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Evaluation of methods for establishing vegetation in created wetland mitigation sites in eastern Nebraska

Andrew A. Miller
University of Nebraska at Omaha, miller3103@cox.net

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EVALUATION OF METHODS FOR ESTABLISHING VEGETATION IN CREATED WETLAND MITIGATION SITES IN EASTERN NEBRASKA

by

Andrew A. Miller

Thesis

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<u>Supervisory Committee</u>

Dr. Tom Bragg
Dr. David Sutherland
Dr. Jeffery Peake

ABSTRACT

EVALUATION OF METHODS FOR ESTABLISHING VEGETATION IN CREATED
WETLAND MITIGATION SITES IN EASTERN NEBRASKA

Andrew A. Miller, MS

University of Nebraska, 2008

Advisor: Dr. Tom Bragg

Seventeen wetland mitigation sites in eastern Nebraska were evaluated, by vegetative zone, to assess the relative success of active and passive wetland vegetation establishment techniques. For sites with available records of species introduced, 46% of the seeded species and 31% of the transplanted species were successfully established suggesting that the intentional introduction of species (i.e. active methods) provides some degree of success in wetland creation. No significant differences were observed within or among active or passive methods for Species Richness (S), Shannon-Wiener diversity (H'), or the Floristic Quality Index (FQI) (Kruskall-Wallis test $P < 0.05$). However, while not statistically significant, general trends showed that, in the temporarily flooded zones, seeding resulted in both the highest overall plant diversity and highest FQI (S = 20.2, H' = 1.74, FQI = 8.99) and, among species with cover values > 0.5%, the lowest percent non-native species (6.2%). In the seasonally flooded zone, the highest diversity and highest FQI resulted from a combination of seeding and the addition of donor soil and transplants (S = 30.0, H' = 2.598, FQI = 19.1). This combination of treatments also had the lowest percent of nonnative species with canopy cover values > 0.5 % for the seasonally flooded zone (0.0%). In contrast, the highest diversity and highest FQI values in the permanently flooded zone were observed with the addition of donor soil ($S = 13$, $H' = 1.191$, FQI = 9.6), although the percent of nonnative species with canopy cover values > 5 % was lowest with a combination of seeding and the addition of donor soil and transplants. General trends shown in this study suggest that, among currently recommended procedures for vegetation establishment in wetland creation, active techniques, such as, seeding, donor soil addition, and transplanting, are equally or more effective in obtaining both higher diversity and floristic quality and fewer non-native species than are passive techniques, such as natural colonization. A combination of methods may also be successful in creating wetland plant diversity, although the result was only noted for the seasonally flooded zone. The results of this study provide information that should be useful in creating wetlands until more rigorous studies on the process are completed. The study also provides a database against which future assessments of the study sites may be compared.

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INTRODUCTION

Wetlands are transitional areas between terrestrial and aquatic ecosystems where either the water table is usually at or near the surface or the surface is covered by shallow water temporarily, seasonally or permanently (Kent 1994). Wetland plant composition varies greatly due to differences in factors such as landscape position, water source, duration and frequency of flooding, and geology. In Nebraska, wetland ecosystems include marshes, riparian wetlands, littoral wetlands, fens, wet meadows, seeps, shrub or forested wetlands, and depressional wetlands. These wetland ecosystems provide important ecosystem services including water purification, flood reduction and habitat for wildlife as well as having an educational and recreational value.

Since statehood in 1867, Nebraska has lost approximately 35% of its wetlands (Dahl 1990). It was not until 1977, with the passage of amendments to the Clean Water Act, that these wetlands, and others across the nation, came under federal protection. This protection came in the form of Section 404, which authorized the United States Army Corps of Engineers (USACE) to control dredging and filling practices affecting wetlands. The permitting process for these activities first requires applicants to consider avoiding wetlands, then to consider ways to minimize impacts to wetlands. Only, as a last resort, does the process require compensatory mitigation for unavoidable impacts. In recent years, the success of compensatory mitigation in the form of created wetlands has been evaluated across the U.S. (Kusler and Kentula 2000, National Academy of Sciences 2001, Turner et al. 2001). These studies report that created wetlands have not been successful in replacing natural wetlands with most of the failures attributed to either improper construction of the wetland or failure to ensure the establishment of appropriate hydrology. Even of the wetlands that have been considered successfully created, there is still a concern that they do not adequately replace natural wetland structure and function.

Wetlands that are destroyed for land development, agriculture or other purposes, can be mitigated using several methods including creation, restoration, enhancement and preservation, either on-site or off-site (USACE & EPA, 2008). In Eastern Nebraska, impacts to wetlands from land development are usually mitigated by creating new wetlands (personal observation). Created wetlands are wetlands developed on land on which they did not occur historically. The process of creating wetlands requires two important considerations. First is the need to create the hydrology that provides the physical conditions for a wetland and, second, is the need to establish the wetland (hydrophytic) plant community that provides the basis for animal life as well as hydrologic buffering and water purification functions (Hammer 1992). Among the many recommended approaches used to establish wetlands, most fit in one of two general categories: (1) active methods, such as, seeding, adding wetland topsoil from existing wetlands (donor soil) or transplanting wetland vegetation, or (2) passive methods, which allow vegetation to colonize sites naturally (Kusler and Kentula 1990, Hammer 1992, Kent 1994, Mitsch and Gosselink 2000, National Academy of Sciences 2001, USACE 2005).

Since the practice of creating wetlands is in its infancy, little research has been done to evaluate the success of various methods used to establish wetland vegetation.

Further, there is little legislative incentive to evaluate these methods since typical Section 404 permits require wetland mitigation sites be monitored for only three to five years, too short a period of time to assess successful establishment of either the wetland plant community or the abiotic conditions that together mitigate for the loss of natural wetlands. Assessing long-term success can only be measured over several climatic cycles (Mitsch and Wilson 1996, D'Avanzo 1990 as cited in Kusler and Kentula 2000). Additionally, lack of detailed records on past wetland creation efforts (e.g. seeding rates, species lists, etc.) complicates rigorous evaluation by the scientific community.

A crucial measure of successful wetland creation is the establishment of desired wetland vegetation appropriate to the region in which the site occurs. Evaluating vegetation during the first few years of a wetland creation project provides a first assessment of the success of such efforts, including (1) the rate with which wetland vegetation is established and (2) the degree of success, particularly with respect to the composition and diversity of early establishment. Further, by extrapolation, successfully established wetland vegetation suggests, albeit without supporting data, that appropriate hydrologic conditions were created implying the replacement of some degree of lost ecosystem-level wetland functions.

Methods for Wetland Creation

Once the hydrologic conditions have been created, several different procedures may be used to establish vegetation at a created wetland. In general, both active and passive wetland vegetation establishment methods are used, with little present consensus on which is best. Costs of these procedures, however, vary. For example, among active methods, transplanting vegetation costs an average of $22,500-$45,000 per hectare, (based on 46 cm planting centers) compared to a diverse wetland seed mix, which costs approximately $1,200-$6,000 per hectare (Prairie Restoration Inc. 2007, Openlands 2007). In contrast, passive methods involve only creating the physical environment that provides appropriate hydrology for a wetland then allowing the native species to colonize through natural dispersion, thus minimizing the cost of this approach. Of course, some degree of immigration to a site occurs with either active or passive techniques, whether intended or not.

Active Methods

Seeding.– Hammer (1992) and Kent (1994) recommend seeding only to establish wetland meadows (i.e., graminoid communities), since emergent and submergent wetland plant seeds do not successfully germinate in wetter marsh environments. Reinartz and Warne (1993), however, showed that early introduction of wetland seed in depressional marshes resulted in twice as much diversity of grasses and forbs in the short-term as occurred with naturally colonized wetlands. Other studies recommend combining seeding with other methods. For example, Hoag et al. (2001) and Milner (2003) observed that combining seeding with transplanting achieved the best wetland vegetation establishment.

Donor Soil.– Several studies indicate the addition of wetland donor soils, with their preserved seed bank, enhances the success of wetland creation (Dunn and Best 1983, Erwin et al. 1985, Kent 1994, Vivian-Smith and Handel 1996, Brown and Bedford 1997, Stauffer and Brooks 1997). Research by the National Academy of Sciences on wetland creation for mitigation purposes also recommends including donor soils, as well as plant material salvaged from donor sites, to supplement natural colonization if necessary (Dawe et al. 2000, as cited in National Academy of Sciences 2001). Other studies, however, found adding donor soil to be ineffective. For example, Iverson and Wali (1982) observed that, after adding both donor soils and transplanting native species, only 10% of the species that became established either were recorded at the former wetlands or were known to be transplanted to the site.

Transplanting.– Transplanting is designed to quickly establish a diverse wetland plant community consisting of desirable species without having to wait for dispersal or seed germination and development (Hammer 1992). Similarly, Kent (1994) recommends salvaging marsh species in the form of plugs from nearby wetlands, particularly for establishing permanently flooded wetlands. Hoag et al. (2001), however, state that revegetating wetlands with herbaceous species plugs of greenhouse grown material has a much higher establishment rate than seeding or transplanting plants from nearby wetlands. In either case, transplanting, the most expensive approach available, has neither been found to establish more rapidly nor to have more desirable species established than sites allowed to be naturally colonized (Mitsch et al. 1998, Iverson and Wali 1982). Mitsch et al. (1998) also noted that species richness with transplanting was only slightly higher than in an adjacent created wetland of the same size that was allowed to colonize naturally. As with soil addition, the National Academy of Sciences research recommends using transplant material as a supplement when native recruitment via dispersal is found to be ineffective (National Academy of Sciences 2001).

Passive Methods

Natural Colonization.– Frenkel and Morlan (1991) are among those that suggest transplanting may not be necessary to establish suitable wetland plants in a created wetland. These, and other proponents of passive vegetation establishment, indicate that active methods, such as seeding perennial species to a site, may prevent the establishment of the diversity of annuals and perennials that randomly occur during early stages of natural wetland succession (Noon 1995, Tilton 1991). For example, Noon (1995) showed that plants established from naturally recruited seeds survived longer, grew faster and spread more than plants established from commercial seed sources. Similarly, Dawe et al. (2000) found that unplanted blocks of estuary marshes eventually had a higher species richness and cover than planted blocks. Because of these findings, the National Academy of Sciences (2001) recommends using natural recruitment first for vegetation establishment in creating wetlands.

Given the lack of consensus, and the considerable costs in dollars and effort that are incurred to establish functioning wetlands, an assessment of the success of different wetland vegetation establishment efforts was considered useful. The purpose of my study was to provide such an assessment.

METHODS

The general approach of my study was to select wetland mitigation sites for which methods used to establish vegetation were known and to quantify the vegetation characteristics at each site. These data were then used to assess the success of vegetation establishment methods based on Species Richness, Shannon Diversity, Floristic Quality Assessment, the proportion of non-native species present, and the number of introduced species that were established.

Study Sites

Most study sites considered were selected from a list of wetland mitigation sites established from 1995-2003 as recorded by the USACE-Nebraska Regulatory Office in Douglas and Sarpy County, Nebraska. Additional wetland mitigation bank sites were considered from Nebraska Department of Roads and the Papio-Missouri River Natural Resources District sites. The following criteria were used to identify those sites appropriate for my study:

1. Available information on vegetation establishment techniques.
2. Created before 2003, three years prior to my evaluation.
3. Categorized as a Palustrine Emergent type wetland (Cowardin 1979).
4. Located within a 160-kilometer radius of the Omaha metropolitan area.

Of an initial 73 sites reviewed, seventeen met the above criteria, nine in Douglas County, six in Sarpy County and two in Lancaster County (Table 1, Appendix Fig. 1). I attempted to identify an equal number of sites for each type of wetland establishment technique but was only able to obtain multiple sites for those seeded commercially, those using donor soil, and those using natural colonization. While limited in their ability to generalize results of the treatment, using single replicate treatment sites was able to add some depth to my study as well as to provide baseline information on sites against which to compare any future reevaluations. Of the seventeen sites selected for study, six exclusively used a passive method, specifically Natural Colonization (NC), and 11 used some type of active method (Table 1). Of the 11 active methods, six were Seeded (S), two used Donor Soil (DS) and one used Transplants (T). The remaining two sites were combinations of treatments, one using seeding and the addition of donor soil and transplants (S-DS-T) and the other using seeding and the addition of donor soil (S-DS).

The climate of the study area is typical of temperate continental North America. Yearly mean temperatures average 11˚ C, ranging from -4.5˚ C in January to 26.7˚ C in July (NOAA 2007). Annual rainfall averages 76.8 cm, most of which falls during the growing season as rain. During the July-August 2003 field season, abnormally dry to moderate drought conditions were reported for the region (U.S. Drought Monitor 2003). Temperatures during July and August 2003 averaged 25.8˚ C and 25.6˚ C, respectively, which is 0.95˚ C and 1.95˚ C higher than normal. Precipitation for 2003 totaled 59.1 cm, 17.7 cm below normal (NOAA 2007). Soils at the study sites generally consisted of deep, calcium rich, loamy soils formed on wind-borne Loess (Table 1) (Bartlett 1975).

Table 1. General information for study sites. NC = naturally colonized; S = seeded; DS = donor soil; T = transplant. PEMA = Palustrine Emergent Temporarily Flooded, PEMC = Palustrine Emergent Seasonally Flooded, PEMF = Palustrine Emergent Semi-permanently Flooded, A = Adjacent, I = Isolated. SCL = Silty Clay Loam, ULC = Urban Land Complex, SA-Silty Alluvium, SC = Silty Colluvium, SL = Silt Loam, SAL = Sandy Loam. TF = Temporarily Flooded, SF = Seasonally Flooded, PF = Permanently Flooded. * Seeded several years after construction. † = Plots less than 100m, combined data. ** One year seeding delay. + = Estimate. All sites in 6th Prime Meridian. 7812 = Smithland-Kenridge Silty Clay Loam, 9701 = Udarents-Urban Land Complex, 6452 = Clamo-Zook-Kezan Silty Clay Loam, 7234 = Judson Silty Clay Loam, 7235 = Judson-Nodaway Channeled-Contrary Complex, 9715 = Urban Land-Udorthents Complex, 8480 = Gibbon-Wann Complex, 7050 = Kennebec Silt Loam, 7099 = Zook Silty Clay Loam.

Site No.	Site Name	Treatment	Size (ha.)	Type	Est.	Land Use	Adjacent (A) or Isolated (I)	Public Land Survey System	Soil Unit Symbol	Water Regime and Plot No.
1	Rumsey Station	S**	0.58	PEMC	1995	Undevelop.	A	S. 30 T14N, R13E	SCL (7812)	TF-1
	Hickory Ridge	S, DS, T	0.29	PEMA	2000	Developed	I	NW1/4 S. 16 T14N, R11E	ULC (9701)	SF-1, PF-1
12	Bob Roth	S	2.06	PEMC	1996	Undevelop.	A	SE1/4 S. 18 T14N, R13E	SCL (6452)	TF-1, SF-1
13	Tregaron-Site 2	DS	0.69	PEMC	1996	Developed	I	S. 33 T14N, R13E	SCL (7812)	TF-1, SF-1
15	Fox Ridge Estates	NC	0.51	PEMA	1996	Developed	A	SE1/4 S. 08 T13N, R13E	SCL (7234)	TF-1
17	Immanuel Ret. Comm. Fac.	NC	0.88	PEMC	1999	Developed	I	S.1/2 S. 28 T15N, R11E	SCL (7234)	TF-1, SF-1, PF-1
25	Marathon Realty-Starwood	NC	0.14	PEMC	1998*	Developed	A	NE1/4 S. 33 T16N, R12E	ULC (9701)	SF-1
26	Eagle Hills	DS, S	0.40	PEMA	1998	Developed	A	NE1/4 S. 30 T14N, R13E	SCL (7812), SA, SC (7235)	SF-2
29†	Deer Creek	DS	1.34	PEMA/ PEMC	1999*	Developed	I	SW1/4 S. 30 T16N, R12E	SA (9715)	TF-1, SF-1, PF-1
30	Quail Hollow-North	NC, S*	0.42	PEMC	1999	Developed	I	NW1/4 S. 10 T14N, R11E	ULC (9701)	TF-1, SF-1
34†	NDOR-Waterloo	S	1.21	PEMA/ PEMC	2000	Undevelop.	A	NW1/4 S. 02 T15N, R10E	SL, SAL (8480)	TF-1, SF-1
35†	NDOR -Waverly	S	14.6	PEMC		Undevelop.	I	SW1/4 S. 09 T12N, R07E	SL (7050), SCL (7099)	TF-1, SF-1
37†	NDOR Lincoln-Davey	S	1.21+	PEMC/ PEMF	1995	Undevelop.	A	NE1/4 S. 25 T11N, R07E	SL (7050)	TF-1, SF-1
42	Stone Creek	NC	0.40+	PEMA	2002	Undevelop.	A	NE1/4 S.03 T15N, R11E	ULC (9701)	TF-1
45	City of Omaha-Adams Park	T	0.61+	PEMC/ PEMF	2000*	Developed	A	NW1/4 S.09 T15N, R13E	SCL (7234)	TF-1, PF-1
46†	Linden Estates (M2 & M3)	NC	1.56	PEMC	1996	Developed	A	SE1/4 S.13 T15N, R11E	ULC (9701)	TF-1, PF-1
48	156th & Maple	NC	0.40+	PEMA	2000	Developed	A	S.02 T15N, R11E	SCL (7234)	TF-1

Data Collection

Wetland vegetation typically develops in three major zones along a hydrologic gradient from the wetland to the surrounding upland matrix (Hammer 1992). Because species composition and diversity vary within each of these zones (Cronk and Fennessy 2001), sampling was stratified by separately evaluating each of these zones, although not all zones were present at all sites. To assist in identifying these zones, functional characteristics were assigned to most wetland plant species in the United States based on each species probability of occurring in a wetland or upland (Reed 1988). The wetland plant species are grouped into five categories: Obligate (OBL) = > 99% probability of occurring in a wetland; Facultative Wetland (FACW) = 67-99% probability; Facultative (FAC) = 34-66% probability; Facultative Upland (FACU) = 1-33% probability; and Upland (UPL) = < 1% probability of occurring in a wetland. The three hydrologic zones separately evaluated, modified from Cowardin 1979, were:

- <u>Permanently/Semi-permanently Flooded (PF)</u>: This zone is flooded either all year or for the majority of the growing season. I identified this zone by the presence of standing water and a predominance of obligate (OBL) wetland species Reed 1988).
- <u>Seasonally Flooded (SF)</u>: This zone is flooded for several months during the year but, while the surface usually is dry by the end of growing season, water may be near the surface. I identified this zone by the presence of numerous indicators of past flooding, such as watermarks, sediment deposits or desiccation cracks. Plants in this zone range from obligate (OBL) to facultative wetland (FACW) wetland species (Reed 1988).

- Temporarily Flooded (TF): This zone is flooded for a several weeks during the growing season but dry the rest of the year. I identified this zone by the presence of only a few indicators of past flooding, such as, watermarks, sediment deposits, and desiccation cracks. Plants in this zone include facultative wetland (FACW), facultative (FAC) and upland (UPL) species (Reed 1988). FAC and UPL species are capable of persisting in either wetlands or uplands.

Vegetation at each site and hydrologic zone was sampled during July and August of 2003. Sampling at each site was based on a 3-m * 100-m (300 m^2) plot, a size that is consistent with the recommendation of Mueller-Dombois and Ellenberg (1974) for temperate grasslands (Barbour et al. 1987). The plot was centrally placed within each hydrologic zone with the long axis positioned perpendicular to hydrologic gradient. If a 100-m long plot could not be placed continuously within a hydrologic zone, smaller length plots were sampled until a total of 100-m length was sampled. For divided plots (Sites 29, 34, 35, 37, and 46), vegetation cover values were proportionally averaged before further analysis. The geographic coordinates of each site were recorded at the mid-point of the 3-m end of each plot using a Magellan ©, recreational-use GPS unit (Appendix Table 1).

Within each plot, plant canopy cover was visually estimated for each species using a protocol modified from Daubenmire (1959). Cover classes used were 1%, 1-5%, 5-25%, 25-50%, 50-75%, 75-95%, 95-99% and > 99%. Species that could not be identified in the field were collected, assigned a temporary I.D. number, and later identified at the

University of Nebraska at Omaha Herbarium (OMA). Nomenclature for species followed Rolfsmeier and Steinauer (2003). Other observations recorded for each site included the presence of adjacent wetlands and adjacent land use (Table 1).

Data Analysis

Parameters used to measure the success of a wetland creation, at the level of individual species, include *canopy cover* and *frequency* for each species for each zone and treatment. These values were then used to calculate *species diversity* and the FQI to characterize results at the community level. Mid-Point values for each cover category were used in calculations of both species and community parameters. Overall, species frequency was calculated by dividing the number of plots in which a species occurred by the total number of plots in which it could have occurred for each treatment and hydrologic zone evaluated in the study. The percent of non-native species (%NNS) and the percent of desired introduced species that were successfully established (%ISE) parameters were calculated using the presence of species in sample units.

Species Diversity

Species Richness (S) and Shannon Diversity (H') were used to quantify species diversity (Magurran 1988). Species Richness is a count of all species present in a sample unit. The Shannon-Wiener Diversity Index (H'), a standard equitability index, was calculated based on each species' average canopy cover.

Floristic Quality Index (FQI)

The Floristic Quality Assessment (FQA), by which the Floristic Quality Index (FQI) is calculated, is a protocol designed to assign values to the quality of natural areas (Swink and Wilhelm 1979, 1994). The FQI differs from diversity measures, such as Species Richness and the Shannon-Wiener Index, principally in that the diversity measures (1) make no qualitative assignment of the perceived fidelity of a species to a particular habitat or ecosystem, (2) require equal sized sampling areas because of the direct relationship between diversity and the size of an area sampled, and (3) include all species, whether native or not, whereas the FQI ignores non-native species (i.e. it assigns no value to them). Because of these differences, diversity and FQI values were not expected to show similar results in all cases.

The FQI is based on a score derived from the combined ecological conservatism of plant species present at the site. Ecological conservatism is expressed numerically as a *Coefficient of Conservatism,* or *C*-value and is the *a priori* assignment of the fidelity of a species to native, undisturbed habitats for the study region. Scientists familiar with local species assign these *C*-values. Native ruderal species that are particularly aggressive in dominating heavily disturbed habitats are assigned a *C*-value of zero whereas species with a high fidelity to relatively undisturbed native plant communities are assigned a *C*-value of 10. Between these extremes are species with various degrees of habitat fidelity as reflected in their assigned *C*-values. Non-native species, designated by an asterisk (*), are not assigned a value in this procedure thus, effectively, their value equals zero (0).

An exception was *Phalaris arundinacea,* which was considered a non-native species in this study because of the high probability that those identified were a non-native variety (see discussion below). This non-native classification, however, contradicts Rolfsmeier and Steinauer's (2003) designation of *P. arundinacea* as a native, although they did assign it a *C*-value of zero. To be consistent with this designation, zero was used in this study but, only in FQI calculations. Plants not identified to the species level, such as *Polygonum* sp., were assigned the lowest *C*-value for that genus. Thus, for plots that contain several of these partially unidentifiable species, the FQI that was calculated may not reflect the true quality of the site.

The FQI score for a site was calculated using the formula:

FQI = Mean $C\sqrt{N}$ where:

Mean C = mean of the *C*-value of all species conservatism. Non-native species were not considered in the calculation of the Mean C.

N = number of native species.

The Coefficient of Conservatism assigned to each species by Rolfsmeier and Steinauer (2003) was used to calculate the FQI values used in this study (Appendix Tables 2-9). See the Appendix for a more detailed description of this protocol.

Statistical Procedures

Descriptive statistics were based on percent canopy cover values of each species for each site and zone. Where multiple comparison tests showed significant differences within sites, the Kruskall-Wallis nonparametric test was used to test for significant differences among treatments and hydrologic zones based on *S*, *H′*, and FQI values. Differences were considered significant at $P \leq 0.05$. Statistical analyses were performed using the Minitab statistical package (Minitab 2003).

<u>Percent Non-Native Species (%NNS).-</u> The %NNS was assessed separately because among these species are those that often create monocultures that can out-compete native wetland species for resources and thus are of particular concern in creating wetlands. *Phalaris arundinacea* is an example of a species in this category (Maurer et al. 2003). Other invasive species of regional concern include *Phragmites australis* and *Typha* spp. (personal communication with USACE Omaha District Banking Chairman). In particular, the concern for *P. arundinacea* led the USACE-Omaha District to establish a minimum composition for invasive species in their assessment of the quality of created wetlands (USACE 2005). Specifically, USACE criteria state that, for a site to be considered successfully established, invasive species cover may not exceed 10% three years after establishment.

The percent of non-native species (%NNS) for each zone of each site was calculated by dividing the number of non-native species in each plot by the total number of species in that plot and converting the result to a percent. Individual plot data were then averaged to determine %NNS by treatment and zone. The same calculation was completed using only species with > 5% cover in order to identify those species in sufficient abundance to indicate a substantive component of wetlands. Designation of species as a non-native was based on Rolfsmeir and Steinauer (2003).

<u>Percent Introduced Species Establishment (%ISE)</u>.– The %ISE was calculated by dividing the number of introduced species present at a site by the total number of species reported to have been introduced by seeding or transplanting to that site with the result multiplied by 100 to convert to percent. Introduced species are defined in this paper as species intentionally introduced from a known source. In this study, only seeded and transplant methods provided such lists of introduced species, although not always available for each site (Appendix Table 10). The %ISE was calculated by site rather than by zone primarily because seed or transplant placement was likely to have occurred across much of the restored site in the absence of clear zones at the time of the wetland creation. The proportion of total species richness at a site that could be attributed to introduced species was calculated by dividing the number of introduced species at a site by the total number of species at the site.

RESULTS

A total of 118 species were identified in the 30 plots evaluated for the study. Of these, 99 species (84%) were native and 19 (16%) were non-native (Tables 2-4, Appendix Tables 2-9). Sixteen (14%) of the 118 species had a *C*-value ≥ 5 with seven (41%) of the seventeen study sites containing at least one of these species. Selection of a *C*-value ≥ 5 was intended to specifically identify highly desirable species. Of species with *C*-values ≥ 5, *Schoenoplectus tabernaemontani* (*C*-value = 5) and *Scirpus atrovirens* (*C*-value = 5) were the most frequently observed, occurring in 80% of the plots in the PF zone (mean canopy cover = 1%) and 58% in the SF zone (mean canopy cover = 9%), respectively (Tables 2-4).

Table 2. Average canopy cover of species present in at least 50% of treatments in the Temporarily Flooded zone (Appendix Tables 2-9). NC = Naturally Colonized, S = Seeded, DS = Donor Soil, DS-S = Donor Soil and Seeded, T = Transplant, S-DS-T = Seeded with Donor Soil and Transplant. *C* = *Coefficient of Conservatism*. * = A *Coefficient of Conservatism* value is not assigned for non-native species. ** = Designated as non-native species in this study. Parenthetical values for each treatment indicate the number of plots from which the mean species cover values were calculated. *** = Species that could not be identified to the species level were assigned the lowest *C*-value for that genus. Decimals are used instead of zeroes for visual clarity. "-" = No Data.

Species	*C*	Canopy Cover (%) by Treatment					
		NC (4)	S (6)	DS (2)	DS-S	T (1)	S-DS-T
Ambrosia artemisiifolia	0	1.6	3.2	0.3	-	.	-
Apocynum cannabinum	2	.	10.5	1.5	-	.	-
Bidens sp.***	1	.	0.1	0.3	-	.	-
Calystegia sepium	1	0.1	2.5	.	-	.	-
Conzya canadensis	0	0.1	0.1	.	-	.	-
Cyperus esculentus	0	.	1.0	1.5	-	.	-
*Echinochloa crusgalli***	*	9.4	11.1	18.8	-	.	-
Erigeron strigosus	2	3.8	0.6	.	-	.	-
Helianthus annuus	0	0.3	.	0.3	-	.	-
Juncus torreyi	4	0.1	2.5	.	-	.	-
Leersia oryzoides	4	9.4	6.3	.	-	.	-
Panicum sp.***	0	0.1	0.1	0.3	-	.	-
*Phalaris arundinacea***	0	5.1	31.4	31.3	-	.	-
*Poa pratensis***	*	.	0.5	7.8	-	37.5	-
Polygonum coccineum	2	3.9	0.6	0.3	-	.	-
*Polygonum persicaria***	*	0.1	0.1	.	-	.	-
Polygonum sp.***	0	0.8	0.1	.	-	.	-
Populus deltoides	3	0.1	6.3	18.8	-	0.5	-
*Rumex crispus***	*	0.9	0.2	.	-	0.5	-
Salix amygdaloides	4	9.4	2.7	18.8	-	.	-
Salix exigua	3	3.8	0.6	18.8	-	.	-
Scirpus atrovirens	5	0.1	0.6	.	-	.	-
Solidago gigantea	3	.	0.7	1.5	-	3.0	-
Symphyotrichum lanceola.	2	.	0.5	0.3	-	15.0	-
Symphyotrichum pilosum	0	.	6.3	7.5	-	.	-
Symphyotrichum sp.***	0	0.3	2.5	.	-	.	-
*Typha angustifolia***	*	0.1	3.5	1.5	-	.	-
Verbena hastata	4	0.1	0.7	0.3	-	.	-

Table 3. Average canopy cover of species present in at least 50% of treatments in Seasonally Flooded zone (Appendix Tables 2-9). NC = Naturally Colonized, S = Seeded, DS = Donor Soil, DS-S = Donor Soil and Seeded, T = Transplant, S-DS-T = Seeded with Donor Soil and Transplant. *C = Coefficient of Conservatism.* * = A *Coefficient of Conservatism* value is not assigned for non-native species. ** = Designated as non-native species in this study. Parenthetical values for each treatment indicate the number of plots from which the mean species cover values were calculated. Decimals are used instead of zeroes for visual clarity. "-" = No Data.

Species	*C*	Canopy Cover (%) by Treatment					
		NC (2)	S (5)	DS (2)	DS-S (2)	T	S-DS-T (1)
Carex vulpinoidea	5	.	0.1	0.3	.	-	3.0
Cyperus esculentus	0	0.3	0.2	1.5	32.8	-	.
*Echinochloa crusgalli***	*	42.5	0.7	48.5	7.5	-	0.5
Eleocharis palustris	6	.	1.3	0.3	1.5	-	.
Mimulus ringens	6	1.5	0.1	.	0.5	-	3.0
*Phalaris arundinacea***	0	7.5	21.0	.	18.8	-	3.0
Polygonum coccineum	2	.	8.2	1.5	.	-	0.5
*Polygonum persicaria***	*	.	0.6	.	1.5	-	3.0
Populus deltoides	3	0.3	.	0.3	73.8	-	.
*Rumex crispus***	*	.	0.2	0.3	1.5	-	0.5
Salix amygdaloides	4	7.5	.	.	42.8	-	15.0
Salix exigua	3	.	0.1	.	0.5	-	3.0
Scirpus atrovirens	5	9.0	15.1	.	0.3	-	15.0
*Typha angustifolia***	*	73.8	44.5	.	31.5	-	0.5

Table 4. Average canopy cover of species present in at least 50% of treatments in Permanently Flooded zone (Appendix tables 2-9). NC = Naturally Colonized, S = Seeded, DS = Donor Soil, DS-S = Donor Soil and Seeded, T = Transplant, S-DS-T = Seeded with Donor Soil and Transplant. *C = Coefficient of Conservatism.* * = A *Coefficient of Conservatism* value is not assigned for non-native species. ** = Designated as non-native species in this study. Parenthetical values for each treatment indicate the number of plots from which the mean species cover values were calculated. Decimals are used instead of zeroes for visual clarity. "-" = No Data.

Species	*C*	Canopy Cover (%) by Treatment					
		NC (2)	S	DS (1)	DS-S	T (1)	S-DS-T (1)
*Echinochloa crusgalli***	*	1.5	-	37.5	-	.	.
Eleocharis palustris	4	.	-	0.5	-	3.0	.
Schoenoplectus tabernaem.	5	0.5	-	0.5	-	3.0	.
*Typha angustifolia***	*	42.5	-	85.0	-	85.0	3.0

Treatment Success

No significant differences were observed among treatments for Species Richness (S) Shannon-Wiener diversity (H'), or the Floristic Quality Index (FQI) (Kruskall-Wallis test $P < 0.05$) (Table 5). However, while not significant, some trends were observed that may be helpful in wetland creation efforts until more controlled studies can be conducted. For example, the highest overall plant diversity was recorded with the Seeded (S) treatments ($S = 17.33$, $H' = 1.568$) and the second highest with a combination of Donor Soil and Seeded treatments (DS-S) ($S = 17$, $H' = 1.489$) (Table 5). In contrast, the lowest diversity was recorded with the Transplant (T) treatment ($S = 6.5$, $H' = 0.852$).

Similar results were reflected in the FQA by which the highest overall FQI was recorded with the combination of Donor Soil and Seeded treatments (DS-S) (FQI = 12.2). In contrast to diversity results where the second highest values were obtained with combined donor soil and seeding, the second highest FQI was obtained with the combination of Seeded, Donor Soil, and Transplant treatments (S-DS-T) (FQI = 11.6). Also differing from diversity results, where the lowest values were recorded with transplant, the lowest FQI was in the Naturally Colonized (NC) treatment (FQI = 5.1)

Non-native species averaged 26% of all species identified at study plots (n=30). Within treatment groups, average non-native species ranged from 20% in Seeded (S) and Donor Soil (DS) treatments to 39% in Transplant (T) treatments (Table 6). For species with a canopy cover value greater than 5%, a subset of species intended to indicate those making up a substantive proportion of the treatment vegetation, the %NNS ranged from

Table 5. Average Species Richness (*S*), Shannon-Wiener Diversity (*H′*), and FQI (± standard deviation of means) by treatment and hydrologic zone. No significant differences were determined among treatments (Kruskall-Wallis test, $P < 0.05$). *n* = the number of individual plots from which mean values were calculated. PF = Permanently Flooded, SF = Seasonally Flooded, TF = Temporarily Flooded. "-" = No Data.

Treatment and Zone	*n*	*S*	*H'*	FQI
Donor Soil				
TF	2	12.5 ± 3.54	1.438 ± 0.689	5.59 ± 1.52
SF	2	6.5 ± 3.54	0.359 ± 0.231	4.52 ± 1.56
PF	1	13.0	1.191	9.62
Combined Zones	5	10.2 ± 4.21	0.957 ± 0.663	5.97 ± 2.37
Donor Soil, Seeded				
TF	0	-	-	-
SF	2	17.0 ± 0.00	1.489 ± 0.611	12.16 ± 0.877
PF	0	-	-	-
Combined Zones	2	17.0 ± 0.00	1.489 ± 0.611	12.16 ± 0.877
Naturally Colonized				
TF	4	10.5 ± 7.23	0.977 ± 0.837	3.61 ± 3.33
SF	2	9.5 ± 4.95	1.311 ± 0.414	7.29 ± 3.96
PF	2	5.0 ± 1.41	0.360 ± 0.374	6.00 ± 1.41
Total	8	8.9 ± 5.67	0.906 ± 0.692	5.13 ± 3.19
Naturally Colonized, Seeded				
TF	1	9.0	1.170	7.20
SF	1	14.0	1.783	6.64
PF	0	-	-	-
Combined Zones	2	11.5 ± 3.54	1.476 ± 0.433	6.92 ± 0.395
Seeded				
TF	5	20.2 ± 9.83	1.740 ± 0.672	8.98 ± 5.78
SF	4	13.8 ± 7.37	1.353 ± 0.607	8.45 ± 2.39
PF	0	-	-	-
Combined Zones	9	17.3 ± 8.96	1.568 ± 0.637	8.75 ± 4.35
Seeded, Donor Soil Transplant				
TF	0	-	-	-
SF	1	30.0	2.598	19.10
PF	1	2.0	0.149	4.00
Combined Zones	2	16.0 ± 19.80	1.370 ± 1.73	11.6 ± 10.68
Transplant				
TF	1	5.0	0.864	4.68
SF	0	-	-	-
PF	1	8.0	0.840	8.57
Combined Zones	2	6.5 ± 2.12	0.852 ± 0.017	6.63 ± 2.75

none in combined Seeded, Donor Soil, and Transplant treatments (S-DS-T), to 16% for Transplant (T) and 17% for Naturally Colonized (NC) treatments.

Treatment Success by Zone

Temporarily Flooded (TF)

Neither mean species diversity (*S*, *H′*) nor the FQI differed significantly among treatments in the temporarily flooded zone ($P \leq 0.05$ Kruskall-Wallis test), although some consistent trends were observed. For example, the average diversity and average FQI values were highest with seeding treatments (*S* = 20.2, *H′* = 1.74, FQI = 8.99) (Table 5). The second most successful technique, based on diversity indices, was the use of donor soil (*S* = 12.5, *H′* = 1.438). Based on the FQA, however, the second most successful technique occurred with natural colonization and seeding (NC-S) (FQI = 7.2). The least successful technique was the use of transplants (T), based on species diversity (*S* = 5.0, *H′* = 0.864), and natural colonization (NC), based on the FQA (FQI = 3.61).

The percent of non-native species for all species ranged from 11% in the naturally colonized-seeded treatment to 40% with transplanting. However, when considering only those species present in more than trace amounts (i.e. > 5% cover), the %NNS ranged from 6% with seeding to 20% with transplanting (Table 6).

Seasonally Flooded (SF)

Neither mean species diversity (*S, H′*) nor the FQI differed significantly among treatments ($P \leq 0.05$ Kruskall Wallace test) in the seasonally flooded zone, although, as

Table 6. Average percent of non-native species (%NNS) by treatment and hydrologic zone. *n* = the number of individual plots from which mean values were calculated. PF = Permanently Flooded, SF = Seasonally Flooded, TF = Temporarily Flooded. "-" = No Data.

Treatment	n	All Non-native Species (%)	Non-native Species with > 5% Cover (%)
Donor Soil			
TF	2	31.5 ± 7.1	15.0 ± 7.1
SF	2	11.0 ± 16.0	5.5 ± 8.0
PF	1	15.0	15.0
Combined Zones	5	20.0 ± 13.0	11.2 ± 7.4
Donor Soil/Seeded			
TF	-	-	-
SF	2	20.5 ± 12.0	9.0 ± 13.0
PF	-	-	-
Combined Zones	2	20.5 ± 12.0	9.0 ± 13.0
Naturally Colonized			
TF	4	36.5 ± 12.0	16.0 ± 8.6
SF	2	28.0 ± 14.0	28.0 ± 7.1
PF	2	29.0 ± 5.7	8.5 ± 12.0
Combined Zones	8	33.4 ± 10.0	17.1 ± 10.0
Naturally Colonize/Seeded			
TF	1	11.0	11.0
SF	1	36.0	14.0
PF	-	-	-
Combined Zones	2	23.5 ± 17.0	12.5 ± 2.1
Seeded			
TF	5	21.6 ± 7.9	6.2 ± 7.0
SF	4	16.2 ± 4.9	13.3 ± 6.8
PF	-	-	-
Combined Zones	9	20.0 ± 7.1	9.3 ± 7.0
Seeded/Donor Soil/Transplant			
TF	-	-	-
SF	1	23.0	0.0
PF	1	50.0	0.0
Combined Zones	2	36.5 ± 19.0	0.0 ± 0
Transplant			
TF	1	40.0	20.0
SF	-	-	-
PF	1	38.0	13.0
Combined Zones	2	39.0 ± 1.4	16.5 ± 4.9

with other zones, some consistent trends are worth noting. For example, average diversity and average FQI values were highest with combined seeding, donor soil addition, and transplanting (S-DS-T) treatments ($S = 30.0$, $H' = 2.598$, FQI = 19.1). Based on the Shannon-Wiener Index, the second most successful technique was the use of combined natural colonization and seeding (NC-S) ($H' = 1.783$). However, based on both Species Richness and the FQI, the second most successful treatment was the use of donor soil and seeding treatments (DS-S) ($S = 17$, FQI = 12.15). The least successful treatment in the SF zone, by all measures, was the use of donor soil (DS) ($S = 6.5$, $H' = 0.359$, FQI = 4.52).

The greatest percent of non-native species occurred with the naturally colonized-seeded treatment (NC-S). Specifically, the percent of non-native species ranged from 11% in the donor soil treatment to 36% with naturally colonized-seeded, although, when considering only those species present in more than trace amounts (i.e. > 5% cover), none were found in this amount in the combined seeded, donor soil and transplant (S-DS-T) treatment to 28% for natural colonization (NC) (Table 6).

Permanently Flooded (PF)

The small number of replicates for this zone did not support statistical analysis for diversity comparisons among treatments, although there were consistent trends. For example, the highest diversity and highest FQI values were observed with the use of donor soil (DS) ($S = 13$, $H' = 1.191$, FQI = 9.6), and the second highest occurring with transplanting (T) ($H' = 0.84$, $S = 8$, FQI = 8.6) (Table 5).

The least successful method for all parameters calculated occurred with the combined use of seeding, donor soil addition and transplanting (S-DS-T) ($S = 2.0$, $H' = 0.149$, FQI = 4.0).

The percent of non-native species ranged from 15% in the donor soil treatment (DS) to 50% with combining seeding with use of donor soil and transplants (S-DS-T), although, when considering only those species present in more than trace amounts (i.e. > 5% cover), the range was from none in this cover category with combined seeded, donor soil and transplant treatment to 13% for the transplant treatment (Table 6).

Introduced Species Establishment

Although all sites were open to some degree of natural immigration of disseminules, lists of species specifically seeded or transplanted to a site were available for six of the twelve sites using active vegetation treatments (Table 1, Appendix Table 10).

Of these six, five sites were seeded (S) and one was a transplant (T). In the seeding treatments (n = 5), an average of 46% and in the transplant treatment (n = 1) an average of 31% of the species initially introduced to the site were identified in the post-construction evaluation (Table 7). A range of 5-22% of the total species richness at seeded sites and 42% at the transplant site could be attributed to these successfully introduced species.

Table 7. Success of species seeded or planted at sites. S = Seeded, T = Transplant (Appendix Table 10)

Site	Treatment	No. of Species Seeded	No. of Species Established	Contribution to Species Rich. (%)
1	S	6	1	22
12	S	9	6	27
34	S	7	4	34
35	S	8	4	24
37	S	8	3	27
45	T	16	5	12

DISCUSSION

Treatment Effects

Neither total diversity (*S*, H') nor the Floristic Quality Index (FQI) of created mitigation wetlands differed significantly among wetland vegetation establishment techniques, whether considered by site or by hydrologic zone. This result may be a consequence of many variables including (1) the distance to and quality of the nearest seed sources, (2) differences in seedbed preparation, soil material, timing of plantings, climate conditions, or quality and viability of seed, and (3) differences in the quality or storage of donor soil. While not significant, differences among treatments hint at possible considerations, beyond cost, that may prove useful in future wetland creation efforts.

Seeding Treatment

In general, incorporating seed, either alone or in combination with other treatments, resulted in the most diverse wetland creations in the temporarily flooded and seasonally flooded zones, although these results varied somewhat.

For example, in the temporarily flooded zone, seeded sites had both the highest diversity ($S = 20.2$, $H' = 1.74$) and highest FQI (FQI = 8.98) although, in the seasonally flooded zone, the highest diversity occurred when seeding was combined with donor soil addition and transplanting ($S = 30.0$, $H' = 2.60$, FQI = 19.1) (Table 5). These conclusions generally agree with those of Reinartz and Warne (1993) who found early introduction of wetland seed, an active method, appeared to encourage short-term diversity of wetlands when compared to naturally colonized wetlands, a passive method. Results also agree with Hoag et al. (2001) and Milner (2003) who recommended seeding with transplanting for best success.

In contrast, however, seeding appears less successful at establishing diversity in permanently flooded areas ($S = 2.0$, $H' = 1.49$, FQI = 4), a result consistent with observations by Hammer (1992) and Kent (1994). In my study, however, seeding was only used at one permanently flooded zone and there it was used in combination with the addition of donor soil and transplanting. The result was the least diverse plant community among those evaluated.

Transplant Treatment

Previous studies suggest that transplanting is the most effective vegetation establishment technique (Hammer 1992, Kent 1994, Hoag et al. 2001). For example, the National Academy of Sciences (2001) included similar recommendations on specific treatments based on their research on created wetlands. Based on these findings, they recommended transplanting for wetland creation, although only after native recruitment via dispersal was found to be ineffective. Results from the present study, however, are less conclusive. Transplants generally resulted in diverse wetlands in the permanently flooded zone, where it had the second highest diversity ($S = 8.0$, $H' = 0.84$) and FQI rating (FQI = 8.57) (Table 5). This is consistent with findings of Hammer (1992), Kent (1994), and Hoag et al. (2001). Transplants alone were not used in seasonally flooded zone sites but, when combined with the addition of donor soil and seeding, the result was the highest diversity ($S = 30.0$, $H' = 2.59$) and FQI rating (FQI = 19.10) for this zone. Combining seeding with transplanting, although without donor soil addition, also was recommended by Hoag et al. (2001) and Milner (2003) in seasonally flooded zones. However, transplants alone were the least successful treatment in establishing diverse stands in the temporarily flooded zone ($S = 5.0$, $H' = 0.86$, FQI = 4.68).

Donor Soil Treatment

Donor soil treatment alone was most successful in establishing a diverse plant community in the permanently flooded zone ($S = 13.0$, $H' = 1.19$, FQI = 9.62) (Table 5) and was reasonably successful in the temporarily flooded zone ($S = 12.5$, $H' = 1.43$, FQI = 5.59). In contrast, however, donor soils alone were the least successful when establishing a diverse wetland in the seasonally flooded zone, a result that differs from that reported by Kent (1994).

Some differences between these studies may explain the different results obtained. For example, in the study by Kent, at least 20-25 cm of soil and plants were immediately transported to the seasonally flooded zone and flooded.

In the present study, however, neither the depth of donor soil addition or whether the site was then immediately flooded were known. In addition, there is no indication of how long the donor soil was stockpiled. If stored too long, seeds and propagules may have become less viable.

While as a single treatment, donor soil addition was not considered successful for the seasonally flooded zone, although opposite results were obtained when combined with seeding and transplanting. For example, this combined treatment resulted in the highest diversity recorded for the seasonally flooded zone ($S = 30$, $H' = 2.60$) and FQI (19.1), a result that generally agrees with treatment effects recorded by Kent (1994), Dunn and Best (1983), Erwin et al. (1985), Vivian-Smith and Handel (1996), Brown and Bedford (1997), Stauffer and Brooks (1997) and Dawe et al. (2000).

Natural Colonization

Except for one site (Site 17), natural colonization alone resulted in diversity and FQI values that were among the lowest recorded in any of the zones, from temporarily flooded ($S = 10.5$, $H' = 0.98$, FQI = 3.61), to seasonally flooded ($S = 9.5$, $H' = 1.31$ FQI = 7.29), to permanently flooded ($S = 5.0$, $H' = 0.36$, FQI = 6.00) (Table 5). Low diversity with natural colonization contradicts studies by Frenkel and Moran (1991), Tilton (1991), Noon (1995), Mitsch et al. (1998) and Dawe et al. (2000), all of which suggest the procedure is equivalent or superior to active methods.

Variables that may affect the success of natural colonization, and thus may account for these differences among studies, include distance of wetland seed sources from the site of the wetland creation and the quality or quantity of seed available at the donor site.

Species Effects

Introduced Species Establishment

Little information is available in the literature about the survival of species introduced to a created wetland. Most references, however, indicate that transplants of individual species are more successful than seeding of the same species, especially in zones flooded for long durations (Hoag et al. 2001 and Milner 2003). For example, a general rule of thumb is to expect less than one-half of the species added by seeding to establish (Personal communication, Prairie Moon Nursery). Results from the present study generally agree with this estimate since with only 46% (n = 5) of the seeded species were present three years after establishment with these species accounting for only 13% of the total species richness (Table 7). No similar rule of thumb has been reported for transplants, although this study suggests a similar result since only 31% (n = 1) of the transplanted species initially introduced were present at the study site three years after introduction, contributing 42% of total species richness. While these may be considered low rates of establishment, seeding treatments resulted in a higher average diversity and average FQI value ($S = 17$, $H' = 1.57$, FQI = 8.75) than sites that relied exclusively on natural colonization ($S = 8.9$, $H' = 0.91$, FQI = 5.13) (Appendix Tables 2-9).

As for the present study, results of introducing species by transplanting were less conclusive. Transplanting did not result in higher diversity (*S* = 6.5, *H′* = 0.85) than was recorded in sites naturally colonized. It did, however, result in a higher average FQI value (FQI = 6.63).

Non-native Species Establishment

Non-native species were ubiquitous, averaging 26% of all species found in study plots (*n* = 30), although those species with a canopy cover > 5% averaged only 12% (Table 6, Appendix Tables 2-9). This overall percent of non-native species is higher than the 17% reported by Balcombe et al. (2005) at wetland mitigation sites in West Virginia, and the 19% reported by Spieles (2005) at wetland mitigation sites around the country, but lower than the 50% reported by Magee et al. (1999) in Oregon. Numerous temporal and spatial variables probably account for these differences.

Seeded, donor soil, and donor soil-seeded treatments were characterized by the lowest proportion of non-native species (20 - 20.5%) (Table 6). Seeded and donor soil-seeded treatments also recorded the highest diversity (*S* = 17.3 and 17.0, *H′* = 1.568 and 1.489, respectively) and FQI (FQI = 8.75 and 12.2, respectively) (Table 5) suggesting that rapid establishment of a native species community may inhibit non-native species establishment. Treatments with the highest proportion of non-native species in the present study were transplants (39%), followed by combined seeded-donor soil-transplant treatments (36%), and the naturally colonized treatment (33%).

Characteristic Species Establishment by Zone

Species of the Temporarily Flooded Zone. --: *Phalaris arundinacea* was the most frequent species in the temporarily flooded zone occurring in 69% of the plots (mean canopy cover = 37%) followed by *Ambrosia artemisiifolia* (62% occurrence in plots; mean canopy cover 2%) (Table 2, Appendix Tables 2-9). The native *P. arundinacea*, collected in Nebraska in the late 1800's, is believed to have been replaced by a variety of that species derived from vigorous alien cultivars (Merigliano and Lesica, 1998). The extant *P. arundinacea* (*C*-value = 0) is considered an aggressive, non-native species that dominates many wetland plant communities across the U.S. (Fennessy et al. 1994, Galatowitsch et al. 1999, Maurer et al. 2003). Its dominance has been attributed to tolerance of a wide range of environmental conditions, including increased nutrient loads and the species ability to colonize waste ground and areas with altered hydrology (Galatowitsch et al. 1999). In addition, the invasiveness of *P. arundinacea* as a non-native is facilitated by biological characteristics such as clonal growth, long growing period, high allocation of resources to production, and rapid growth (Maurer et al. 2003).

A. artemisiifolia (*C*-value = 0) is a native, annual forb distributed throughout North America (USDA NRCS 2008). This plant is considered a weed in the Great Plains, although, fruits are consumed by upland game birds, some songbirds and mammals (Stubbendieck et al. 1994). While not characterized as a wetland plant by Reed (1998), *A. artemisiifolia* is common in dry or moist sites, especially in disturbed places (Stubbendieck et al. 1994). Temporarily flooded wetlands provide this type of environment, especially when they remain dry for weeks or months.

Species of the Seasonally Flooded Zone.--: *Typha angustifolia* was the most frequent species in the seasonally flooded zone occurring in 75% of the plots (mean canopy cover = 36%) (Table 3, Appendix Tables 2-9). The second most frequent species in the SF zone was shared among *P. arundinacea*, *Scirpus atrovirens* and *Cyperus esculentus,* all with 58% frequency and with mean canopy covers of 13%, 9% and 6%, respectively. *T. angustifolia* (*C*-value = *) is generally considered an aggressive plant that is not native to Nebraska but that dominates many wetland plant communities in Nebraska and across the U.S. (Odum 1988; as cited by D'Avanzo 1990, Fennessy et al. 1994, Galatowitsch et al. 1999, and Balcombe et al. 2005). Its dominance has been attributed to tolerance of a wide range of environmental conditions, including increased nutrient loads and its ability to colonize waste ground areas and areas with altered hydrologic conditions (Galatowitsch et al. 1999).

Scirpus atrovirens (*C*-value = 5) is a native perennial wetland sedge species found throughout the U.S. (USDA NRCS, 2008). Similarly, *Cyperus esculentus* (*C*-value = 0) is a native, perennial species found along streams and lakes and in meadows and lawns throughout the U.S. (USDA NRCS, 2008). *C. esculentus* is considered one of the most common, aggressive and difficult to control ruderal species in the Great Plains, but is an important food for waterfowl, muskrats, other rodents, deer, and wild turkey (Stubbendieck et al. 1994).

Species of the Permanently Flooded Zone.-- *Typha angustifolia* and *Schoenoplectus tabernaemontani* were the most frequent species in the permanently flooded zone, both with 80% occurrence in plots, although the canopy cover of *T. angustifolia* was substantially higher than that of *S. tabernaemontani* (mean canopy cover = 52% and 1%, respectively) (Table 4, Appendix Tables 2-9). *S. tabernaemontani* (*C*-value = 5) is a native, obligate wetland bulrush species distributed throughout North America. It grows in marshes, along lake and stream shores and in wet meadows where it provides important cover for waterfowl and seeds that are a food source for waterfowl (Snyder 1993). *Eleocharis palustris* and *Echinochloa crusgalli* were the second most frequent species in the PF zone (40% occurrence in plots; mean canopy cover 1% and 8%, respectively). *E. palustris* (*C*-value = 4) is a native, perennial, obligate wetland spike rush species found throughout the U.S. This species provides both a food source and cover for wildlife while also serving to control erosion in wetland creation and restoration (Roemer and Schultes 2005). *E. crusgalli* (*C*-value = *) is a non-native, annual, ruderal grass species often found in disturbed wet sites, fields and waste places. Seeds of this species are an important food source for waterfowl and are also eaten by upland game birds and songbirds (Stubbendieck et al. 2003).

CONCLUSION

While limited to one region and to created-wetland sites with somewhat different histories, this study found no significant differences among vegetation establishment treatments, whether active (donor soil, seeded or transplant, alone or in combinations) or passive (natural colonization). Therefore, other factors, such as cost and effort required should be equally as important in determining the most effective means by which to establish diverse, high quality vegetation, for example at wetland mitigation sites.

While differences among treatments were not significant, trends observed in the current study may prove helpful in wetland creation efforts until more controlled studies are conducted. General trends observed, however, differ, depending on the vegetation or hydrologic zone of interest. For example, seeding resulted in the highest diversity and FQI value in the temporarily flooded zone, while a combination of seeding, donor soil addition and transplanting had the highest diversity and FQI in the seasonally flooded zone. In the permanently flooded zone, however, the greatest diversity and FQI were recorded with donor soil addition, although transplanting was a close second. While not the intent of this study, it is also important to note that diversity (S, H') and the FQI did not consistently give the same results thus care must be taken to ensure selecting the index that most closely meets study objectives. In combination, this study provides preliminary guidance that should prove useful in wetland creation until more rigorous studies can provide more definitive information. Importantly, this study also provides a database against which future assessments of the study sites may be compared.

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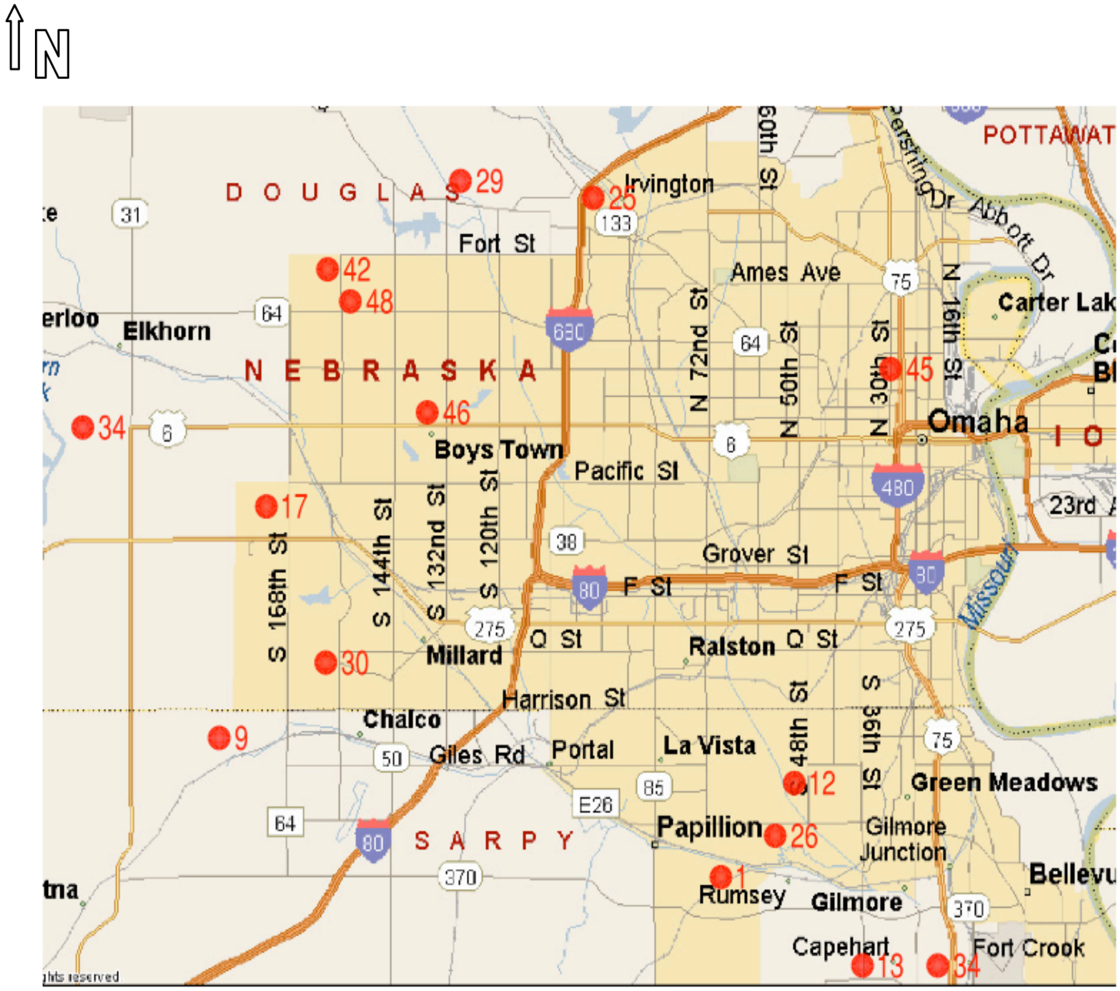
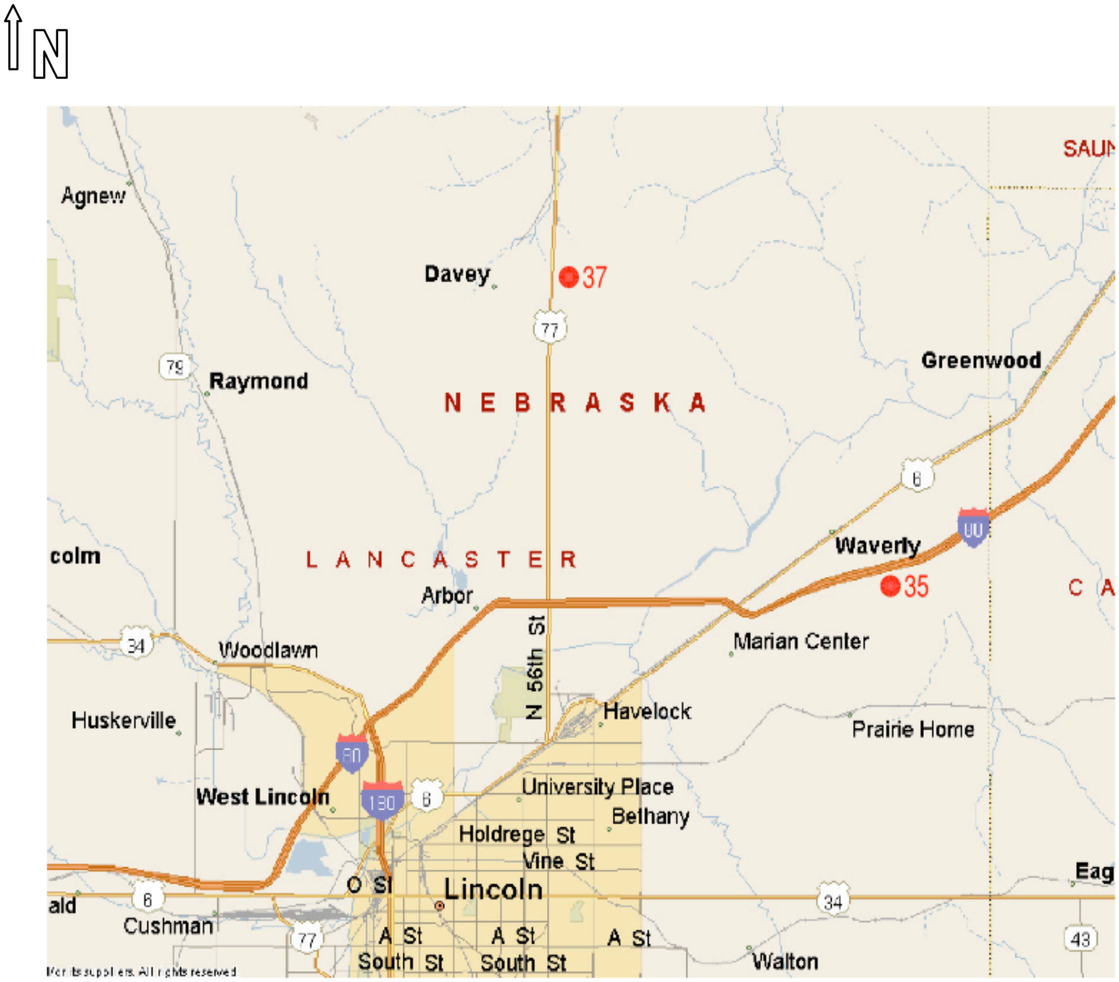
APPENDIX



Appendix Fig. 1. Approximate locations of study sites in Douglas and Sarpy Counties. Sites are depicted by dots with corresponding site number.



Appendix Fig. 2. Approximate locations of wetland mitigation sites in Lancaster County. Sites are depicted by dots with corresponding site number.

Appendix Table 1. GPS coordinates for sample plots at each site. Unless otherwise indicated coordinates were recorded at the end of each plot. Accuracy +/- 3 meters. - = No Data.

Site	Plot	Latitude	Longitude	Latitude	Longitude
1	Plot 1	41.1496167	96.0021833	41.1499333	96.0014667
9	Plot 1**	41.1842333	96.1906667	-	-
12	Plot 1	41.1795333	95.9956167	41.1796333	95.9970667
	Plot 2	41.1791833	95.9948500	41.1792500	95.9958500
13	Plot 1	41.1101667	95.9331667	41.1109500	95.9338167
15	Plot 1	41.1041833	95.9700333	41.1043667	95.9698667
17	Plot 1	41.2407667	96.1848833	-	-
	Plot 2	-	-	-	-
	Plot 3*	-	-	-	-
25	Plot 1	41.3185833	96.0683000	41.3189167	96.0683667
26	Plot 1	41.1551167	95.9925000	41.1555833	95.9921333
	Plot 2	41.1549500	95.9912333	41.1552167	95.9910167
29	Plot 1	41.3255333	96.1174333	41.3260333	96.1181500
	Plot 2*	41.3260500	96.1181667	41.3264667	96.1182333
	Plot 3**	41.3257167	96.1177167	41.3257167	96.1177167
	Plot 3**	41.325717	96.117717	-	-
30	Plot 1	41.2002667	96.1688000	41.2007833	96.1688167
	Plot 2	41.1994333	96.1689000	41.2001667	96.1688833

Appendix Table 1 (cont.). GPS coordinates for sample plots at each site. Unless otherwise indicated coordinates were recorded at the end of each plot. Accuracy +/- 3 meters. - = No Data.

Site	Plot	Latitude	Longitude	Latitude	Longitude
34	Plot 1**	41.2583667	96.2834500	41.2587000	96.2843000
	Plot 1**	-	-	-	-
	Plot 2**	41.2568000	96.2877667	41.2575333	96.2882500
	Plot 2**	41.25680	96.28777	41.257533	96.288250
35	Plot 1	40.8932333	96.5689000	40.8932833	96.5700000
	Plot 2**	40.8927833	96.5675667	40.8931500	96.5684500
	Plot 2**	40.8925167	96.5678167	40.8928333	96.5681333
37	Plot 1**	41.0179167	96.6401500	41.0187000	96.6401500
	Plot 1**	41.0224333	96.6383667	41.0224500	96.6395000
	Plot 2	41.0215333	96.6380333	41.0219167	96.6383167
42	Plot 1	41.3030500	96.1620667	41.3031167	96.1627000
45	Plot 1	-	-	-	-
	Plot 2	41.2852167	95.9655500	41.2856500	95.9654667
46	Plot 1**	41.2697167	96.1300500	41.2701000	96.1302500
	Plot 1**	41.2695833	96.1182000		
48	Plot 1	41.3003167	96.1565167	41.3012000	96.1566000
	Plot 1***	41.3004500	96.1564833	-	-

* = 50m x 6m plot, ** Plot less than 100 m combined with another plot less than 100m to create 1-100m plot, *** Mid-point of irregular shaped plot.

Appendix Table 2. Species canopy cover (%) and plot data by zone and site for Naturally Colonized Sites 17 and 25. PF = Permanently Flooded, TF = Temporarily Flooded, SF = Seasonally Flooded. *C* = Coefficient of Conservatism. * = *Coefficient of Conservatism* designation for non-native species, ** = Non-native species. Decimals are used instead of zeroes for visual clarity. A higher FQI indicates a more desirable habitat.

		Site No. 17			Site No. 25
Species	*C*	Plot 1 (PF)	Plot 2 (TF)	Plot 3 (SF)	Plot 1 (SF)
Species Richness		6	19	3	6
Sum of *C*		14.0	26.0	32.0	10.0
C mean w/ only natives		3.5	2.2	3.2	2.0
C Mean w/ all species		2.3	1.4	2.5	1.7
FQI		7.0	7.6	10.1	4.47
Non-Native Species (%)		33.3	36.8	23.1	16.7
Species:					
Ambrosia artemisiifolia	0	.	3.0	.	.
Bidens cernua	3	15.0	.	.	.
Cyperus esculentus	0	.	.	0.5	.
*Echinochloa crusgalli***	*	3.0	37.5	85.0	.
Equisetum hyemale	4	.	0.5	3.0	.
Erigeron annuus	1	0.5	.	.	.
Erigeron strigosus	2	.	15.0	.	.
*Festuca arundinacea***	*	.	3.0	.	.
Hordeum jubatum	1	.	3.0	.	.
Juncus acuminatus		.	.	3.0	.
Juncus interior	4	.	.	0.5	.
Leersia oryzoides	4	.	37.5	.	.
Mimulus ringens	6	.	.	3.0	.
Oenothera sp.	1	.	.	0.5	.
Panicum sp.	0	.	0.5	.	.
*Phalaris arundinacea***	0	.	.	.	15.0
*Polygonum persicaria***	*	.	0.5	.	.
Polygonum sp.	0	.	3.0	.	0.5
Populus deltoides	3	.	0.5	0.5	.
*Rumex crispus***	*	.	3.0	.	.
Salix amygdaloides	4	.	37.5	15.0	.
Salix exigua	3	.	15.0	.	.
Schoenoplectus tabernaemontani	5	0.5	0.5	3.0	37.5
Scirpus atrovirens	5	0.5	.	15.0	3.0
*Sonchus asper***	*	.	0.5	15.0	.
Symphyotrichum sp.	0	.	0.5	.	0.5
*Taraxacum officinale***	*	.	0.5	.	.
*Typha angustifolia***	*	85.0	0.5	62.5	85.0

Appendix Table 3. Species and plot data by zone and site for Naturally Colonized Sites 42, 46, 48 and 15. PF = Permanently Flooded, TF = Temporarily Flooded, SF = Seasonally Flooded. *C* = Coefficient of Conservatism. * = *Coefficient of Conservatism* designation for non-native species, ** = Non-native species. Decimals are used instead of zeroes for visual clarity. A higher FQI indicates a more desirable habitat.

Species	*C*	Site No. 42 Plot 1 (TF)	Site No. 46 Plot 1 (PF)	Site No. 48 Plot 1 (TF)	Site No. 15 Plot 1 (TF)
Species Richness		14	4	4	5
Sum *C*		17.0	10.0	0.0	4.0
C mean w/ only natives					
C Mean w/ all species		1.4	2.5	0.0	1.0
FQI		1.2	2.5	0.0	0.8
Non-native Species (%)		4.85	5	0	2
Species:					
Ambrosia artemisiifolia	0	3.0	.	0.5	.
Ambrosia trifida	0	15.0	.	.	.
Bidens vulgata	1	0.5	.	.	.
*Bromus japonicus***	*	15.0	.	.	.
Calystegia sepium	1	.	.	.	0.5
Conzya canadensis	0	0.5	.	.	.
Helianthus annuus	0	0.5	.	0.5	.
Juncus torreyi	4	0.5	.	.	.
Leersia oryzoides	4	.	0.5	.	.
*Medicago lupulina***	*	0.5	.	.	.
Oenothera sp.	1	3.0	.	.	.
*Phalaris arundinacea***	0	62.5	0.5	85.0	85.0
Polygonum coccineum	2	0.5	.	.	15.0
*Rumex crispus***	*	.	.	.	0.5
Schoenoplectus tabernaemontani	5	.	0.5	.	.
Scirpus atrovirens	5	0.5	.	.	.
*Setaria pumila***	*	.	.	0.5	.
Symphyotrichum sp.	0	0.5	.	.	.
Typha latifolia	1	.	97.0	.	.
Urtica dioica	1	.	.	.	0.5
Verbena hastata	4	0.5	.	.	.

Appendix Table 4. Species canopy cover (%) and plot data by zone and site for Seeded Sites 30, 1 and 12. TF = Temporarily Flooded, SF = Seasonally Flooded. *C* = Coefficient of Conservatism. * = *Coefficient of Conservatism* designation for non-native species, ** = Non-native species. Decimals are used instead of zeroes for visual clarity. A higher FQI indicates a more desirable habitat.

Species	*C*	Site No. 30		Site No. 1	Site No. 12	
		Plot 1 (SF)	Plot 2 (TF)	Plot 1 (TF)	Plot 1 (SF)	Plot 2 (TF)
Species Richness		14	9	22	17	17
Sum *C*		21.0	22.0	48.0	32.0	26.0
C mean w/ natives		2.1	2.4	2.7	2.3	1.9
C mean w/all species		1.4	2.4	2.2	1.9	1.5
FQI		6.64	7.2	11.5	8.6	7.1
Non-native Species (%)		33.3	0.0	18.2	17.6	17.6
Species:						
Amaranthus tuberculatus	0	.	.	0.5	.	.
Ambrosia artemisiifolia	0	3.0	3.0	0.5	.	0.5
Apocynum cannabinum	2	.	.	.	15.0	62.5
Asclepias incarnata	4	.	.	.	0.5	.
Asclepias speciosa	1	.	.	.	0.5	0.5
Asclepias verticillata	3	.	.	.	.	0.5
Bidens cernua	3	.	.	0.5	.	.
Calystegia sepium	1	.	.	.	.	15.0
Carex sp.	2	3.0	.	0.5	.	0.5
Carex vulpinoidea	4	0.5	.	.	.	.
Cirsium sp.	1	.	.	0.5	.	.
Conzya canadensis	0	.	.	0.5	.	.
Cyperus esculentus	0	0.5	.	.	0.5	.
*Echinochloa crusgalli***	*	3.0	.	3.0	0.5	0.5
Eleocharis palustris	4	.	.	.	0.5	.
Erigeron sp.	3	.	.	0.5	.	.
Erigeron strigosus	2	.	3.0	.	.	.
Eupatorium rugosum	4	.	-	0.5	.	.
Geum canadense	3	.	0.5	.	.	.
Helianthus tuberosus	4	.	.	.	0.5	.
Juncus sp.	3	0.5	.	.	.	.
Leersia oryzoides	4	.	.	37.5	.	.
Lycopus americanus	4	.	.	0.5	0.5	.
Mimulus ringens	6	.	.	0.5	.	.
Oenothera biennis	1	.	15.0	.	0.5	.
Panicum sp.	0	.	.	.	.	0.5
Panicum virgatum	4	.	.	.	.	0.5
*Phalaris arundinacea***	0	37.5	85.0	62.5	15.0	3.0

Appendix Table 4 (cont.). Species canopy cover (%) and plot data by zone and site for Seeded Sites 30, 1 and 12. TF = Temporarily Flooded, SF = Seasonally Flooded. *C* = Coefficient of Conservatism. * = *Coefficient of Conservatism* designation for non-native species, ** = Non-native species. Decimals are used instead of zeroes for visual clarity. A higher FQI indicates a more desirable habitat.

		Site No. 30		Site No. 1	Site No. 12	
Species	*C*	Plot 1 (SF)	Plot 2 (TF)	Plot 1 (TF)	Plot 1 (SF)	Plot 2 (TF)
Species (continued):						
*Poa pratenis***	*	15.0	.	.	.	.
*Polygonum cespitosum***	*	.	.	0.5	.	.
Polygonum coccineum	2	.	.	.	37.5	3.0
Polygonum lapathifolium	2	3.0	.	.	.	.
Polygonum pensylvanicu.	0	.	.	.	3.0	.
*Polygonum persicaria***	*	3.0	.	.	.	0.5
Polygonum punctatum	4	.	.	37.5	.	.
Polygonum sp.	0	.	.	0.5	.	.
Populus deltoides	3	.	.	.	.	0.5
*Rumex crispus***	*	0.5	.	.	0.5	0.5
Salix amygdaloides	4	.	.	.	.	0.5
Scirpus atrovirens	5	37.5	3.0	0.5	37.5	.
Scutellaria lateriflora	5	.	.	0.5	.	.
*Setaria faberi***	*	.	.	0.5	.	.
Solidago canadensis	2	.	.	.	.	37.5
Solidago gigantea	3	.	0.5	3.0	15.0	.
Symphyotrichum lanceol.	2	.	.	.	0.5	3.0
Symphyotrichum novae-.	4	0.5	15.0	.	.	.
*Typha angustifolia***	*	.	.	3.0	0.5	.
Typha latifolia	1	37.5	.	.	.	.
Verbena hastata	4	.	3.0	0.5	.	.

Appendix Table 5. Species canopy cover (%) and plot data by zone and site for Seeded Sites 34, 35 and 37. TF = Temporarily Flooded, SF = Seasonally Flooded. *C* = Coefficient of Conservatism. * = *Coefficient of Conservatism* designation for non-native species, ** = Non-native species. Decimals are used instead of zeroes for visual clarity. A higher FQI indicates a more desirable habitat.

		Site No. 34		Site No. 35		Site No. 37	
Species	*C*	Plot 1 (SF)	Plot 2 (TF)	Plot 1 (SF)	Plot 2 (TF)	Plot 1 (SF)	Plot 2 (TF)
Species Richness		5	33	11	23	22	6
Sum *C*		16.0	83.0	18.0	34.0	46.0	0.0
C mean w/ natives		4.0	3.1	1.8	2.3	2.5	0.2
C mean w/all species		3.2	2.7	1.6	2.0	2.4	0.17
FQI		8.0	16.1	5.7	9.8	11.5	0.45
Non-native Species (%)		20.0	13.0	9.1	14.3	5.0	17.0
Species:							
Acalypha rhomboidea	0	.	.	.	.	0.5	.
Amaranthus tuberculatus	0	.	.	.	.	.	62.5
Ambrosia artemisiifolia	0	.	15.0	.	.	.	.
Apocynum cannabinum	2	.	.	0.5	0.5	.	.
Asclepias incarnata	4	.	0.5	.	.	.	.
Bidens sp.	1	.	0.5	.	.	.	.
Calystegia sepium	1	.	.	.	.	0.5	.
Carex sp.	2	.	.	15.0	3.0	0.5	.
Cassia chamaecrista	1	.	.	.	.	3.0	.
Coreopsis tinctoria	1	.	0.5	.	15.0	.	.
Cyperus esculentus	0	.	3.0	**	.	.	3.0
*Duchesnea indica***	*	.	3.0	.	.	.	.
*Echinochloa crusgalli***	*	.	0.5	.	.	.	62.5
Echinodorus berteroi	6	0.5	3.0	.	.	.	.
Eleocharis acicularis	4	.	**	.	.	.	.
Eleocharis palustris	4	.	37.5	3.0	0.5	3.0	.
Erigeron strigosus	2	.	0.5	.	.	.	.
Unknown Forb		.	0.5	.	0.5	.	.
Unknown Forb 2		.	0.5	.	.	.	.
Glycyrrhiza lepidota	4	.	0.5	.	.	.	.
Helianthus sp.	3	.	.	.	0.5	.	.
Juncus interior	4	.	0.5	.	.	.	.
Juncus nodusus	6	.	15.0	.	.	.	.
Juncus sp.	3	.	.	.	0.5	.	.
Juncus torreyi	4	.	15.0	.	.	0.5	.
Leersia oryzoides	4	.	0.5	.	.	15.0	.
Lippia sp.	3	.	15.0	.	.	.	.

Appendix Table 5 (cont.). Species canopy cover (%) and plot data by zone and site for Seeded Sites 34, 35 and 37 (cont.). TF = Temporarily Flooded, SF = Seasonally Flooded. *C* = Coefficient of Conservatism. * = *Coefficient of Conservatism* designation for non-native species, ** = Non-native species. Decimals are used instead of zeroes for visual clarity. † = species with no cover value. A higher FQI indicates a more desirable habitat.

Species	*C*	Site No. 34		Site No. 35		Site No. 37	
		Plot 1 (SF)	Plot 2 (TF)	Plot 1 (SF)	Plot 2 (TF)	Plot 1 (SF)	Plot 2 (TF)
Species (continued):							
Lycopus americanus	4	.	3.0	.	0.5	0.5	.
Lycopus sp.	5	.	.	.	.	0.5	.
Mimulus ringens	6	.	.	.	.	0.5	.
Mollugo verticillata	9		.	.	.	0.5	.
*Phalaris arundinacea***	0		.	15.0	37.5	37.5	0.5
*Poa pratensis***	*		.	.	3.0	.	.
Polygonum coccineum	2	.	.	.	0.5	0.5	3.0
Polygonum lapathifolium	2	.	.	3.0	37.5	.	.
Polygonum pensylvanicum	0	.	.	15.0	3.0	.	0.5
Polygonum punctatum	4	.	3.0	.	.	3.0	.
Polygonum sp.	0	.	.	.	.	3.0	.
Polygonum sp. (knotweed)	3	.	.	0.5	15.0	.	.
Populus deltoides	3	.	37.5	.	.	.	.
*Rumex crispus***	*	.	.	.	0.5	.	.
Rumex sp.	0	.	0.5	.	.	0.5	.
Sagittaria sp.	3	0.5	.	0.5	.	†	.
Salix amygdaloides	4	.	15.0	.	0.5	.	.
Salix exigua	3	0.5	0.5	.	3.0	.	.
Schoenoplectus pungens	4	15.0	15.0	.	.	.	.
Scirpus atrovirens	5	.	.	.	.	0.5	.
*Setaria viridis***	*	.	3.0	.	.	.	.
Solidago gigantea	3	.	0.5	.	.	.	.
Spartina pectinata	5	.	.	.	3.0	.	.
Symphyotrichum lanceolat.	2	.	.	.	-	3.0	.
Symphyotrichum novae-ang.	4	.	0.5	.	3.0	0.5	.
Symphyotrichum pilosum	0	.	0.5	.	37.5	.	.
Symphyotrichum sp.	0	.	.	.	15.0	.	.
*Typha angustifolia***	*	97.0	3.0	62.5	15.0	62.5	.
Typha latifolia	1	.	.	.	.	0.5	.
Verbena hastata	4	.	0.5	.	.	.	.
Verbena urticifolia	3	.	†	.	.	.	.
Xanthium strumarium	1	.	.	.	.	.	0.5

Appendix Table 6. Species canopy cover (%) and plot data by zone and site for Transplant Site 45. TF = Temporarily Flooded, PF = Permanently Flooded. *C* = Coefficient of Conservatism. * = *Coefficient of Conservatism* designation for non-native species, ** = Non-native species. Decimals are used instead of zeroes for visual clarity. A higher FQI indicates a more desirable habitat.

Species	*C*	Site No. 45 Plot 1 (TF)	Site No. 45 Plot 2 (PF)
Species Richness		5	8
Sum *C*		8.0	21.0
C mean w/ only natives		2.7	3.5
C mean w/ all species		1.6	2.6
FQI		4.68	8.57
Non-native Species (%)		40	25
Species:			
Alisma plantago-aquatica	4	.	0.5
Bidens connata	3	.	0.5
Eleocharis palustris	4	.	3.0
*Poa pratensis***	*	37.5	.
*Polygonum persicaria***	*	.	3.0
Populus deltoides	3	0.5	.
*Rumex crispus***	*	0.5	.
Sagittaria sp.	3	.	15.0
Schoenoplectus tabernaemontani	5	.	3.0
Solidago gigantea	3	3.0	.
Symphyotrichum lanceolatum	2	15.0	0.5
*Typha angustifolia***	*	.	85.0

Appendix Table 7. Species canopy cover (%) and plot data by zone and site for Donor Soil, Seeded Site 26. SF = Seasonally Flooded. *C* = Coefficient of Conservatism. * = *Coefficient of Conservatism* designation for non-native species, ** = Non-native species. Decimals are used instead of zeroes for visual clarity. A higher FQI indicates a more desirable habitat.

		Site No. 26	Site No. 26
Species	*C*	Plot 1 (SF)	Plot 2 (SF)
Species Richness		17	17
Sum *C*		41.0	49.0
C mean w/ only natives		3.2	3.3
C mean w/ all species		2.4	2.9
FQI		11.54	12.78
Non-native Species (%)		23.5	11.8
Species:			
Ammannia coccinea	4	0.5	.
Bidens sp.	1	.	0.5
Cyperus esculentus	0	62.5	3.0
*Echinochloa crusgalli***	*	15.0	.
Eleocharis palustris	4	3.0	.
Eleocharis sp.	3	0.5	.
Equisetum hyemale	4	15.0	.
Fraxinus pennsylvanica	2	0.5	0.5
Juncus interior	4	.	3.0
Lindernia dubia	5	3.0	.
Lippia sp.	3	3.0	.
Lythrum alatum	6	.	0.5
Mimulus ringens	6	0.5	0.5
*Phalaris arundinacea***	0	37.5	.
Poa pratensis	*	.	0.5
*Polygonum persicaria***	*	3.0	.
Populus deltoides	3	62.5	85.0
Potentilla norvegica	2	.	0.5
*Rumex crispus***	*	3.0	.
Salix amygdaloides	4	0.5	85.0
Salix exigua	3	0.5	0.5
Scirpus atrovirens	5	.	0.5
Solidago canadensis	2	.	0.5
Teucrium canadense	4	.	0.5
*Typha angustifolia***	*	62.5	0.5
Verbena hastata	4	.	0.5
Verbena urticifolia	4	.	0.5

Appendix Table 8. Species canopy cover (%) and plot data by zone and site for Donor Soil Site 13 and 29. PF = Permanently Flooded, TF = Temporarily Flooded, SF = Seasonally Flooded. *C* = Coefficient of Conservatism. * = *Coefficient of Conservatism* designation for non-native species, ** = Non-native species. Decimals are used instead of zeroes for visual clarity. † = species with no cover value. A higher FQI indicates a more desirable habitat.

Species	*C*	Site No. 13		Site No. 29		
		Plot 1 (TF)	Plot 2 (SF)	Plot 1 (SF)	Plot 2 (PF)	Plot 3 (TF)
Species Richness		10	4	9	13	15
Sum *C*		13.0	11.0	9.0	32.0	21.0
C mean w/ only natives		1.6	2.8	1.3	2.9	2.1
C mean w/ all species		1.3	2.8	1.0	2.5	1.4
FQI		4.53	5.6	3.44	9.62	6.65
Non-native Species (%)		20	0	22.2	15.4	33.33
Species:						
*Agrostis stolonifera***	*	.	.	.	.	15.0
Ambrosia artemisiifolia	0	.	.	.	.	0.5
Ambrosia trifida	0	.	.	0.5	.	†
Ammannia coccinea	4	.	.	.	0.5	.
Apocynum cannabinum	2	3.0	.	.	.	.
Bidens sp.	1	.	.	0.5	0.5	0.5
*Bromus tectorum***	*	.	.	.	.	0.5
*Cannabis sativa***	*	0.5	.	.	.	.
Carex sp.	2	.	.	0.5	.	.
Carex vulpinoidea	4	.	0.5	.	.	.
Cyperus acuminatus	3	.	.	.	0.5	.
Cyperus esculentus	0	.	.	3.0	37.5	3.0
*Echinochloa crusgalli**	*	.	.	97.0	37.5	37.5
Eleocharis palustris	4	.	0.5	.	0.5	.
Helianthus annuus	0	0.5	.	.	.	.
Helianthus tuberosus	4	.	.	.	.	†
Lindernia sp.	5	.	.	.	0.5	.
Mimulus ringens	6	.	.	.	.	†
Panicum sp.	0	.	.	.	.	0.5
*Phalaris arundinacea***	0	62.5	.	.	.	.
*Poa pratensis***	*	0.5	.	.	.	15.0
Polygonum coccineum	2	0.5	3.0	.	.	.
Polygonum pensylvanicum	0	.	.	3.0	0.5	.
Populus deltoides	3	.	.	0.5	.	37.5
Rorippa curvipes	3	.	.	3.0	0.5	.
*Rumex crispus***	*	.	.	0.5	.	.
Salix amygdaloides	4	.	.	.	0.5	37.5

Appendix Table 8 (cont.). Species and plot data by zone and site for Donor Soil Site 13 and 29. PF = Permanently Flooded, TF = Temporarily Flooded, SF = Seasonally Flooded. *C* = Coefficient of Conservatism. * = *Coefficient of Conservatism* designation for non-native species, ** = Non-native species. Decimals are used instead of zeroes for visual clarity. A higher FQI indicates a more desirable habitat.

Species	*C*	Site No. 13		Site No. 29		
		Plot 1 (TF)	Plot 2 (SF)	Plot 1 (SF)	Plot 2 (PF)	Plot 3 (TF)
Salix exigua	3	.	.	.	0.5	37.5
Schoenoplectus tabernaem.	5	.	.	.	0.5	.
Solidago gigantea	3	3.0	.	.	.	.
Symphyotrichum lanceolat.	2	0.5	.	.	.	.
Symphyotrichum pilosum	0	15.0	.	.	.	.
*Typha angustifolia***	*	.	.	.	85.0	3.0
Typha latifolia	1	.	97.0	.	.	.
Verbena hastata	4	0.5	.	.	.	.

Appendix Table 9. Species canopy cover (%) and plot data by zone and site for Seeded, Donor Soil/Transplant Site 9. PF = Permanently Flooded, SF = Seasonally Flooded. *C* = Coefficient of Conservatism. * = *Coefficient of Conservatism* designation for non-native species, ** = Non-native species. Decimals are used instead of zeroes for visual clarity. A higher FQI indicates a more desirable habitat.

	Site No. 9		
Species	*C*	Plot 1 (SF)	Plot 2 (PF)
Species Richness		30	2
Sum *C*		92.0	4.0
C mean w/ only natives		4.0	4.0
C mean w/ all species		3.2	2.0
FQI		19.1	4
% Non-native Species (%)		20.7	50
Species:			
*Agrostis stolonifera***	*	0.5	.
Asclepias incarnata	4	0.5	.
Carex comosa	5	3.0	.
Carex frankii	5	0.5	.
Carex lupulina	8	0.5	.
Carex scoparia	5	0.5	.
Carex vulpinoidea	4	3.0	.
Cyperacea	*	3.0	.
*Echinochloa crusgalli***	*	0.5	.
Eupatorium rugosum	4	0.5	.
Forb		0.5	.
Helenium autamnale	6	0.5	.
Juncus tenuis	3	0.5	.
Juncus torreyi	4	0.5	.
Leersia oryzoides	4	15.0	.
Mimulus ringens	6	3.0	.
*Phalaris arundinacea***	*	3.0	.
Polygonum coccineum	2	0.5	.
*Polygonum persicaria***	*	3.0	.
*Rumex crispus***	*	0.5	.
Sagittaria brevirostra	4	.	85.0
Salix amygdaloides	4	15.0	.
Salix exigua	3	3.0	.
Schoenoplectus pungens	4	0.5	.
Scirpus atrovirens	5	15.0	.
Scirpus cyperinus	7	0.5	.
Solidago gigantea	3	0.5	.
Spartina pectinata	5	15.0	.
Symphyotrichum sp.	0	15.0	.
*Typha angustifolia***	*	0.5	3.0
Xanthium strumarium	1	3.0	.

Floristic Quality Index (FQI)

The Floristic Quality Assessment (FQA), by which the Floristic Quality Index (FQI) is calculated, is an evaluation procedure that results in a single number that represents the quality of the evaluated habitat (Swink and Wilhelm, 1994). Habitat quality is based on a score derived from the ecological conservatism of each species found at a site, where ecological conservatism is the *a priori* assignment of the fidelity of a species to a habitat expressed numerically as a *Coefficient of Conservatism* or *C*-value. *C*-values range from 0-10.

Coefficients of Conservatism have been assigned to plant species of various habitats in Nebraska (Rolfsmeier and Steinauer 2003), Missouri (Ladd 1993), Minnesota (Milburn et al. 2007), Michigan (Herman et al. 2001), Illinois (Taft et al. 1997), Indiana (Rothrock 2004), Ohio (Andreas et al. 2004), the Dakotas (The Northern Great Plains Floristic Quality Assessment Panel 2001), Wisconsin (Nichols 1998; Wisconsin Floristic Quality Assessment, 2002), Florida (Cohen et al. 2004), Mississippi (Herman et al. 2006), and Ontario (Oldham et al. 1995). The FQA used in this study has been applied in various ecosystems including restored and natural wetlands in North Dakota (Mushet et al. 2002) and restored native prairies and wetlands in Nebraska (Rolfsmeier and Steinauer 2003). This method is recommended by the USACE-Omaha District to evaluate vegetation quality at wetland mitigation sites (USACE 2005).

Species assigned a value of “0-1” are adapted to severe disturbance and are generally considered ruderal or opportunistic invaders, species assigned a value of “2-3” are associated with more stable, though degraded, habitat and are considered ruderal-competitive species. Species assigned a value of “4-6” have a high consistency of occurrence within a given community type, but persist under moderate disturbance, and species with a value of “7-8” are associated with natural areas but can persist in somewhat degraded areas. Species assigned a value of “9-10” are species exhibiting a high degree of fidelity to a narrow range of synecological parameters (Taft et al. 1997). Non-native species are not assigned a value but are indicated with an asterisk on species lists. *C*-values are used to calculate a Floristic Quality Index (FQI) in each site. The FQI at a site is calculated using the formula: FQI = Mean $C\sqrt{N}$, where Mean *C* = mean *Coefficient of Conservatism* of all species and N =number of species.

Appendix Table 10. Sites with species known to have been introduced during vegetation establishment. These data were not available for all sites.

Species	Site No. 1	Site No. 9	Site No. 12	Site No. 26	Site No. 30	Site No. 34	Site No. 35	Site No. 37	Site No. 45
Acorus sp.		X							
Acorus calamus				X					
Agropyron smithii	X								
Agrostis alba	X								
Alisma plantago-aquatica								X	
Alisma trivale									X
Andropogon gerardii	X				X				
Asclepias incarnata				X					
Bidens frondosa						X	X		
Butomus ambellatus		X							
Ceratophyllum demersum									X
Carex scoparia		X							
Carex sp.					X				
Carex spp.			X						
Carex stipata									
Carex stipata (or *comosa)*					X	X	X		
Carex vulpinoidea						X	X		
Coreopsis tinctoria								X	
Cyperus sp.		X							
Echinochloa crusgalli			X						
Eleocharis spp.									X
Elymus virginicus	X				X				
Eryngium yuccifolium					X				
Glyceria striata			X						
Hibiscus lasiocarpus									X
Iris brevicaulus				X					

Appendix Table 10 (cont.). Sites with species known to have been introduced during vegetation establishment. These data were not available for all sites.

Species	Site No. 1	Site No. 9	Site No. 12	Site No. 26	Site No. 30	Site No. 34	Site No. 35	Site No. 37	Site No. 45
Iris sp.		X							
Iris virginica									X
Lobelia cardinalis									X
Nuphar luteum									X
Nymphaea odorata									X
Panicum virgatum	X								
Phalaris arundinacea	X		X						
Polygonum amphibium								X	
Polygonum hydropiperoides								X	
Polygonum pensylvanicum			X	X		X	X	X	
Pontederia cordata									X
Rosa sp.					X				
Sagittaria latifolia						X	X	X	X
Scirpus sp.		X							
Scirpus acutus									X
Scirpus americanus						X	X		
Scirpus atrovirens			X		X				
Scirpus cyperinus									
Scirpus validus							X		X
Spartina pectinata			X			X	X	X	
Sparganium eurycarpum			X						X
Tripsacum dactyloides								X	
Trollius ledebourii									X
Typha latifolia		X	X						
Vallisneria americana									X
Verbena hastata					X				
Zizia aurea					X				