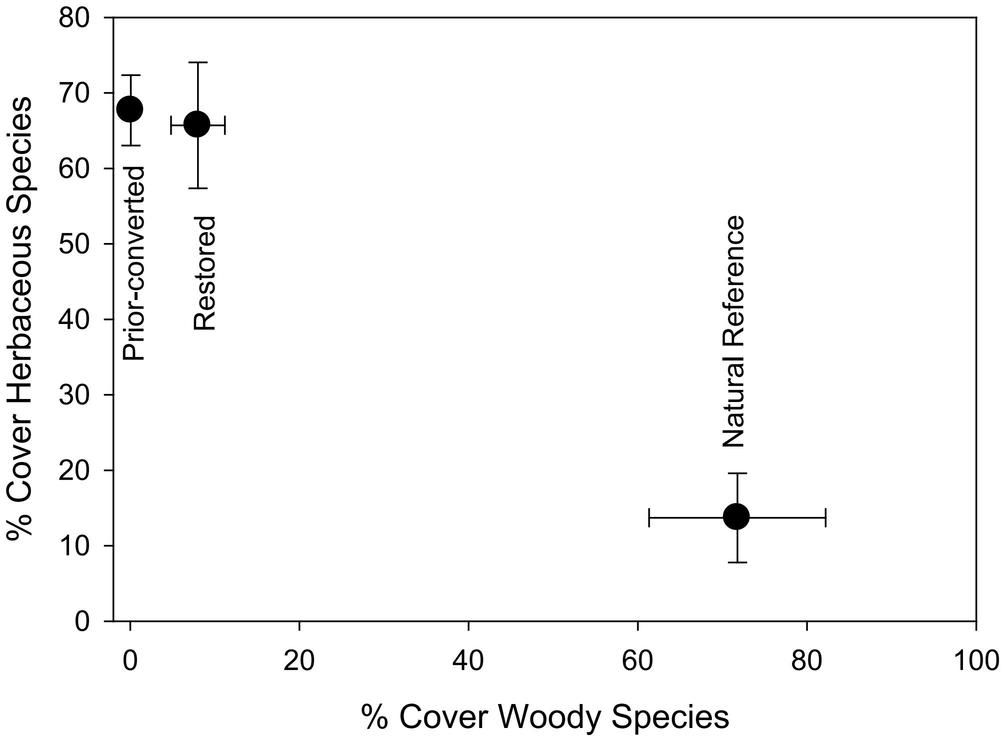
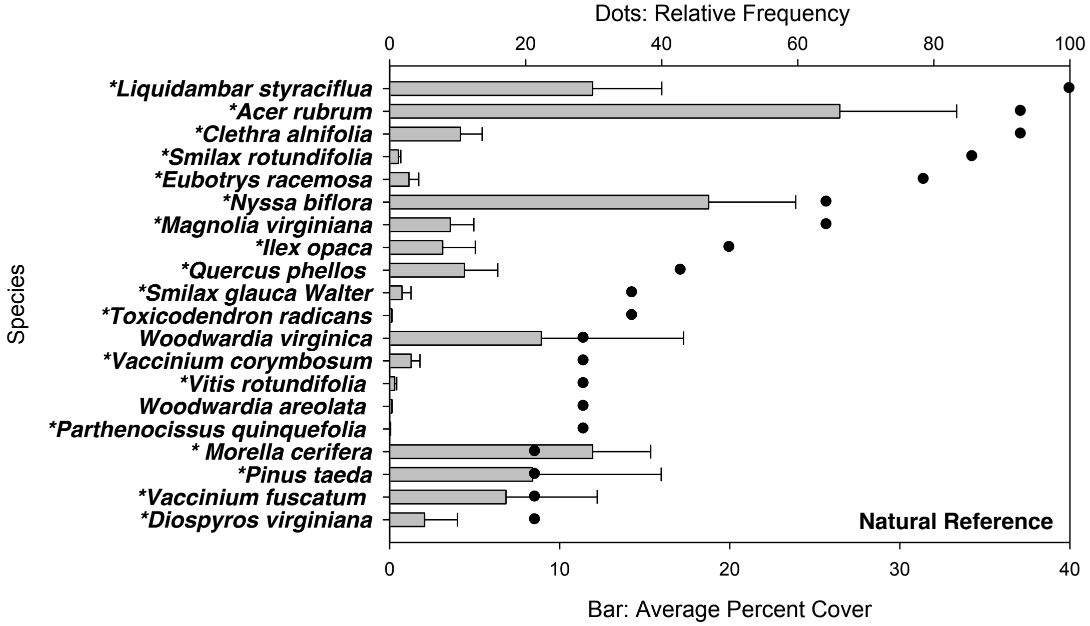
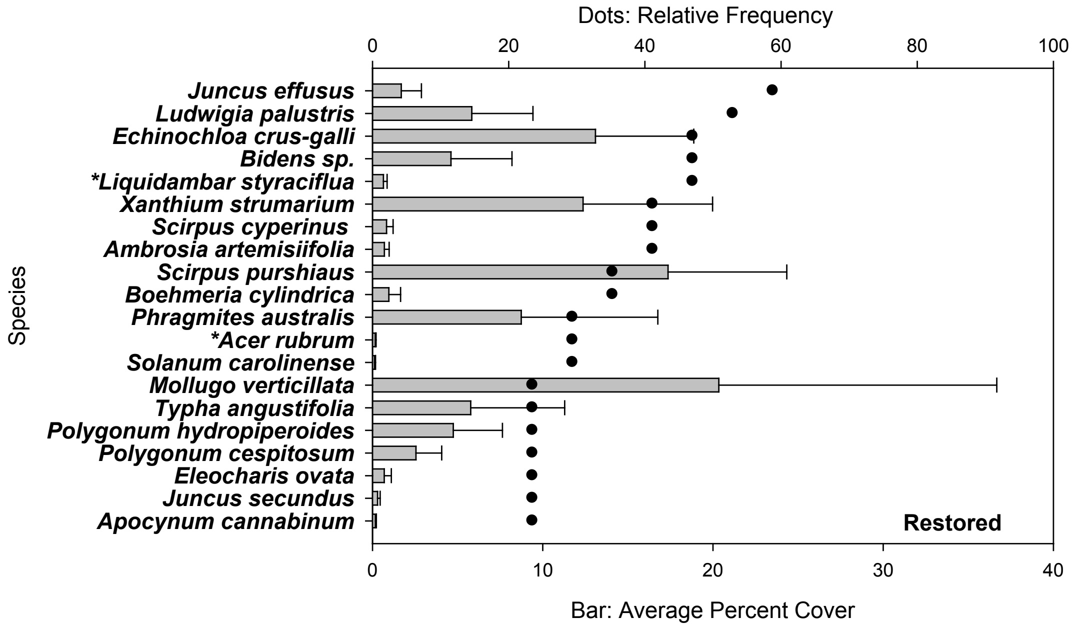


Figure 5: Cover of herbaceous and woody plants per site in depressional wetlands in the Mid-Atlantic Coastal Plain, extrapolated from mean cover in quadrats. Plotted cover values are mean +1SE.





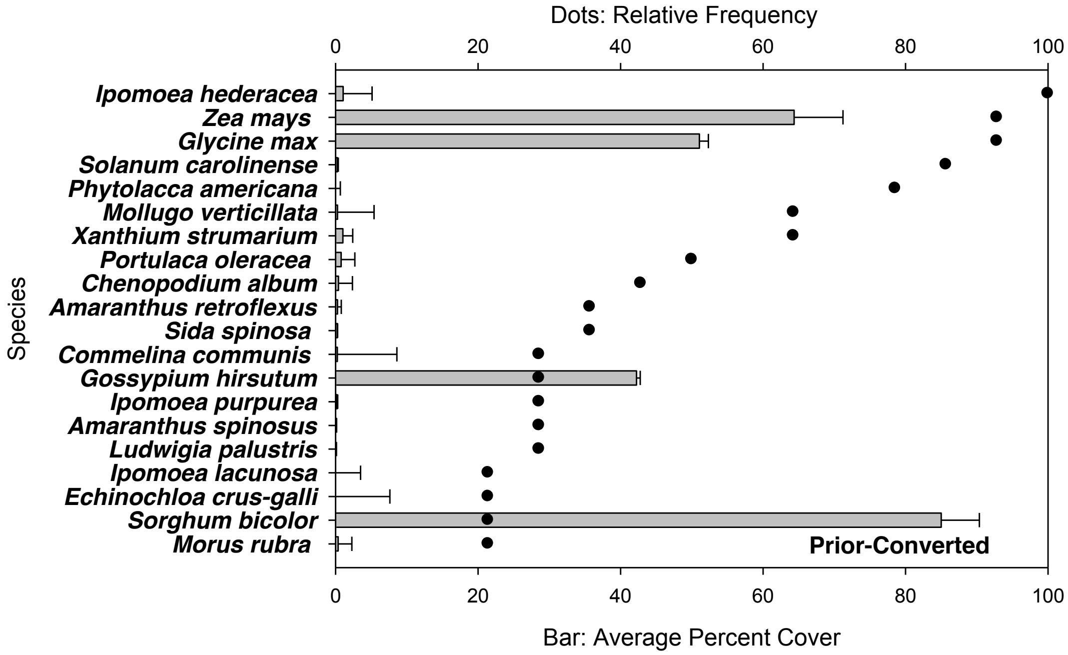


Figure 6: Cover and frequency of dominant plant species found in natural reference wetlands, restored wetlands, and prior-converted croplands, in the Mid-Atlantic Coastal Plain. The plant species listed represent the 20 most frequent species with the highest average percent cover in the sites they were found in. Plotted cover values are mean +1SE. Stars before species name indicate woody species.

Plant Community Structure

Restored and natural sites had similar Shannon Evenness Index scores (about 0.5) that were significantly higher than the prior-converted sites (about 0.1; Figure 7). More than 90% of the species in both the natural reference and restored sites were native; this was significantly higher than the prior-converted sites where less than half of the species were native (Figure 8). Plant species in restored wetlands had significantly higher mean wetness coefficients (about 1.5, corresponding to the range of FAC+ to FACW-; Table 2) than natural reference sites (about 1 or FAC+; Figure 10). Prior-converted sites had the lowest mean wetness coefficients of about -2 corresponding to FACU+ (Figure 10). Species in natural reference sites had significantly higher mean coefficients of conservatism (about 4; Figure 11) than restored and prior-converted sites (about 3 and 1 respectively; figure 11).

Vegetation Indices

FQAI scores in restored sites were significantly lower than natural reference sites (around 12 and 15 respectively), but six times higher than prior-converted sites (around 2, Figure 12). Both natural reference and restored sites had FAQWet scores around 5, which were significantly higher than the prior-converted sites (around -1, Figure 13).

Anthropogenic Activity Index

Restored wetlands had lower AAI scores than prior-converted sites (around 8 and 15 respectively; Figure 14), but not as low as the natural reference sites (around 2). There was a stronger negative correlation between AAI scores and FQAI scores than between AAI and FAQWet scores, but both were significant (R^2 =0.64 and 0.30 respectively, p< 0.001; Figures 15 and 16).

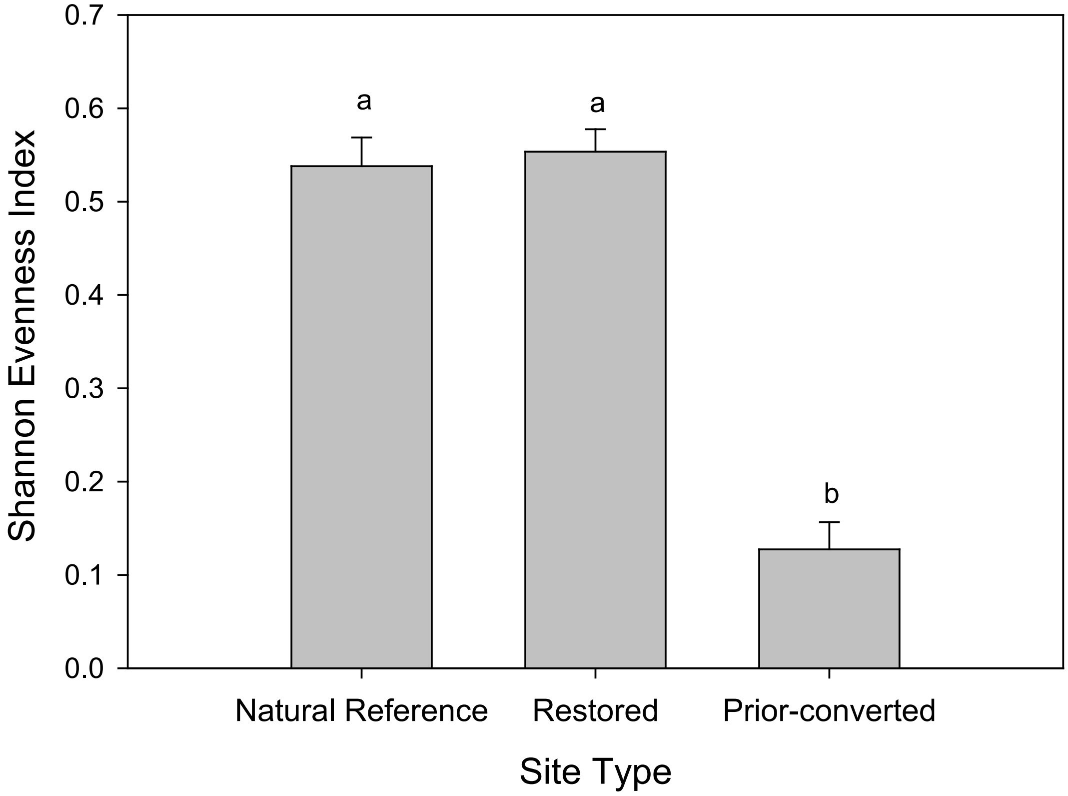


Figure 7: Shannon Evenness Index calculated based on mean percent cover of species in natural reference, restored, and prior-converted sites in the Mid-Atlantic Coastal Plain. Plotted values are mean + 1SE and means with different letters represent statistically significant differences (Tukey, p < 0.05).

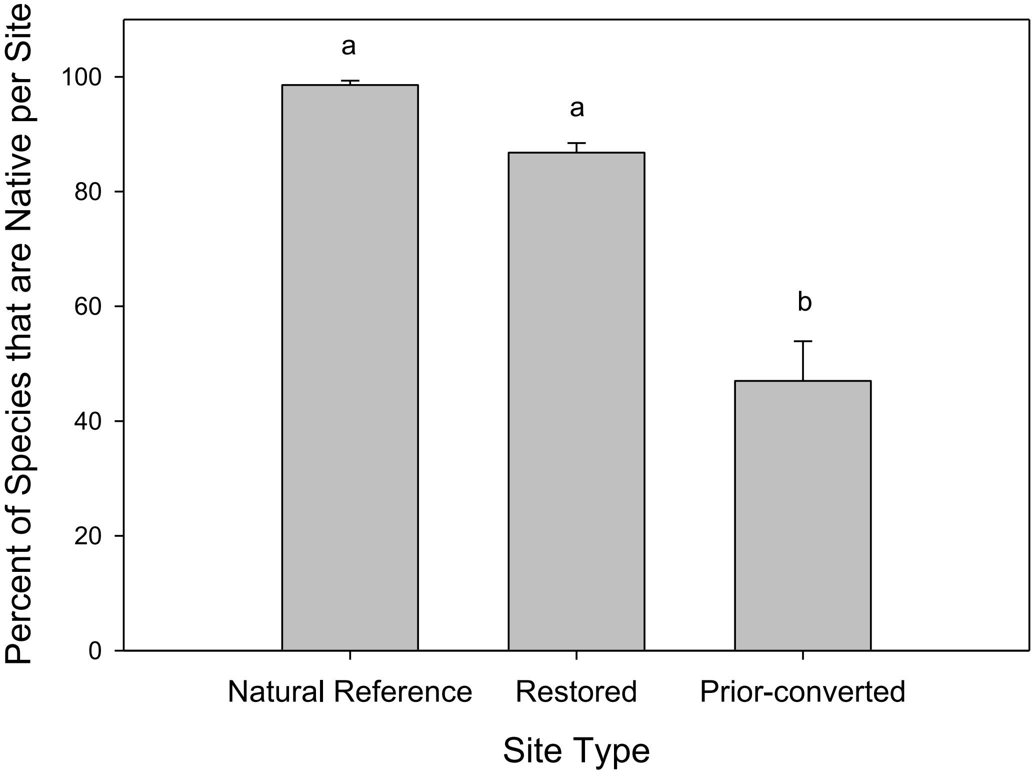


Figure 8: Percent of species per site that are native to the Unites States of America. Plotted values are mean + 1SE and means with different letters represent statistically significant differences (Tukey, $p < 0.05$).

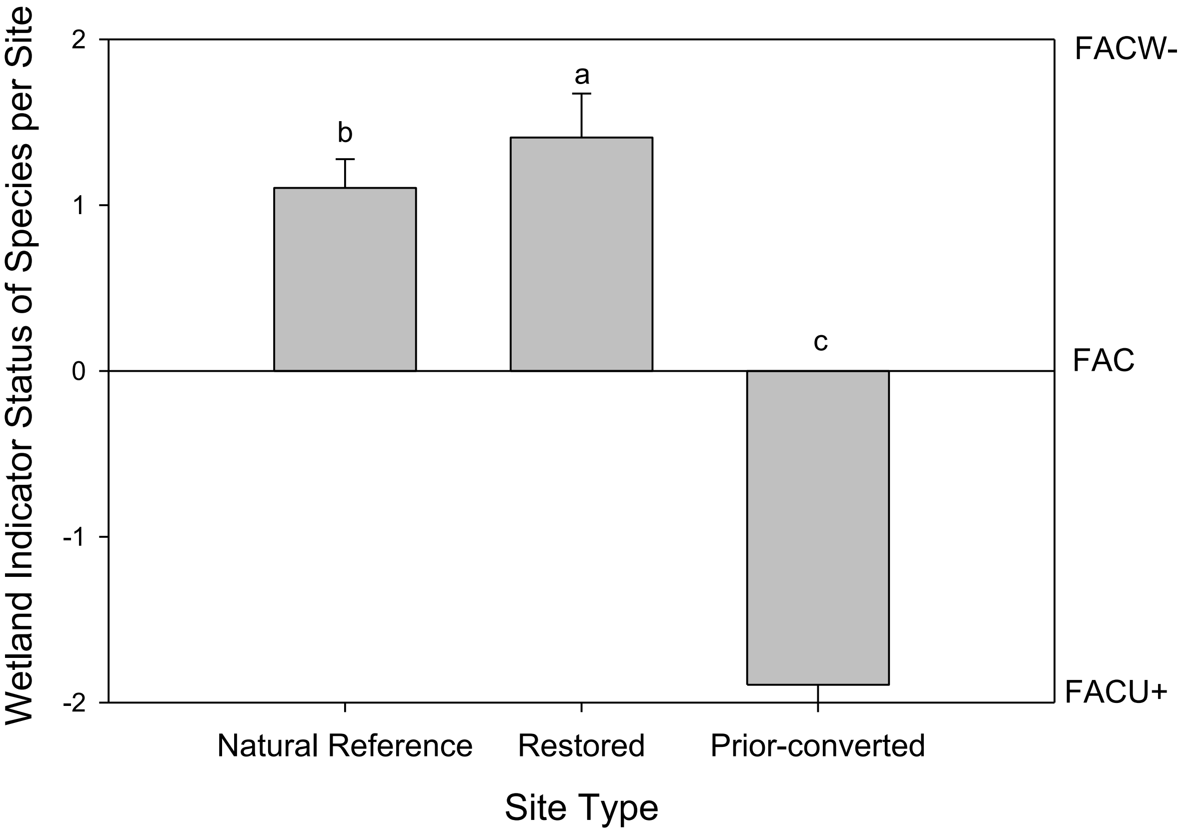


Figure 9: Wetland indicator status assigned to plant species found at each site. Plotted values are mean + 1SE and means with different letters represent statistically significant differences (Tukey, $p < 0.05$).

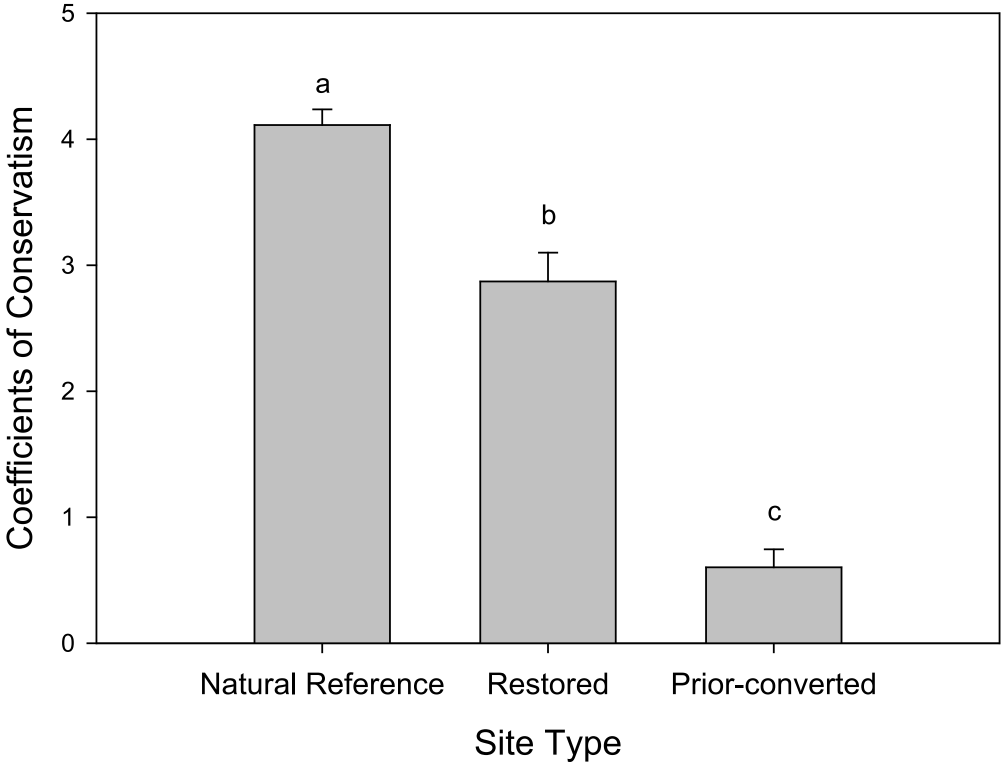


Figure 10: Coefficient of conservatism assigned to plant species found at each site. Plotted values are mean + 1SE and means with different letters represent statistically significant differences (Tukey, $p < 0.05$).

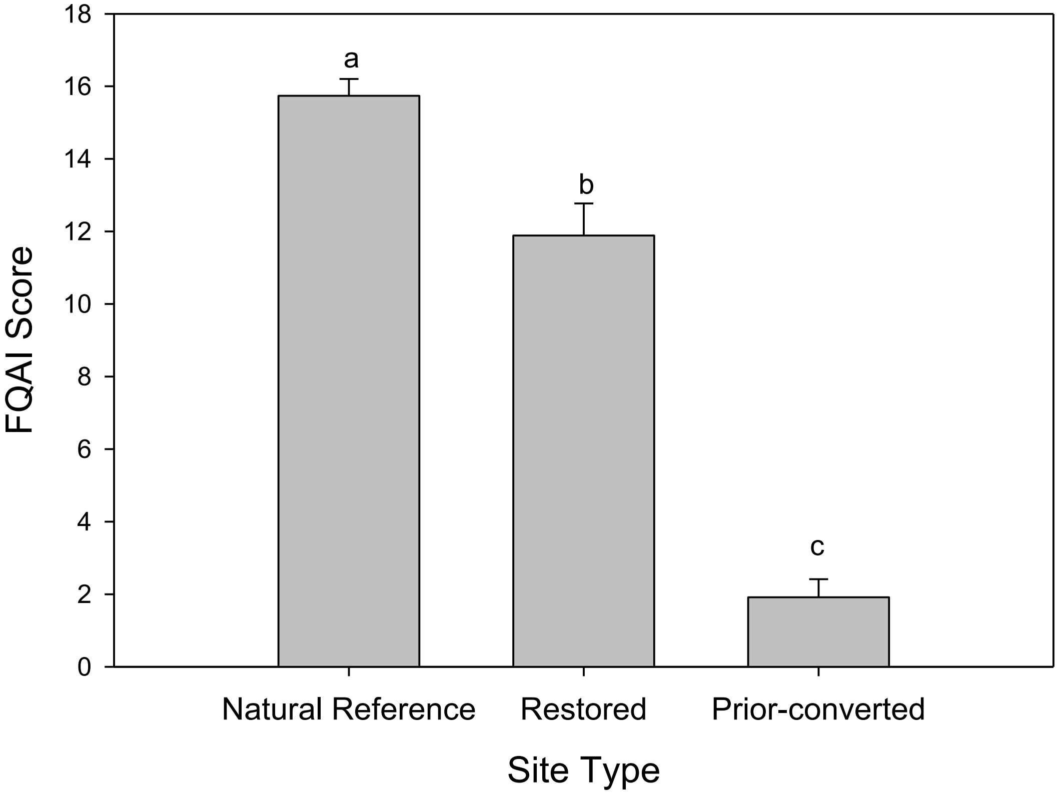


Figure 11: Floristic Quality Assessment Index (FQAI) scores (Andreas and Lichvar 1995, Ervin et al. 2006). Index is based on coefficients of conservatism. Plotted values are mean + 1SE and means with different letters represent statistically significant differences (Tukey, $p < 0.05$).

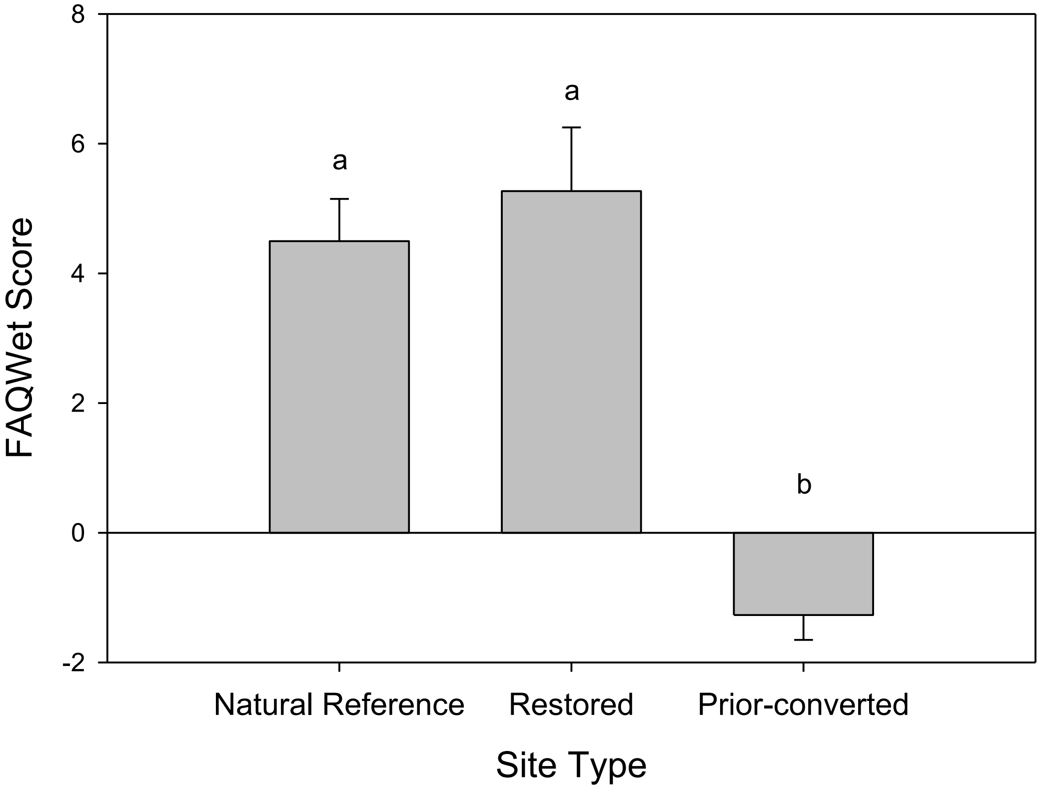


Figure 12: Floristic Assessment Quotient for Wetlands (FAQWet) scores (Ervin et al. 2006). Index is based on Wetland Indicator Status as well as native status of plant species found in sites. Plotted values are mean + 1SE and means with different letters represent statistically significant differences (Tukey, $p < 0.05$).

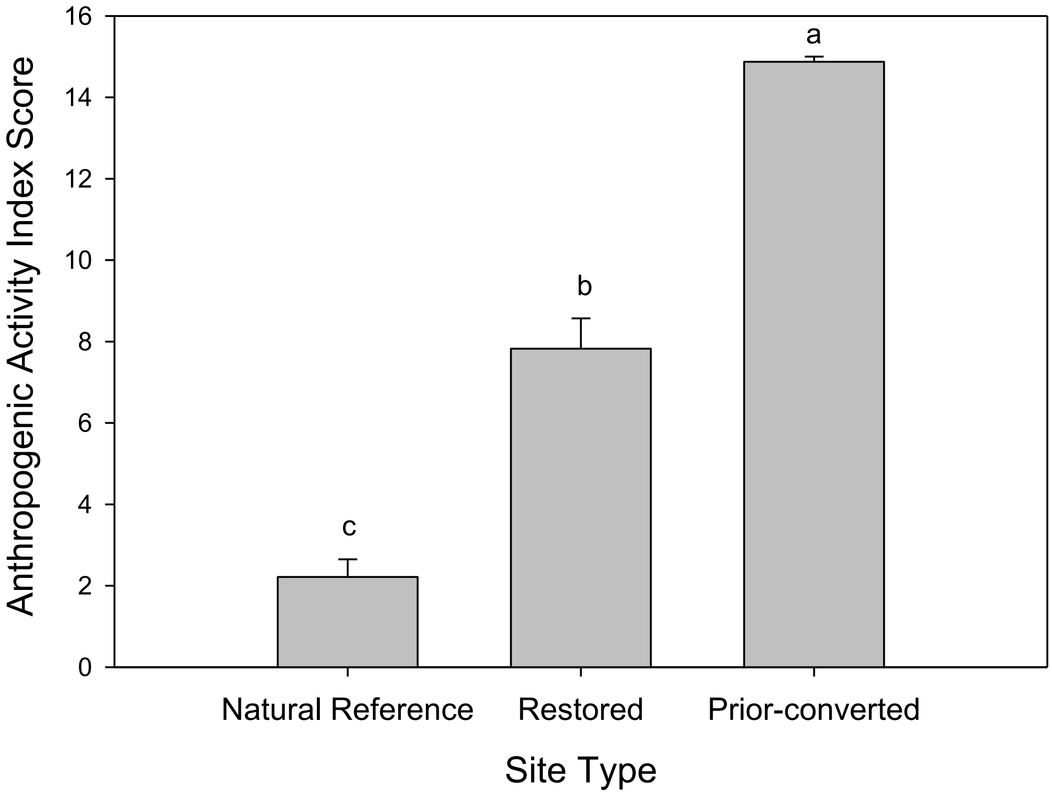


Figure 13: Anthropogenic Activity Index Scores based on past and continued human disturbance (Herman 2005, Ervin et al. 2006). Plotted values are mean + 1SE and means with different letters represent statistically significant differences (Tukey, $p < 0.05$).

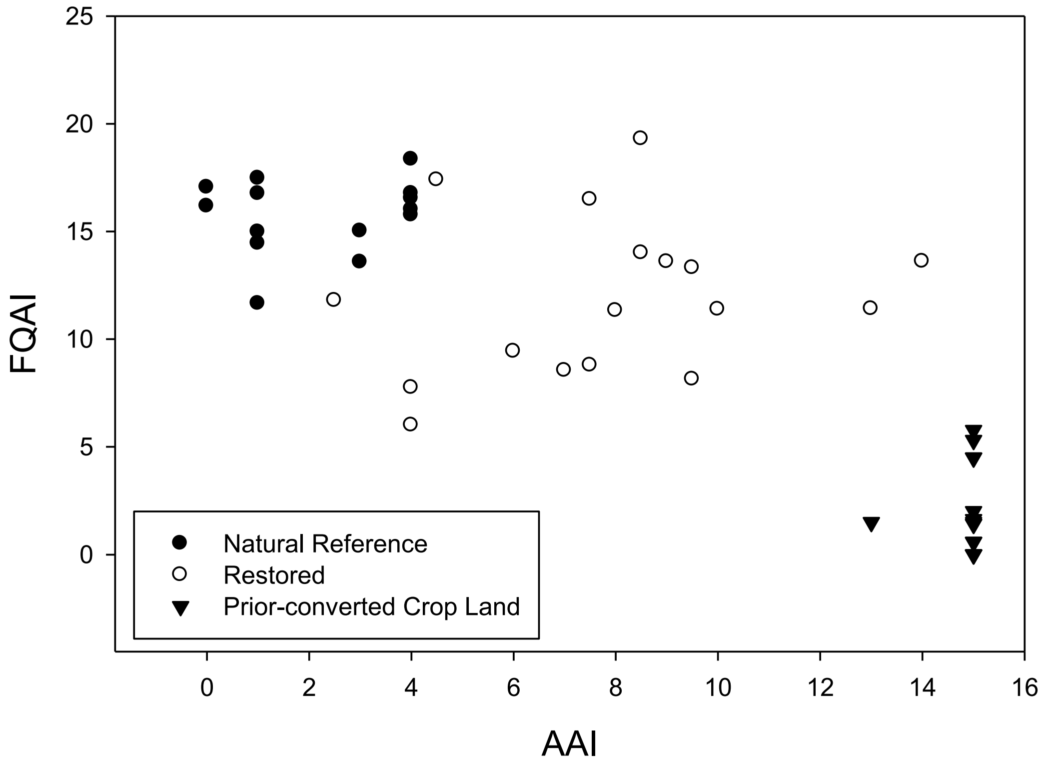


Figure 14: Relationship between the Floristic Quality Assessment Index (FQAI) and the Anthropogenic Activity Index (AAI) scores assigned to each site. $p < 0.001$, $R^2 = 0.64$.

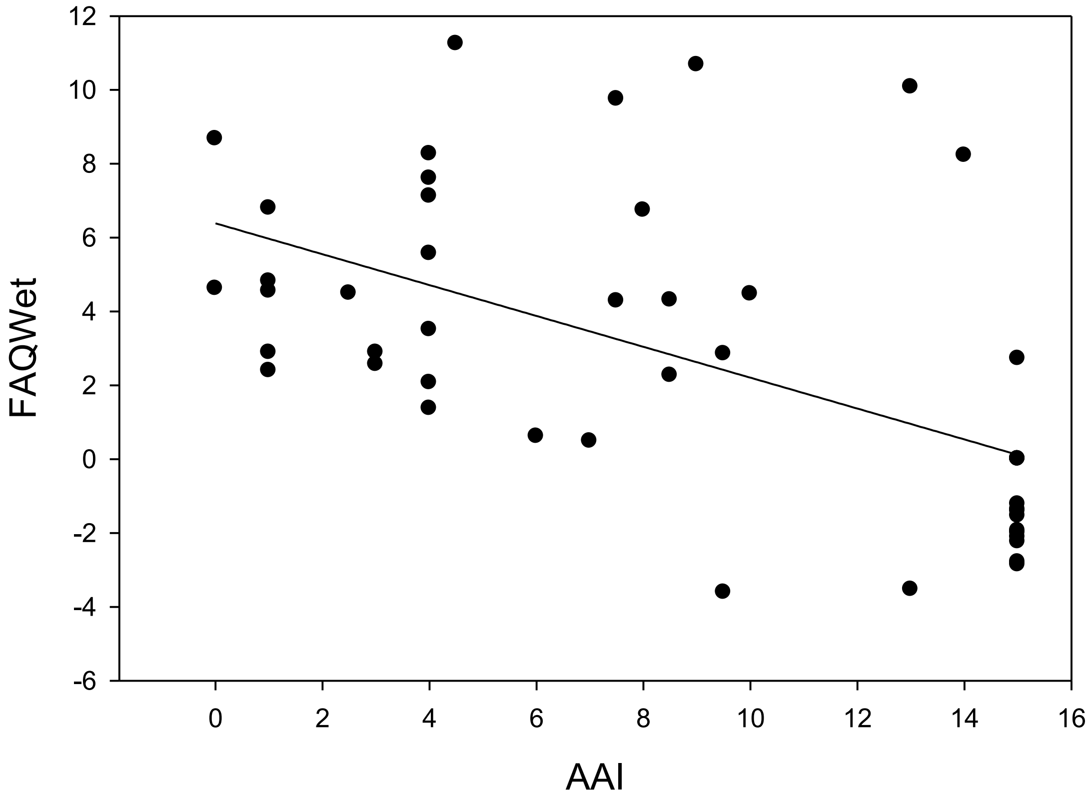


Figure 15: Relationship between the mean Floristic Assessment Quotient for Wetlands (FAQWet) and the Anthropogenic Activity Index (AAI) scores assigned to each site. $P<0.001$, $R^2 = 0.30$.

Discussion

Plant Community Composition

Natural reference, restored, and prior-converted sites had different plant communities. There was little species overlap between site types and the differences between the forested natural reference sites and the herbaceous restored sites were visually apparent. Natural reference sites had more than 75% cover by woody species while restored and prior-converted sites both had low cover by woody species (less than

10%). All but one of the dominant plant species in the natural reference sites were woody; this is in direct contrast with restored and prior-converted sites where dominant species were all herbaceous with the exception of two woody species, which were found in less than 50% of the sites and had low cover (less than 1%) in restored sites. Although the plant communities in the restored sites were composed of different species than those found in natural reference sites, they were by many other indices more like natural references sites than prior-converted sites.

Native Species

Natural reference and restored sites both had high percentages of native wetland plant species when compared with conventional row crop species in prior-converted sites. However, two non-native species listed on the Database of Plants Invading Natural Areas in the United States (http://www.invasive.org/weedus/), *Echinochloa crus-galli* and *Phragmites australis*, were found in nearly half of the restored sites and had relatively high average percent cover (over 10%) in the sites they were found. Studies have shown that human disturbance and increases in nutrient levels promote the spread of invasive species into new areas (Minchinton and Bertness 2003, Perry et al. 2004, and Price et al. 2011). Thus, restored wetlands in agricultural areas are more vulnerable to invasion than natural sites because they are disturbed during restoration and typically receive runoff containing nutrient, herbicide, and sediment from the farms that surround them.

Richness

Restored sites had the highest species richness. An average restored site contained almost 25 species, about 5 more species than a natural reference site and 15 more than a prior-converted site. This is consistent with other studies that found higher species richness in recently restored freshwater wetlands than in natural reference wetlands (Balcombe et al. 2005, Matthews et al. 2009, and Gutrich et al. 2009). In a study of 11 indicators of floristic quality, Matthews et al. (2009) looked at the vegetation in 29 mitigation wetland sites and over 100 natural reference sites in Illinois and found that restored sites had greater native species richness than reference sites (approximately 70 and 25 respectively). In a comparison of 11, mostly created, palustrine scrub-shrub and emergent mitigation wetlands in West Virginia, created wetlands had higher species richness than the reference sites (13 and 8 respectively; Balcombe et al. 2005). However other studies have found no difference in species richness (Spieles et al. 2010) or a decrease from high initial richness after restoration to less than half the richness of the reference sites by year 14 (Gutrich et al. 2009). Mature forests are likely to have fewer individual plants, and thus lower species richness, than emergent marshes because a tree generally takes up more space than an herb. It is also important to remember that species richness alone does not denote ecosystem integrity; many low nutrient wetlands with low diversity have high ecosystem integrity. The species found in a site must be looked at to determine whether richness indicates ecological health or degradation (Ehrenfeld 2000).

Floristic Quality

A higher FAQWet score reflects a more hydrophytic and native plant community. Natural reference and restored sites had FAQWet scores around 4, while prior-converted sites were dominated by upland conventional row crop species with negative FAQWet scores. This index may not be useful for comparing floristic quality between forested and herbaceous sites. Trees tend to be less tolerant of very wet conditions than herbaceous or submerged aquatic species, existing in elevated areas of wetlands on hummocks or stream banks (Lugo 1990). The natural reference sites were dominated by *Liquidambar styraciflua*, *Acer rubrum*, and *Clethra alnifolia* (FAC/FAC+ species) and *Nyssa biflora* (OBL). This suggests that FAQWet may be biased in favor of herbaceous wetlands. FAQWet scores lacked a strong correlation with the Anthropogenic Activity Index (R^2 =0.30). A study in Mississippi of riparian wetlands also found that FAQWet was not well correlated with AAI (R^2 =0.19) and determined that FAQWet was not sensitive to floristic quality differences in riparian areas where the disturbed sites were dominated by weedy herbaceous species and the less disturbed sites that were dominated by tree species (Tietjen and Ervin 2007). Like species richness, a high FACWet score may indicate high floristic quality or it can indicate highly disturbed restored wetlands that were wetter than natural sites due to anthropogenic manipulation (Ervin et al. 2006). This may have been the case for many of restored sites in this study, many of which had perched water tables and berms used to retain water leading to longer hydroperiods and greater depths of inundation (Fenstermacher 2012). This is reflected in average wetness coefficients; species in restored sites were more hydrophytic than those found in natural reference sites.

Coefficients of conservatism and FQAI scores were significantly different between all three types of sites, but were more similar between natural reference and restored sites than between restored and prior-converted sites. Species in natural reference sites had an average coefficient of conservatism rank of 4, which is assigned to native species generally associated with specific plant communities tolerant of some disturbance. Restored site species had an average rank of 3, indicating the presence of native species typical of disturbed sites, and species in prior-converted sites had an average rank of less than 1, indicating a mix of native and non-native opportunistic species typical of disturbed sites (Andreas and Lichvar 1995).

A high FQAI score reflects greater ecosystem integrity because the plant communities are composed of native species found only in undisturbed areas. Natural reference sites had the highest integrity with scores of 16, restored sites 10, and prior converted sites 2. A study comparing recently restored emergent marshes to older restored sites and a reference wetland, found a higher FQAI score in the reference site (around 27) than in the recent and older restored sites (21 and 22 respectively) (Stefanik and Mitsch 2012). A study in the marshes of the Great Lakes found that average coefficients of conservatism were a better indicator of floristic quality than FQAI because they were less influenced by sampling area and species richness (Bourdaghs et al. 2006)

Human Disturbance

Anthropogenic Activity Index (AAI) scores showed another dramatic difference between the natural reference sites and the restored sites. AAI rates a wetland from 0 to 15, with 0 indicating low surrounding land use intensity, intact buffers around the wetland, no evidence of hydrologic disturbance or habitat alteration, and a high diversity of microhabitats as evidenced by microtopography and low percentages of open water. Natural reference sites had low scores (an average of 2), reflecting low human disturbance. Restored sites had mean scores of 8, suggesting that they were impacted by either ongoing or historic human disturbance. Prior-converted sites had the highest possible score (average of 15), which was to be expected in farm fields with active drainage and plowing.

There was a significant negative correlation between AAI and FQAI scores, which indicates that as human disturbances increase, floristic quality and ecosystem integrity decreases. Other studies have found similar trends. Lopez and Fennessy (2002) assigned a disturbance rank based on parameters similar to the AAI to 20 depressional wetlands in Ohio and found a significant negative correlation between FQAI and disturbance. They found that lower FQAI scores were associated with many of the conditions observed in the restored sites that were sampled as part of this study including: wetlands surrounded by agricultural fields, less intact vegetation buffers, greater hydrologic alteration, and greater distance to other wetlands. In another study that compared 53 wetlands in Mississippi and Alabama, Ervin et al. (2006) found a significant correlation between AAI and both FQAI and FAQWet. They also found that the FQAI correlation was stronger than the FAQWet (around 0.24 and 0.18 respectively).

Exploring Plant Community Differences

Most of the restored wetlands sampled were either WRP or CP23, both of which use the NRCS Practice Standard Code 657. The practice standard defines wetland restoration as the return of vegetation, soils, and hydrology to pre-human disturbance conditions to the extent possible so as to “restore wetland function, value, habitat, and diversity.” The fact that the restored sites do not have the same vegetation as the natural reference sites suggests some combination of the following: the sites are too young to reflect a transition from herbaceous marsh to forested wetland; restoration of natural conditions was not possible given current restoration technology; although NRCS guidelines indicate that the restoration of historic conditions is desirable, other objectives are being prioritized to the determinant of this objective; or some other factor is preventing succession.

During the implementation of USDA wetland restorations, an herbaceous wetland community is considered to be an acceptable precursor to a forested wetland and can be maintained that way for CRP restorations, but not under WRP (personal communication, Steve Strano, NRCS). Given the correct environmental conditions, restorations will theoretically follow a functional trajectory toward the development of characteristics that match those of natural wetlands (reference sites) (Mitsch and Gosselink 2007). However, there are many factors that control plant community development and determining the correct set of conditions to restore can be difficult.

Restored sites ranged in age from 3 to 11 years. It will take many years to develop a mature forest plant community. It has been suggested that wetland restorations may take 100 years before reaching the functional equivalent of natural sites (Moreno-Mateos et al. 2012). Two of the dominant tree species in natural sites were found in many restored sites, but in small numbers and at very low percent cover. Perhaps given enough time, succession in restored sites will take place and a thick canopy cover will shade out current herbaceous species, creating the proper conditions for forested wetland shrubs and mosses to establish. This topic will be further discussed in chapter 3.

Propagule availability is often limiting in restored wetlands (Middleton 1999 and Ketterning and Galatositsch 2011). Propagules can come from the seed bank, be planted during restoration, or be dispersed from offsite by wind, water, or animals. With the exception of *Cephalanthus occidentalis*, viable seeds of woody wetland species were not found in agricultural seed banks of former bald cypress swamps of the Mississippi Alluvial Valley along the Cache River in IL (Middleton 2003). This suggests that even without the practice of removing the topsoil during restoration, woody plant propagules might not be found in the seedbanks of the restored sites I surveyed.

There are several issues with species intentionally introduced during restoration: 1) not all of the sites were planted and not all of the trees planted in the restored sites were the same ones found in the natural sites; 2) planted trees tend to have high mortality rates (D'Avanzo 1990); and 3) continued human disturbance can preclude the development of desired plant communities **(**Minchinton and Bertness 2003, Perry et al. 2004, and Price et al. 2011). This topic will be further explored in chapter 3.

The AAI and FQAI scores indicated that restored sites continue to experience more human disturbance than natural sites. Mowing, soil moving, and proximity to row crops, roads, and other wetlands can all affect plant community development. Mowing, which was observed at some restored sites, can directly prevent succession from herbaceous to forested communities from taking place. Many of the restored sites were surrounded on two or three sides by conventional row crops and receive fertilizer and herbicide in the runoff. Nutrient input from agricultural fields has been found to encourage the establishment of invasive species in wetlands. *Typha* in the Everglades (Koch and Reddy 1992) and *Phragmities australis* in coastal marshes are two examples (Minchinton and Bertness 2003).

NRCS Practice Code 657 allows for no more than 30% of the restored wetland area to be a plant community different from what would have existed pre-disturbance. However, there are a number of exceptions to this rule under CRP and amongst our study sites it appears that the exceptions are more commonly implemented than the general 30/70 rule. It is possible that this is the case due to landowner preference, since the WRP and CRP are voluntary and USDA will tailor implementation to meet landowner expectations within USDA guidelines. For a few reasons, landowners may not be interested in having a forested wetland in their backyard: it may be considered less aesthetically pleasing while trees are growing to maturity (Clewell and Lea 1990), it may block the view, and this habitat may not attract waterfowl for hunting or bird watching like an open pond with marshy edges. Thus it is likely that some of the sites were never designed to transition into forested wetlands that match the reference sites. This raises the question of whether or not the 30% rule is being effectively implemented and, if not, whether the rule should be changed.

The difficulty of restoring a wetland that is connected hydrologically to ground water may also be a factor. Water table levels are unpredictable and fluctuate from year to year and from season to season; creating a perched water table is a more reliable way to ensure wet conditions. Furthermore, if regional ground water levels have been lowered through time, it may be impossible to restore a wetland to its previous hydroperiod and geomorphology. This may explain why the hydrogeomophology of restored sites is so different than natural sites. Many restored sites had ponded water in the summer when natural sites were dry. Forested wetlands exist only where the hydroperiod is long and deep enough to exclude upland species, but not so wet as to kill trees (Lugo 1990). Perhaps the restored sites sampled as part of this study were too wet for tree species to establish and persist.

A study from 1987-1997 conducted by Tyndall (2000) in a Maryland depressional wetland suggested that natural reference sites may have had larger canopy openings dominated by three zones of herbaceous plants prior to a several year drought that dropped water table levels. *Liquidambar styraciflua* and *Acer rubrum* increased from 22-88% cover between 1987 and 1992, suggesting that this period of drawdown gave *L. styraciflua* and *A. rubrum* the chance to establish. A general lowering of the water table from ditching and irrigation as well as the suppression of forest fires are offered as two reasons why the woody cover has persisted. This suggests that natural reference sites used for my study are different from how they were even 20 years ago (in part from anthropogenic degradation on a broader landscape level); that the natural reference sites may have been more similar to the restored sites in the past; and that another prolonged drought could induce succession in the restored sites.

Although restored sites do not provide the same functions as natural sites due to their structural differences, they still provide many functions associated with wetlands that meet broad CRP and WRP goals. As emergent marshes dominated by herbs, grasses, and sedges, the majority of restored sites provide food and habitat for migratory birds and waterfowl. Restored sites provide support to diverse native wetland plant communities. The vegetation and depressional shape improve water quality by trapping sediment, removing nitrate, slowing down the movement of floodwater, and improving aesthetics. Due to their structural differences and position in the landscape, restored sites may even provide more of the services landowners are interested in than natural sites.

Conclusions

Restored depressional wetland in agricultural areas of the Mid-Atlantic Coastal Plain have succeeded in developing diverse native wetland plant communities that are likely to provide many of the broad functional goals of the federal programs which supported their restoration. However, after 3 to 11 years restored sites do not match native conditions and many sites do not appear to be moving in that direction, due in part to active management (e.g., mowing). It is important to recognize that although these restorations provide important ecosystem services, wetlands of different types inherently provide different services. Therefore, the ecosystem services being replaced are not necessarily the same as those which were originally lost. Important questions that should be addressed by future research include: 1) What is the landscape scale effect of this shift in wetland type on resultant services? 2) Should wetland restoration implementation practices be adjusted in order to minimize or compensate for this functional shift? 3) Is the restoration of historic conditions under WRP and CRP a practical goal? Until we are successful in restoring wetlands to pre-disturbance conditions, we need to acknowledge our limitations and prioritize the conservation of our remaining natural ecosystems along with the restoration of specific ecosystem services.

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Chapter 3: Vegetation Establishment and Succession in Restored Wetlands in the Delmarva Peninsula

Introduction

More than 50% of wetlands in the lower 48 United States were lost between the 1780s and the 1980s from conversion to agriculture and urbanization. In the Mid-Atlantic Coastal Region, Maryland lost 73% if its wetlands and Delaware 54% (Dahl 1990). In the Delmarva Peninsula forested depressional bays and flat wetlands that covered the landscape were logged, ditched, drained and planted with conventional row crops.

Some of these sites have been restored through federal programs like the Wetland Reserve Program and the Conservation Reserve Program in order to regain the functions, values, habitat, and diversity provided by natural wetlands. Wetland restoration is defined by the NRCS Conservation Practice Standard Code 657 as: "The rehabilitation of a degraded wetland or the reestablishment of a wetland so that soils, hydrology, vegetative community, and habitat are a close approximation of the original natural condition that existed prior to modification, to the extent practicable." Theoretically a restored wetland will follow a functional trajectory toward the development of characteristics that match those of local natural wetlands (reference wetlands). However, wetland ecosystems are regionally distinct and complex. The steps required to return a degraded wetland to a natural wetland have not been agreed upon and require tailoring to each site (Zedler and Callaway 1999). Most wetland restoration efforts in the US have focused on emergent marsh areas leading to the development of established methods for marsh restoration. The restoration of forested wetlands takes significantly longer and restoration methods are less well studied (Clewell and Lea 1990).

The theory that restored wetlands will follow a functional trajectory leading them to eventually look and function like a natural wetland is based in part on the theories of self-organization and self-design described by Mitsch and Gosselink (2007). Self-design suggests that plant species and communities develop based on the best fit for the existing environmental conditions. Thus if the environmental conditions of the restored site are like the natural site, the restored site will follow a functional trajectory that matches natural wetland development and end up looking and functioning like the natural sites. This is based on a few assumptions: 1) correct propagules are available, 2) long-term sources of degradation and disturbance are mitigated, and 3) proper hydrology, soils, and nutrient availability are established.

The availability of propagules is an important factor in wetland restoration. Propagules available for use in restoration may already be onsite (from mature trees and seed banks), be supplied by humans during restoration (planting, seeding, or addition of seed bank in added soils amendments), or they may be naturally dispersed to the site by wind, water, or animals (Figure 1).

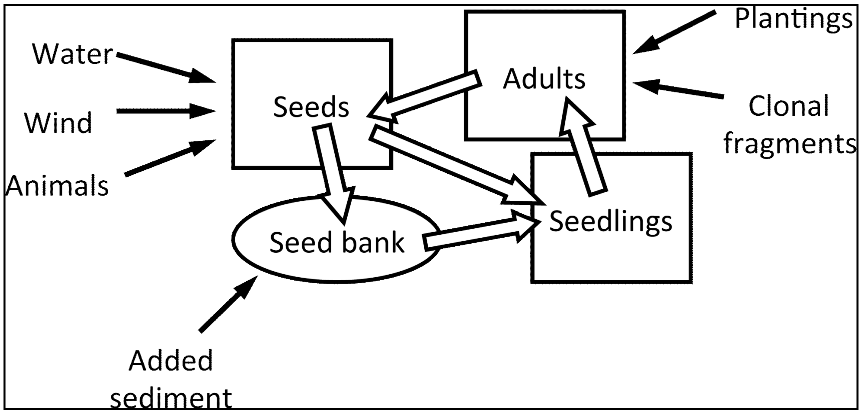

Figure 1: Propagule sources for plant establishment during wetland restoration. Figure from

Baldwin 2004.

Several studies have concluded that propagule availability can be a limiting factor in wetland restorations. Seed banks of farmed fields tend not to contain woody species (Middleton 2003) and even when viable seeds are present, topsoil has frequently been removed from the sites in the process of restoration and stockpiled in berms rendering the seeds unavailable. Not all sites are planted and seeded during restoration and tree and shrub plantings have high mortality rates (Clewell and Lea 1990). This generally leaves natural dispersal from offsite as the only source of woody seeds, but the distance to desired seed sources is often limiting (Clewell and Lea 1990, Middleton 2003, and Herault and Thoen 2009).

Structural remnants of Delmarva bays cover the Delmarva Peninsula in the Mid-Atlantic Coastal Plain near Washington DC (Figure 2). Bay wetlands can be found in the Coastal Plain from New Jersey to Florida. The shallow depressions with sandy rims are thought to have been created by wind blowouts in ponds 16,000-21,000 years ago (Stolt and Rabenhorst 1987). Many natural seasonal depressions are only infrequently connected to each other by overland flow and their hydrology is driven by precipitation, evapotranspiration, and groundwater (Brooks et al. 2011 and Sharitz 2003); the majority are seasonally flooded and function as recharge wetlands in summer and discharge wetlands in winter and spring (Phillips and Shedlock, 1993).The previous chapter described the vegetation of restored and natural reference wetlands in the Mid-Atlantic Coastal Plain. Natural reference sites were dominated by trees and shrubs and restored sites were dominated by herbaceous species. The goal of this study was to examine potential reasons for these differences by looking at seed dispersal mechanisms of the dominant species in natural reference sites, the proximity of restored sties to forested wetland seed sources, and the effect of age on the percentages of woody plant species found in restored sites.

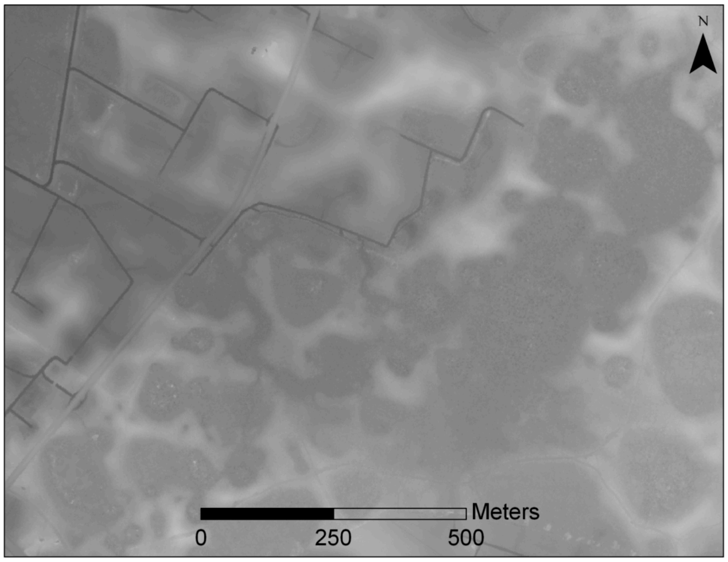

Figure 2: LIDAR image of Delmarva Bays. Darker areas represent depressions. (Image provided by Megan Lang, USDA ARS)

Methods

As-built specifications and notes on the restoration of sites in the Delmarva Peninsula were gleaned for age, size, and method of restoration (including hydrology, plantings, and whether or not topsoil was replaced in excavated sites). Using the vegetation data described in the last chapter, the 20 dominant species in natural reference sites of the Delmarva Peninsula were defined as those with the highest frequency and cover. Seed dispersal mechanisms of each species were determined using previously collected tables (Middleton 1999), U.S. Forest Service publications (Burns and Honkala 1990, Uchytil 1993, Sullivan 1994, and Gucker 2008), and studies on seed dispersal and colonization (Stiles 1980, Jordan 1995, De Stevens 2007, and Lu 2010).

The 2006 MRLC National Land Cover Dataset was used to calculate the percentage of area that was covered in emergent or forested wetlands within a 1-km radius from the center of each of the restored sites sampled in the Delmarva Peninsula. A regression was conducted using the PROCreg procedure in SAS version 9.2 (SAS Institute, Cary, NC). Significance was assigned for $p < 0.05$.

Results

The most common seed dispersal mechanism for the dominant species in the natural reference sites was by bird, either in their guts or attached to the outside of their bodies. Both bird dispersal and animal dispersal were viable mechanisms for at least 50% of species. All of the dominant species in the natural reference sites could be dispersed by a mechanism other than water dispersal (i.e. wind, animal, or bird; Figure 3).

Restored sites had 1-7% area of forested wetlands within a 1-km radius. There was no significant correlation between the percent of species characterized as “woody” in a restored site and the cover of forested wetlands in the 1-km radius of the site (Figure 4; i.e. $p>0.05$). There was also no significant correlation between the percent of “woody” species found in a restored site and the age of the restoration, which ranged from 3-11 years (Figure 5; i.e. $p>0.05$).

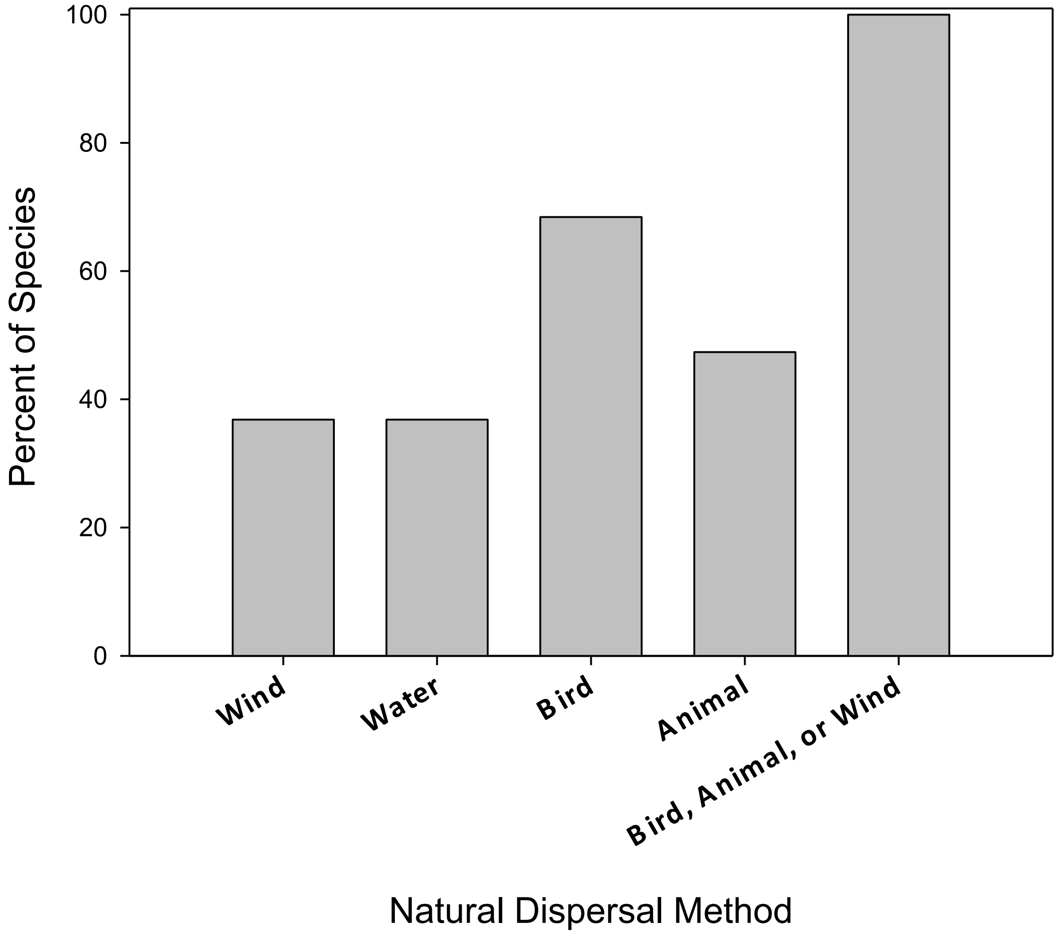

Figure 3: Natural seed dispersal methods of the dominant species in natural references sites (determined by frequency and cover). (Stiles 1980, Burns and Honkala 1990, Uchytil 1993, Sullivan 1994, Jordan 1995, Middleton 1999, De Stevens 2007, Gucker 2008, and Lu 2010)

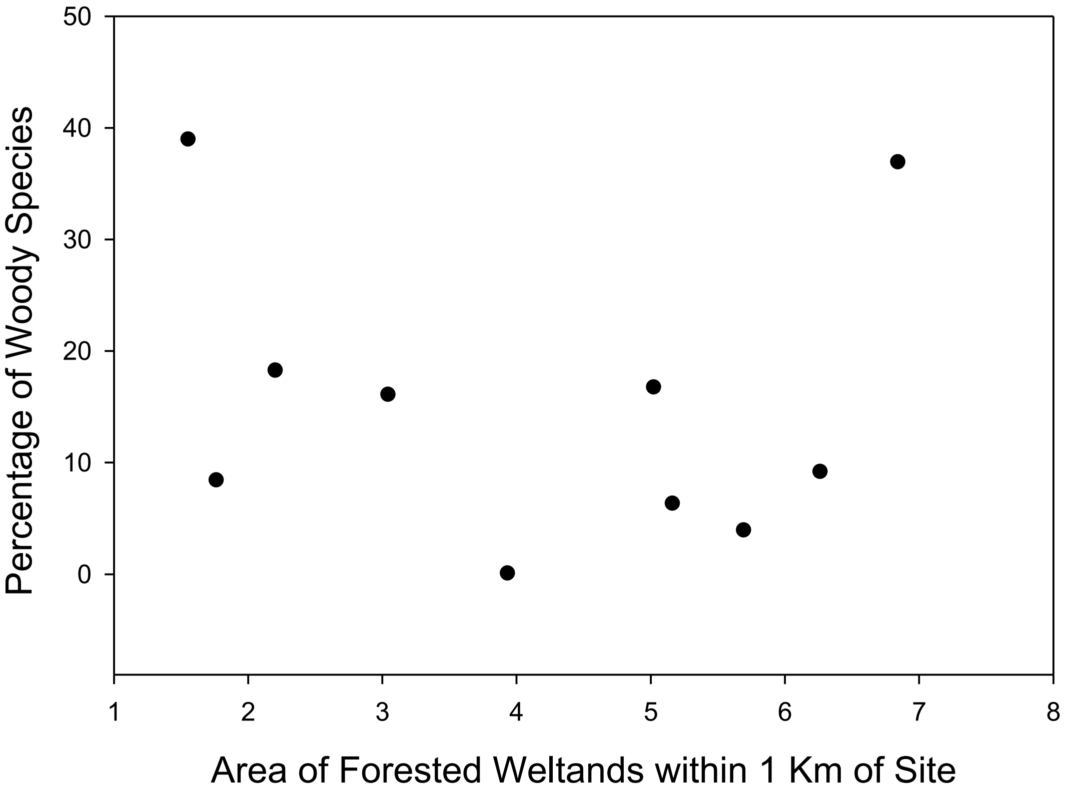

Figure 4: Correlation between the percentage of woody species found at each site and the percent cover of forested wetlands within a 1 KM radius of the site. There was no significant correlation (p>0.05).

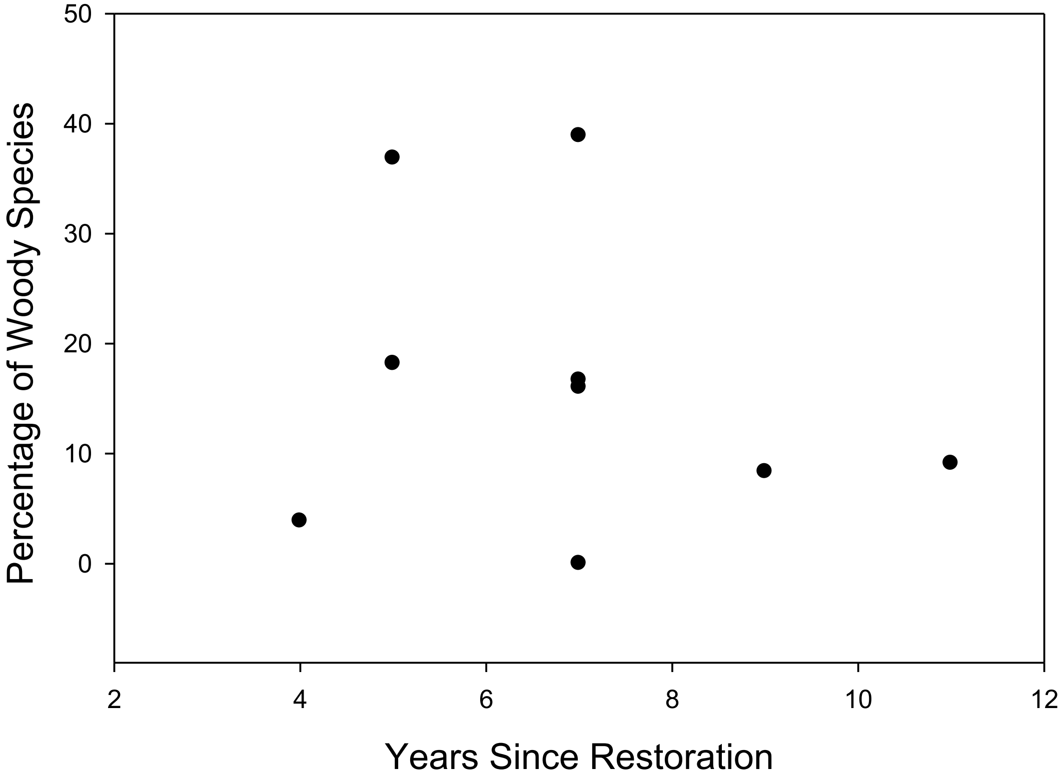

Figure 5: Correlation between the percentage of perennial species found at a site and number of years since the site was restored. There was no significant correlation (p>0.05).

Discussion

A comparison of restored plant communities discussed in the last chapter demonstrated that restored wetlands in the Delmarva Peninsula are dominated by herbaceous plants and have thus far failed to develop the woody species typical of natural reference sites. The goal of this chapter was to look at two potential causes for these findings: propagule sources and age of sites.

The availability of propagules in the restored sites we studied was potentially limited by prior-land use, restoration methods, and isolation from propagule sources. All of the restored sites were farmed prior to restoration. This means that no mature woody species were available onsite to drop propagules and the seed banks of farmed fields tend not to contain viable woody species (Middleton 2003). Topsoil was removed without replacement during restoration of the majority of sites, further removing the potential of woody plant establishment from remnant onsite seed banks (Fenstermacher 2012). Some of the sites were planted with trees according to the as-built plans, but few planted woody species were observed during site visits and the majority of them were small and did not match the species found in natural reference sites. These conditions establish a low probability of woody plant establishment from propagules on site or introduced during restoration, leaving seed dispersal as the remaining viable mechanism of introduction.

Dispersal Mechanisms

Based on data compiled by Beth Middleton (1999) on the dispersal mechanisms of wetland plant species, 60% of wetland seeds are known to disperse via hydrochory (water dispersal), 15% can be dispersed by wind, and 30% can be dispersed by animals (Figure 6). Restored depressional wetlands are unique in that they do not receive overland flow from other wetlands and thus seed dispersal by water is not a viable option. This is reflected in the dispersal mechanisms of the dominant species in the natural references sites. Rather than being dispersed by water, 70% were dispersed by bird, followed by 50% via animal, 40% by wind, and 40% by water. Wind, animals, or birds could disperse all of the dominant species in the natural sites. This appears to indicate that dispersal mechanism alone does not explain why restored sites have thus far failed to develop plant communities dominated by woody species, but it does not account for the possibility that the animals and birds that visit a forested wetland may not be same as those that visit marshy restored wetlands nor does it account for the limited distance a seed travels when dispersed by wind.

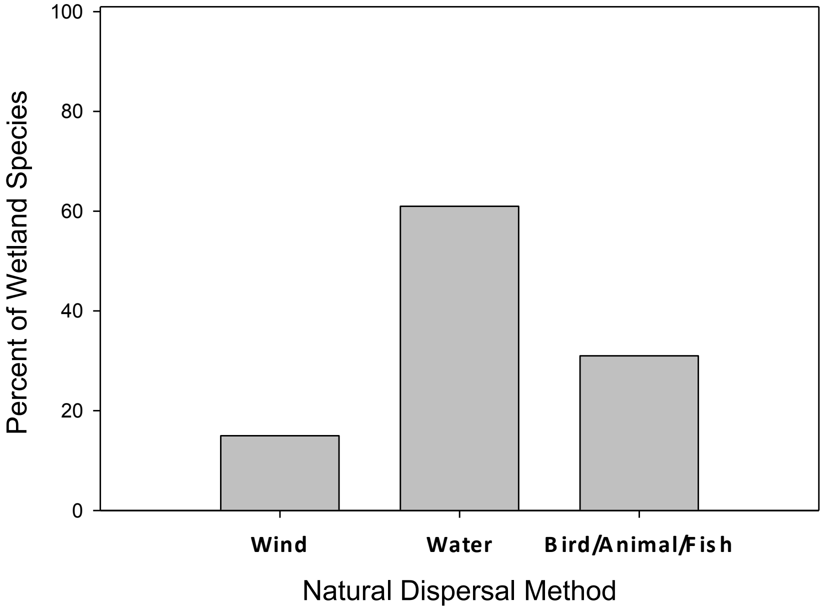

Figure 6: Percent of wetland species that used wind, water, or animal dispersal mechanisms. Data from Appendix 1: Dispersal (Dispersion) of Wetland Species in Middleton (1999).

Proximity to Woody Propagules

Distance to desired seed sources is often limiting in wetland restorations (Clewell and Lea 1990, Middleton 2003, and Herault and Thoen 2009). All of the restored sites had between 1 and 7% cover of forested wetlands within a 1-km radius and there was no correlation between the percent of woody species found in the restored sites and the percent cover of forested wetlands. A 1-km radius may have been too large a range for adequate seed dispersal. For example, *Liquidambar styraciflua* seeds, the most frequently observed species in the natural reference sites, do not tend to disperse farther than 60 m from the tree (Burns and Honkala 1990). Since forests and forested wetlands share many of the same woody species (i.e. *L. styraciflua*, *A. rubrum*, and others) it may have been more illuminating to relate the distance to the nearest forest edge to the percent cover of woody species in a restored wetland. In a study of forested wetland restoration in agricultural fields of Virginia, Hudson (2010) found that seedling stem densities of *L. styraciflua* and *A. rubrum* decreased by 50% between 100 and 150 m from the forest edge. Clewell and Lea (1990) suggested that wetland restoration sites within two tree heights of a forest composed of mature trees would have the most successful natural regeneration of early colonizers like *L. styraciflua* and *A. rubrum.* These studies further confirm that restoration projects need to be within 100 m of a forest edge for rapid natural colonization of woody species.

Age

There was no relationship between the age of the restored sites and the percentage of woody species observed. This may be because it had only been between 3 and 11 years since restoration when the sites were sampled. Once pioneer trees are established, it takes 20 to 30 years for *L. styraciflua* to begin producing seeds and 4 years for *A. rubrum* (Burns and Honkala 1990). Even after seedlings establish, regeneration of mature forest resembling natural reference sites will take far longer than 11 years. However, the trees should grow fast enough to be able to detect a transition from marsh to forest in 3 to 11 years and thus age alone does not seem to explain the differences between restored and natural reference sites.

Other Factors Limiting Succession

Other factors that might limit succession in the restored sites that were sampled include continued disturbance and environmental conditions that differ from natural reference sites. Evidence of regular mowing was observed in wide bands around many of the sites, which would directly prevent succession from marsh to wooded wetland. Herbivory by deer is a common occurrence in rural areas of the East Coast and would have similar effects as mowing in preventing the establishment of woody species. Most sites were located adjacent to agricultural fields, from which they likely receive overland runoff containing herbicides, pesticides, fertilizer, and sediment inputs. The addition of regular agricultural runoff will change the biogeochemistry of restored wetlands, ensuring differences between restored sites and natural references sites that are buffered by surrounding forests. Another environmental difference between restored and natural reference sites is their hydrology. A combination of one or more methods was used to ensure wetland hydrology during restoration; these include excavating a depression, compacting soil to form a perched water table, and/or creation of a berm. Fenstermacher (2012) found that the restored sites in the Delmarva Peninsula tended to have perched water tables. This sets them apart from the natural sites, which are connected to groundwater hydrology and serve as recharge wetlands in the summer (Phillips and Shedlock, 1993), suggesting that after a large summer rain restored sites would be ponded and natural reference sites would be dry. This was supported by observations in the field. Longer and deeper flooding may negatively affect woody seedling establishment and many studies have been done on this topic. In a two-year study of the effect of continuous flooding on swamp-adapted trees, Angelov et al. (1996) reported 95% survival rates of *L. styraciflua* and *Nyssa sylvatica*. However, the negative impact of flooding on *A. rubrum* had been noted by Biggs and Thurnhorst (1993) and Vann and Megonigal (2002). Forested wetlands exist only where the hydroperiod is long and deep enough to exclude upland species, but not so wet as to kill trees (Lugo 1990).

Conclusions

The young age, lack of woody propagules, continued disturbance, and extended hydroperiod of the restored wetlands that were sampled in the Delmarva Peninsula may explain why these sites have yet to develop forest plant communities similar to the natural reference sites sampled in the area. Although the seeds of the dominant species found in natural reference sites can be dispersed by wind and animals, restored sites may be too far away from mature forests for effective dispersal by wind. The animals that visit wooded sites may not be the same as those visiting restored sites, limiting dispersal by bird and animal. Mowing and herbivory in restored sites will preclude woody species establishment and agricultural runoff changes the biogeochemistry of restored sites. Restoration methods have created hydrology in restored sites that is different from natural reference sites, potentially creating longer and deeper hydoperiods that may discourage the establishment of woody species.

Chapter 3 References

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Chapter 4: Conclusions

Historically depressional wetlands in the Mid-Atlantic Coastal Plain were considered to be bug-infested wastelands. The economic value of the land could be improved through draining and conversion to agriculture. The economic and inherent values of depressional wetlands were not recognized until more than 50% of the wetlands in the region had been lost.

The CRP and WRP are two voluntary USDA programs that provide technical and monetary assistance for wetland restoration on private lands. The purpose of these programs is to protect wetlands, provide habitat for migratory birds and other wetland-dependent flora and fauna, protect and improve water quality by trapping sediment and removing nutrients, attenuate floodwater, recharge ground water, protect and improve aesthetics of open spaces, and contribute to education and scientific knowledge (USDA NRCS 2010, USDA FSA 2011). These broad programmatic goals are accomplished by restoring pre-disturbance hydrology, soils, vegetation, and habitat to the extent possible (USDA NRCS Delaware 2000, NRCS 2010, USDA NRCS 2010).

Vegetation was used in this study to assess both the structural and functional success of wetlands restored by the USDA in agricultural areas of the Mid-Atlantic Coastal Region. Chapter 2 addressed whether or not restored sites had developed plant communities typical of pre-disturbance conditions as evidenced by natural reference sites. This chapter also looked at the functional values gained by restoring a prior-converted cropland to a depressional wetland. Chapter 3 suggested possible reasons for the differences observed in the plant communities.

Major Findings

Chapter 2

Restored wetlands had diverse native wetland plant communities that provide many services typically associated with wetlands; however, the herbaceous plant communities in restored sites were not the same as the forested communities of natural reference sites. Both natural reference and restored wetlands were dominated by native FAC or wetter plants, had similar Shannon Evenness Scores, and similar FAQWet scores. But natural reference sites were dominated by woody species (75% cover by woody species and 13% by herbaceous) and restored sites were dominated by herbaceous cover (8% woody and 66% herbaceous). Restored sites had higher species richness than natural sites (averaging around 27 and 17 respectively). Species found in natural reference sites were less tolerant of disturbed conditions than those found in restored sites as indicated by average coefficients of conservatism (around 4 and 3 respectively). This is reflected in the Anthropogenic Activity Index, which indicated that restored sites were four times more impacted by human disturbance than natural reference sites. While vegetation suggested that restored wetlands had higher ecological integrity (FQAI) than prior-converted sites (FQAI around 2), they still had lower integrity than natural reference sites (around 12 and 15 respectively).

Chapter 3

Restoration methods and landscape position influence the environmental factors that drive plant community development. Different hydroperiod, lack of woody propagules, ongoing disturbance, and the young age of the restored wetlands may explain why these sites have yet to develop forested plant communities similar to the natural reference sites. There was no significant correlation between age and the percentage of woody species found in a restored site. Nor was there a correlation between the area of forested wetland within a 1-km radius and the percentage of woody species in a restored site. However, the sample size was small and the analysis would be improved by increasing it. Although the seeds of the dominant woody species found in natural reference sites can be dispersed by wind and animals, restored sites may be too far away from mature forests and natural wetlands for effective dispersal by wind. The animals that visit wooded sites may not be the same as those visiting restored sites, limiting dispersal by bird and animal. Finally, even if woody seedlings establish, regeneration of mature forest resembling natural reference sites will take far longer than 11 years (the age of the oldest restored site).

Conceptual Model

The conceptual model in Figure 2 is an attempt to describe the conditions that lead a restored wetland to develop natural forested vegetation or herbaceous marsh vegetation. The first, and arguably most important factor is hydroperiod; forested wetlands exist only where the hydroperiod is long and deep enough to exclude upland species, but not so wet as to kill trees (Lugo 1990). If the site is too dry it remains an upland, and if the hydroperiod is too deep and too long the site may remain an herbaceous marsh and never transition into forest. The practice of removing topsoil and compacting the subsoil to create a perched water table is likely to change the hydroperiod and discourages plant root growth, which may lead to the creation of an herbaceous marsh. The availability of propagules will affect the type of plant communities that develop. Woody wetland plant propagules are unlikely to be found in the soil after farming (Middleton 2003), which means that they must either be dispersed from offsite or be planted during the restoration. Rapid dispersal from offsite will depend on the distance to seed sources (natural wetlands and mature forests) and the presence of appropriate animal carriers. If species matching those found in natural reference site are planted during restoration and survive, then given adequate time a forested wetland will develop. Active mowing and digging in the site will prevent the establishment of woody plant species, as will herbivory. Agricultural runoff will change the chemistry and nutrient availability in wetlands, but it is difficult to predict exactly how that would affect the plant communities beyond increasing the potential for monostands of invasive species (Koch and Reddy 1992, Minchinton and Bertness 2003).

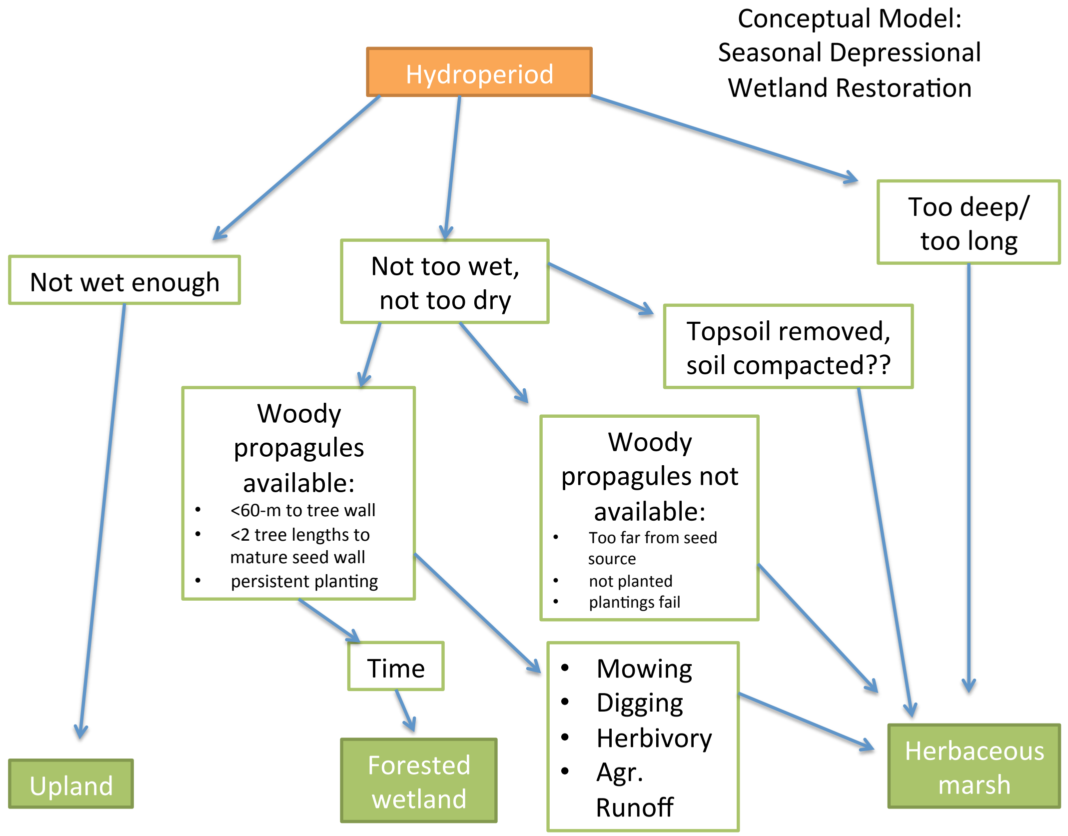

Figure 1: Conceptual model of the factors that drive plant community development in seasonal depressional wetlands of the Mid-Atlantic Coastal Plain.

Reexamining the Goals of Wetland Restorations

Wetland restoration practices have succeeded in creating wetlands, but they do not look like natural wetlands. The question remains: Does it matter? Wetlands are restored in order to provide certain desirable services. Do the differences in natural and restored wetland vegetation indicate that restored wetlands do not provide those services, or provide them to a lesser degree? Or could restored sites even provide more services than natural sites?

Both forests and herbaceous marshes provide food and shelter for wildlife, but as previously suggested, they may provide these things for different types of animals.

Restored marshes benefit ducks, geese, shorebirds, dragonflies, turtles, and amphibians. Natural forested wetlands provide habitat for warblers, woodcock, amphibians, the endangered Delmarva fox squirrel, and bats. (http://www.cheswildlife.org, http://www.fws.gov/chesapeakebay/dfox.htm) Wetlands are home to one in three federally listed threatened or endangered plant and animal species (Dahl and Johnson 1991). It is worth asking whether restored sites provide habitat for these species considering that they are so different from natural sites.

Both trees and herbaceous plant communities will aid in providing clean water by trapping sediment and taking up excess nutrients. Forested sites may immobilize more nutrients than herbaceous sites because their above-ground biomass does not die back every year and re-release nutrients into the system. However, herbaceous sites have more surface area close to the ground to trap sediment. Restored sites are also likely to receive more contaminated runoff than natural sites because they are often in close proximity and down slope from farm fields and often lack a buffer.

As depressions, both natural and restored sites will store a great deal more floodwater than prior-converted sites. However, the amount of water the depressions receive, hold, and process during a rain event will depend on their landscape position, volume, potential to act as a recharge or discharge wetland, and vegetation cover. Both trees and herbs will process a great deal of water during the growing season through evapotranspiration. Natural depressional wetlands will recharge groundwater because water can move through the soil profile. Restored sites with perched water tables will not provide this service.

Both natural and restored sites protect and improve aesthetics of open spaces.

Which type of wetland is more pleasing to the eye is a matter of personal taste, but land managers have reported that people prefer marshes and duck ponds to forested wetlands in their backyards. The landowners I spoke with were proud of their restored wetlands and many had paths from their house to Adirondack chairs facing the open pools of water in the wetlands.

Conclusions

Restorations of depressional wetlands in agricultural areas of the Mid-Atlantic Coastal Plain do not appear to be developing plant communities that match natural reference sites and yet they still provide many of the services associated with wetlands. A few important questions arise out of these findings:

What are we losing when a restoration doesn't restore a site to a natural state?

Why aren't restored sites being returned to a natural state? Are guidelines being ignored? Are the methods faulty? Is it even possible to restore natural conditions?

What, if anything, is gained by enhancing or creating a wetland rather than restoring it?

Answering these questions, improving our understanding of natural wetlands, and having a written record of specific measureable restoration goals will help to improve the restoration practice. If preserving natural ecosystems is important, then we must acknowledge our current limitations and prioritize the conservation of natural wetlands as well as restoration.

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Appendix 1:

The Anthropogenic Activity Index (AAI) worksheet developed by Hudson (2005) was used to document the extent of continued human disturbance in each site

ANTHROPOGENIC ACTIVITY INDEX
(AAI version specified for north and central Mississippi)

Metric 1. Surrounding Land Use Intensity (500 m surrounding buffer)

	Very Low - as expected at reference site	No evidence of disturbance - mature forest, grassland	0
	Low - mostly undisturbed, some human influence	Old fields, secondary forest, shrubby woodlots	1
	Moderate - a significant amount of human influence	Active pasture, high road density, newly fallowed fields, wildlife habitat management, other intermittent agricultural practices	2
	High - Intensive use of land up to buffer or wetland margin	Urban, residential, industrial operations, row cropping, other intensive agricultural operations	3

Metric 2. Intactness and Effectiveness of Buffer (up to approx. 50 m surrounding site)

	Best - ~50 m wide, as expected for reference site	Mature forest, grassland	0
	Moderate – 25-50m wide, some human influence	Mixture of grassland and secondary forest, old fields, shrubby woodlots	1
	Fair - 10-25m wide with significant human influence	Active pasture, newly fallowed field, adjacent roads, wildlife habitat management, other intermittent agricultural practices	2
	Poor - no effective buffer	Row cropping, turf vegetation, adjacent urban development, impervious surfaces, other intensive agricultural practices	3

Metric 3. Hydrologic Alteration

	Very Low - as expected at reference site	No evidence of disturbance	0
	Low - low intensity alteration…	…or past alteration not currently affecting wetland	1
	Moderate - significant, visible influence	Current and active	2
	High - intensive activity	Major disturbance currently and actively affecting hydrology	3

Examples of Alterations

Ditch inlet		Point source inlet		Other (describe):
Tile inlet		Installed weir, outlet		
Berm/dam		Levee		
Road bed		Used for drainage		

Subtotal from this page: ________

ANTHROPOGENIC ACTIVITY INDEX
(AAI version specified for north and central Mississippi)

Metric 4. Habitat alteration (within wetland)

	Very Low - as expected at reference site	No evidence of human activity	0
	Low - low intensity, or not currently affecting wetland	Some removal of vegetation, but vegetation is recovering	1
	Moderate - significant alteration of either vegetation or substrate	Vehicle use, grazed, livestock trails, coarse woody debris removal, mowed	2
	High - intensive disturbance of vegetation and substrate	Dredging, filling, tiling, disking, vehicle use, tree/shrub removal, removal of emergent vegetation	3

Specify Other Activities:

Metric 5. Habitat Quality and Microhabitat Heterogeneity

	Best - considerable habitat heterogeneity, high diversity of microhabitats	Small proportion of open water, 0-25%, large amount of emergent and submersed vegetation and coarse woody debris, some standing dead trees	0
	Moderate - moderate degree of habitat heterogeneity	25-50% open water, some woody debris	1
	Fair - low degree of habitat heterogeneity	50-75% open water, no woody debris	2
	Poor - small amount of habitat heterogeneity, low quality habitat	75-100% open water	3

Subtotal from this page: ________

Additional factors or concerns:

Metric 1 _____

Metric 2 _____

Metric 3 _____

Metric 4 _____

Metric 5 _____

Total Anthropogenic Activity Index Score
(Sum of metrics 1 through 5)

☐

Appendix 2

Species observed at each type of site. Taxonomy according to USDA Plants Database from May 2012.

Species	Natural Reference	Prior-converted	Restored
Andropogon sp.			X
Eleocharis robbinsii			X
Eleocharis sp.			X
Eragrostis pilosa			X
Eupatorium serotinum	X		
Eupatorium sp.		X	X
Fraxinus americana			X
Glycine max		X	X
Hypericum mutilum	X	X	X
Ilex glabra			X
Ipomoea hederacea		X	X
Ipomoea purpurea		X	
Ipomoea sp.		X	X
Juncus acuminatus			X
Juncus canadensis			X
Juncus tenuis	X	X	
Kummerowia striata			X

Species	**Natural Reference**	**Prior-converted**	**Restored**
Lonicera japonica	X		X
Ludwigia alternifolia			X
Panicum verrucosum	X		
Paspalum dissectum		X	
Phytolacca americana	X	X	X
Prunus sp.			X
Rhododenderon sp.	X		
Rubus occidentalis			X
Smilax auriculata	X		
Symphyotrichum sp.			X
Vaccinium atrococcum	X		
Acer negundo	X		
Acer rubrum	X		X
Achillea millefolium			X
Alisma subcordatum			X
Amaranthus hybridus		X	
Amaranthus retroflexus		X	
Amaranthus sp.			X
Amaranthus spinosus		X	
Ambrosia artemisiifolia		X	X
Ammannia coccinea			X

Species	**Natural Reference**	**Prior-converted**	**Restored**
Ammannia latifolia			X
Antennaria sp.			X
Antennaria virginica			X
Apocynum cannabinum		X	X
Apocynum sp.	X		X
Arundinaria gigantea	X		
Baccharis halimifolia			X
Bidens bidentoides			X
Bidens coronata			X
Bidens sp.	X		X
Boehmeria cylindrica	X		X
Campsis radicans			X
Carex arenaria			X
Carex lupuliformis	X		
Carex lurida	X		X
Carex scoparia			X
Carex sp.			X
Carex striata	X		
Carex vulpinoidea			X
Cephalanthus occidentalis	X		X
Chamaesyce maculata			X

Species	**Natural Reference**	**Prior-converted**	**Restored**
Chasmanthium laxum	X		
Chenopodium album		X	
Cicuta maculata			X
Clethra alnifolia	X		
Commelina communis		X	X
Compositae sp.	X		X
Cornus racemosa	X		
Cuscuta sp.			X
Cyperus odoratus		X	X
Cyperus pseudovegetus			X
Cyperus sp.	X	X	X
Cyperus strigosus			X
Daucus carota			X
Dichanthelium aciculare	X		X
Dichanthelium sp.	X		
Dichanthelium sphaerocarpon	X		
Dicranales sp.	X		
Diodia teres			X
Diodia virginiana			X
Diospyros virginiana	X	X	X
Echinochloa crus-galli		X	X

Species	Natural Reference	Prior-converted	Restored
Eleocharis ovata			X
Eleocharis quadrangulata			X
Erechtites hieraciifolia	X		
Eubotrys racemosa	X		
Euonymus americanus	X		
Eupatorium capillifolium			X
Euthamia caroliniana			X
Euthamia graminifolia			X
Euthamia sp.		X	X
Fatoua villosa		X	
Fimbristylis autumnalis			X
Galium obtusum			X
Gallium tinctorium			X
Gossypium hirsutum		X	
Hypericum denticulatum			X
Hypericum punctatum			X
Hypericum sp.			X
Hypnum sp.	X		
Ilex opaca	X		
Ipomoea lacunosa		X	X
Juncus dichotomus Elliott			X

Species	**Natural Reference**	**Prior-converted**	**Restored**
Juncus dudleyi Wiegand			X
Juncus effucus	X		X
Juncus marginatus			X
Juncus scirpoides			X
Juncus secundus			X
Juncus sp.			X
Lactuca sp.	X		X
Leersia oryzoides			X
Leucobryum sp.	X		
Lindernia dubia			X
Liquidambar styraciflua	X	X	X
Ludwigia palustris		X	X
Lycopus sp.			X
Lycopus virginicus			X
Lyonia ligustrina	X		
Magnolia virginiana	X		X
Marchantia	X		
Mikania scandens			X
Mitchella repens	X		
Mollugo verticillata		X	X
Morella cerifera	X		X

Species	**Natural Reference**	**Prior-converted**	**Restored**
Morella pensylvanica	X		
Morus rubra		X	
Nyssa biflora	X		
Oenothera laciniata		X	X
Osmunda regalis	X		X
Oxalis stricta			X
Panicum dichotomiflorum		X	X
Panicum rigidulum	X		
Parthenocissus quinquefolia	X		
Paspalum laeve			X
Phoradendron leucarpum	X		
Phragmites australis			X
Pinus echinata			X
Pinus sp.	X		
Pinus taeda	X		X
Poaceae sp.	X	X	X
Polygonum amphibium	X		
Polygonum cespitosum			X
Polygonum hydropiperoides			X
Polygonum lapathifolium			X
Polygonum pennsylvanicum	X		X

Species	**Natural Reference**	**Prior-converted**	**Restored**
Polygonum persicaria			X
Polygonum punctatum			X
Polygonum sp.		X	X
Portulaca oleracea		X	
Potamogeton sp.			X
Prunus serotina			X
Ptilimnium capillaceum			X
Quercus nigra	X		
Quercus phellos	X		
Quercus rubra	X		
Quercus sp.	X		
Quesrcus palustrus	X		X
Rhexia mariana			X
Rhododendron viscosum	X		
Rosa multiflora			X
Rotala ramosior		X	X
Rubus pensilvanicus	X		
Rubus sp.	X		X
Rudbeckia hirta			X
Rumex crispus			X
Saccharum sp.	X		

Species	**Natural Reference**	**Prior-converted**	**Restored**
Salix caroliniana			X
Salix nigra			X
Salix sp.	X		
Scirpus cyperinus	X		X
Scirpus purshiaus			X
Scirpus sp.			X
Senna hebecarpa			X
Sesbania herbacea			X
Setaria pumila			X
Setaria viridis		X	
Sida spinosa		X	X
Silene antirrhina			X
Smilax bonanox	X		
Smilax glauca	X		
Smilax rotundifolia	X		X
Smilax sp.	X		
Solanum carolinense		X	X
Solidago sp.			X
sourgum		X	
Sparganium americanum			X
Sparganium androcladum			X

Species	**Natural Reference**	**Prior-converted**	**Restored**
Sphagnum sp.	X		
Spiraea latifolia	X		
Symphyotrichum lateriflorum			X
Taxodium distichum			X
Toxicodendron radicans	X		X
Triadenum virginicum			X
Trifolium repens			X
Typha angustifolia			X
Typha latifolia			X
Vaccinium corymbosum	X		
Vaccinium formosum	X		
Vaccinium fuscatum	X		
Verbena bonariensis			X
Vitis rotundifolia	X		
Vulpia octoflora			X
Woodwardia areolata	X		
Woodwardia virginica	X		X
Xanthium strumarium		X	X
Zea mays		X	X
Total Number of Species Found	78	40	142

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