Title

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Chapter 3

Ecological Mitigation Approaches and Performance

Regulatory Compliance and Ecological Performance of Mitigation Wetlands in an Agricultural Landscape

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Abstract: The success of wetland mitigation projects nationwide is typically assessed by comparing the total number of wetland mitigation acres attained to the total number of mitigation acres required by Section 404 permits. In the absence of performance measurements on mitigation wetlands, the success of compensatory mitigation in replacing the ecological values of impacted wetlands is increasingly questioned by wetland scientists. This study focuses on evaluating regulatory compliance and ecological performance of mitigation wetlands in Iowa. Regulatory compliance was determined by comparing delineated wetland areas to permitted losses and by evaluating completeness of permit conditions at 24 randomly selected Iowa Department of Transportation wetland mitigation sites. In a separate study, intensive biological inventories were used to evaluate ecological performance at 12 mitigation and three reference wetlands. Species richness and abundance data were collected on algae, protozoa, aquatic invertebrates, butterflies, amphibians, reptiles, birds and mammals at each site. Species richness and diversity at mitigation sites and reference sites were compared to determine if mitigation wetlands are performing differently than reference wetlands in Iowa. The results are valuable for building and expanding the tools and knowledge necessary to effectively assess and manage the ecological performance of compensatory mitigation wetlands and improve the ecological effectiveness of wetland mitigation.

Introduction

Section 404 of the Water Pollution Control Act or Clean Water Act (CWA) requires mitigation for unavoidable wetland losses resulting from transportation related impacts. Scrutiny of compensatory wetland mitigation programs across the country has taken place in recent years (National Research Council 2001; Storm and Stellini 1994). In the late 1990's, the National Research Council established the Committee on Mitigating Wetland Losses to evaluate how compensatory mitigation required under Section 404 of the CWA is contributing toward satisfying the overall objective of restoring and maintaining the quality of the nation's waters (National Research Council 2001). The committee concluded that the mitigation program fails to meet the goal of no net loss of wetlands for wetland functions. In addition, the committee found that permit conditions fail to clearly define performance expectations and that the mitigation program lacks a suitable mechanism to assure compliance. These conclusions have resulted in increased scrutiny and criticism of compensatory mitigation programs nationwide.

Several recent studies have attempted to evaluate the degree of success of compensatory wetland mitigation programs in other states. Brown and Veneman (2001) found over 50 percent of the mitigation sites sampled (n = 114) were not in compliance with wetland regulations. Sites failed to meet permit conditions largely due to acreage shortfall and out of kind mitigation (e.g., the mitigation wetland was not the type of wetland specified in the permit). Failure due to sites having less area than required by the permit is not uncommon. Nearly 75 percent of the mitigation sites reviewed in Tennessee failed to meet acreage requirements (Morgan and Roberts 2003) and in a similar study, researchers found 44 percent of the sites (n = 44) assessed failed to meet area requirements resulting in a net loss of wetlands (Robb 2002). With an increased awareness in wetland mitigation failure, regulatory agencies are initiating reviews of programs nationwide.

A steady increase in non-compliance inquiries in Iowa prompted the Iowa Department of Transportation to evaluate the compensatory mitigation program at two levels: regulatory compliance and ecological performance. The research objectives of these studies are to:

1. Determine the degree of regulatory compliance with requirements specified in the Clean Water Act Section 404 permits.
2. Quantify biological diversity of mitigation and reference wetlands.
3. Determine if mitigation and reference wetlands are functioning differently.

Methods

Data Collection

Regulatory Compliance

Wetland areas were delineated at 24 randomly selected Iowa Department of Transportation wetland mitigation sites (Figure 1 and Table 1). Wetlands at each study site were identified and their boundaries delineated using the Routine On-Site Determination Method as defined in the Corps of Engineers Wetlands Delineation Manual (Environmental Laboratory 1987). Wetland delineations were conducted in August and September 2003 and from May through August 2004. Wetlands were classified using the Cowardin et al. (1979) system.

Wetland boundaries were identified in the field and mapped using a Trimble GeoExplorer CE® Global Positioning System (GPS) receiver. Data from the receiver were post-processed using Trimble Pathfinder Office® version 3.00 software for an accuracy of <1 meter. The GPS data were then transferred to aerial photography. Because of the variability in mitigation sites, permit conditions, and mitigation objectives, additional data were collected to determine permit compliance (e.g., tree planting survival, waterfowl nesting islands) at specific sites as needed.

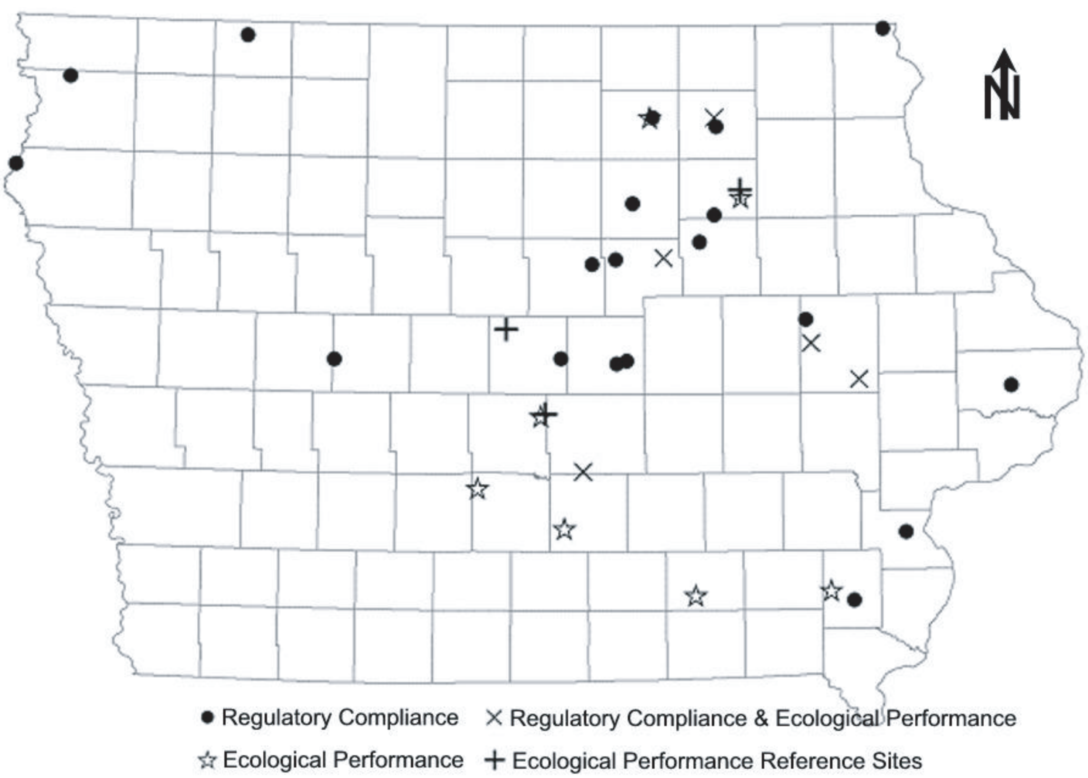

Figure 1. Location of mitigation and reference wetlands evaluated for regulatory compliance and ecological performance in Iowa, USA.

Table 1: Characteristics of mitigation and reference wetlands evaluated for regulatory compliance and ecological performance in Iowa, USA

Site Name	Year Constructed	Mitigation Type
Mitigation Sites		
255th Street	2000	Creation
Abma Tract	2001	Creation
Akron Wetland Mitigation Site	1999	Restoration
Allbones Wetland Mitigation Site	1997	Restoration
Badger*	2000	Restoration
Boevers*	2006	Creation
Brush Creek*	1998	Restoration
Colo Bogs Cummings Tract	1997	Restoration
Denver Bypass 1	1994	Restoration
Dike Mitigation Site B*	1999	Creation
Dunbar Slough	2001	Restoration
George Wyth State Park	1994	Creation
Grooms*	2004	Restoration
Hayes Lake	1998	Creation
Heartland Fen	2000	Creation
Indian Slough	1998	Restoration
Jarvis*	2003	Restoration
Lago Tract Welch WPA	2001	Restoration
Mink Creek*	1998	Creation
New Hampton Bypass Mitigation Site 1*	2002	Restoration
New Hampton Bypass Mitigation Site 2	2002	Enhancement
Palisades Wetland Mitigation Site*	2001	Creation
Partridge Meadows	1999	Creation
Pleasantville*	2002	Restoration
Rainsbarger Wetland Mitigation Site	2002	Creation
Rice Grass B	1995	Creation
Rice Grass A	1996	Creation
South Beaver Creek Wellsburg	2002	Creation
South Point*	2004	Creation
Welton Borrow Site	1995	Creation
Wickiup Hill Linn CCB*	2000	Restoration
Reference Sites		
Doolittle Prairie	-	-
Hay-Buhr	-	-
Engeldinger Marsh	-	-

* Mitigation sites included in ecological performance study.

Ecological Performance

Intensive biological inventories were used to evaluate the biological condition of 12 Iowa Department of Transportation mitigation wetlands and three reference wetlands in Iowa (figure 1 and table 1). Species richness and abundance data were collected at each site for eight species groups, including algae, protozoa, aquatic invertebrates, butterflies, amphibians, reptiles, birds and mammals.

Algae, protozoa, and aquatic invertebrates. Field collection of algae, protozoa, and aquatic invertebrates was done using benthic and surface grab sampling and net sampling for plankton (APHA 1998; US EPA 2002a). Each of the study sites was sampled over a period of three days during five sampling periods between April and November. An average of four samples was collected at each site on each sampling day and samples from similar habitats at any one site were pooled. Sample analysis included microscopic examination of fresh (or settled) samples and digestion and preservation of diatom samples (APHA 1998).

Butterflies. Butterfly data were collected on the species present at each study site every 10 days during the non-frost season. Methods included meander surveys of all habitats and counts of all individuals of each species encountered (Pollard 1991; Pollard and Yates 1993).

Vertebrates. Amphibians were surveyed from April through June to insure sampling of all species present (Heyer et al, 1994; US EPA 2002b). Salamanders were trapped April through June using wire screen funnel traps and hand collected during terrestrial and aquatic searches throughout the survey. Calling surveys and hand collecting of frogs and toads were conducted primarily from April through June during the time that each species is known to breed and continued throughout the survey.

Reptiles were surveyed from May through mid-July when they are most active. Snakes and lizards were documented through meander surveys of the study sites. Aquatic turtle trapping was conducted in all permanent bodies of water possessing suitable turtle habitat using modified fyke nets as described by Legler (1960).

The most intensive surveys for amphibians, reptiles and small mammals utilized drift fences as described by Christiansen and VanDeWalle (2000). Drift fence sampling took place from May through September. Sherman live traps were used in conjunction with the drift fence for small mammals.

Migratory birds were surveyed during March and November and breeding bird surveys took place from May through July (Fairbairn and Dinsmore 2001; US EPA 2002c).

Voucher specimens. Voucher specimens were taken for difficult identifications under current Iowa Department of Natural Resources Scientific Collecting Permits. Voucher specimens collected for this project were processed following standard methods for each species group (Heyer et. al. 1994; Wilson et. al. 1996; APHA 1998; Deblase and Martin, 2000; Winter 2000; Simmons 2002; US EPA 2002a).

Data Analysis

Regulatory Compliance

Regulatory compliance was determined by comparing the delineated wetland acreage at each study site to the total wetland acreage requirements specified in individual CWA Section 404 permits, regardless of how the acreage was obtained (creation, restoration, enhancement or preservation).

Ecological Performance

Diversity at mitigation and reference sites was quantified using Hill's N1 (Hill 1973) as a representative measure of species diversity. Hill's N1 is given by:

$$N1 = \exp(-\sum p_i \ln(p_i)$$

where p_i is the proportion of a given species found at a site. N1 is one method of calculating the "effective number of species" (MacArthur 1965; Hill 1973). It is the exponential of the Shannon index; unlike Shannon's index, Hill's N1 represents a true diversity that behaves linearly and is therefore easier to interpret ecologically than the Shannon form (Peet 1974). Because it is derived from Shannon's index, it also has the advantage of not emphasizing either rare or common species (Jost 2006).

Species diversity of mitigation sites versus reference sites was compared using the Mann-Whitney two-sample rank-sum test (Mann and Whitney 1947) to determine if mitigation wetlands are performing differently than reference wetlands.

Because of the differing number of mitigation sites (n=12) and reference sites (n=3), species richness of mitigation sites versus natural sites was compared using expected species accumulation curves, i.e., sample-based rarefaction curves (Gotelli and Colwell 2001). The curves were calculated using EstimateS Version 8 (Colwell 2006). This program calculates the expected species accumulation and its associated 95 percent confidence intervals using the methods of Colwell et al. (2004).

For each of the major groups of organisms, observations of species abundance for all mitigation sites were amalgamated into one dataset, and data for reference sites were amalgamated into another. As recommended by Gotelli and Colwell (2001), the expected species accumulation curves and their 95 percent confidence interval curves by individuals were rescaled. By comparing the curves for each group of organisms, species richness between the two groups of sites could be compared based upon the actual number of individuals recovered.

Results

Regulatory Compliance

Of the 24 sites evaluated for regulatory compliance, 58 percent (n=14) meet or exceed Section 404 permit requirements. Net gain (13 sites) ranged from 0.19 acre to 27.2 acres. Two sites, Abma Tract and Colo Bogs Cummings Tract, exceed the requirements by 929 percent and 631 percent, respectively. Forty –one percent (n=10) of the mitigation sites failed to meet Section 404 permit requirements. Net loss (10 sites) ranged from 0.2 acre to 14.6 acres. The Denver Bypass 1 site was the worst performer, having failed to establish any wetland mitigation acres and the Akron Wetland Mitigation Site was the best performer with slightly more than 27 wetland mitigation acres, over the permit requirement. A summary of Section 404 permit requirements, delineated wetland acreage and percent compliance for each of the study sites is shown in table 2.

A total of 338.02 acres of wetland were delineated at the 24 sites. This represents a total net increase of 43.91 acres over the Section 404 permit requirements for the projects. However, as shown in Table 2, the majority of the increase is due to just two sites, the Akron Wetland Mitigation Site and Colo Bogs Cummings Tract. If these two sites were removed from the analysis, it would result in a total net loss of 8.58 acres.

Table 2: Section 404 Permit Requirement, delineated wetland acreage and percent compliance for each study site evaluated for regulatory compliance

Site Name	Section 404 Permit Requirement (Acres)	Delineated Wetland (Acres)	Net Gain/Loss (Acres)	Percent Compliance
255th Street	3.87	4.36	0.49	112.7
Abma Tract	1	9.29	8.29	929.0
Akron Wetland Mitigation Site	36	63.15	27.2	175.4
Allbones Wetland Mitigation Site	6	5.5	-0.5	91.7
Brush Creek	16.6	14.11	-2.49	85.0
Colo Bogs Cummings Tract	4.77	30.11	25.34	631.2
Denver Bypass 1	14.6	0	-14.6	0.0
Dike Mitigation Site B	10	14.11	4.11	141.1
Dunbar Slough	34	37.32	3.32	109.8
George Wyth State Park	23.3	15.3	-8	65.7
Hayes Lake	0.6	0.4	-0.2	66.7
Heartland Fen	2.5	3.36	0.86	134.4
Indian Slough	72.8	72.8	0	100.0
Lago Tract Welch WPA	5.1	7.85	2.75	153.9
New Hampton Bypass Site 1	11	10.51	-0.49	95.5
New Hampton Bypass Site 2	1.3	2.24	0.94	172.3
Palisades Wetland Mitigation Site	3.2	5.08	1.88	158.8
Partridge Meadows	7.5	7.69	0.19	102.5
Rainsbarger Wetland Mitigation Site	4.5	5.08	0.58	112.9
Rice Grass B	2	1.06	-0.94	53.0
Rice Grass A	11.9	9.16	-2.74	77.0
South Beaver Creek Wellsburg	2	1.6	-0.4	80.0
Welton Borrow Site	3.07	4.37	1.3	142.3
Wickiup Hill Linn CCB	16.5	13.57	-2.93	82.24
Totals	294.11	338.02	43.91	114.9

The 10 under-performing sites are split equally between creation and restoration (five each) (table 1). Five of these (50 percent) are more than five years post construction, two (20 percent) are five years post construction, one (10 percent) is three years post construction and the remaining two (20 percent) are one year post construction. Of the sites that meet or exceed permit requirements, approximately 93 percent are five years or less post construction and approximately 43 percent are only one year old. Only one of the 14 successful sites is more than five years old.

Overall, mitigation at these 24 sites has resulted in a net gain of nearly 44 acres of wetland over the acreage required by the Section 404 permits. As previously indicated just two sites account for the majority of the excess acreage. Only one site completely failed to meet the definition of a jurisdictional wetland, the Denver Bypass site, which was constructed in 1994 (tables 2 and 3).

Ecological Performance

A summary of species diversity by study site is shown in table 3 and figures 2 and 3. As a way of comparing diversity between the 15 sites, overall diversity was calculated using the effective number of species for each of the eight species groups to determine an average rank for each site. The sites were then given an overall ranking of 1–15 based on the average rank, with 15 representing the highest overall species diversity (table 3 and figure 4).

Table 3: Summary of species diversity as estimated by effective number of species at 15 wetland study sites (12 mitigation and 3 reference) located in Iowa, USA (2005-2006)

	Effective Number of Species (Hills's N1)								
	Algae	Protozoa	Aquatic Invertebrates	Butterflies	Amphibians	Birds	Mammals	Reptiles	Overall Site Rank
Mitigation Sites									
South Point	49.60	13.67	18.15	13.99	4.96	11.28	4.66	4.46	15
Pleasantville	46.29	18.81	11.54	12.34	2.84	4.82	6.97	1.75	13
Mink Creek	39.57	25.20	11.44	12.93	1.99	12.28	6.01	1.00	12
Badger Creek	22.02	14.68	9.10	14.83	2.08	7.74	4.20	5.86	10
Brush Creek	18.79	20.43	10.00	9.97	1.13	15.97	4.12	2.05	9
Wickiup Hill	18.16	8.49	4.11	12.68	1.89	18.02	6.02	1.89	8
Grooms	14.62	3.77	2.55	11.62	5.59	16.61	4.48	2.83	7
New Hampton	37.84	10.62	14.63	6.17	1.15	15.01	2.47	2.00	6
Palisades	30.26	15.64	15.00	8.66	1.11	8.33	3.52	1.51	5
Dike	14.43	16.31	7.02	9.33	3.43	7.88	6.35	1.00	4
Jarvis	0.00	0.00	0.00	13.93	4.34	14.85	2.31	1.89	3
Boevers	15.53	4.21	4.22	8.39	3.94	10.92	6.25	1.00	2
Reference Sites									
Hay-Buhr Area	28.30	28.82	8.47	9.57	1.85	17.41	6.73	7.56	14
Engeldinger Marsh	25.77	14.53	10.42	14.95	4.31	10.86	5.25	1.00	11
Doolittle Prairie	15.31	8.87	4.55	7.43	1.00	8.19	4.06	1.75	1
Mann-Whitney U	19	14	20	19	24	18	15	24	16
2-Tailed P*	0.95	0.63	0.84	0.95	0.45	1.00	0.73	0.45	0.84

*Not significant at α =0.05

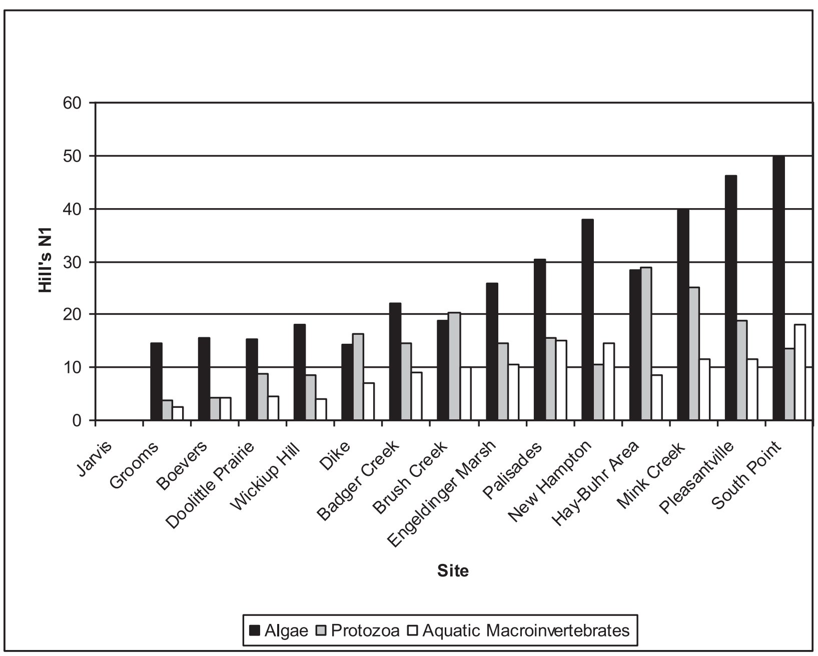

Figure 2. Biodiversity of aquatic organisms as estimated by effective number of species at 15 wetland study sites (12 mitigation and 3 reference) located in Iowa, USA (2005-2006).

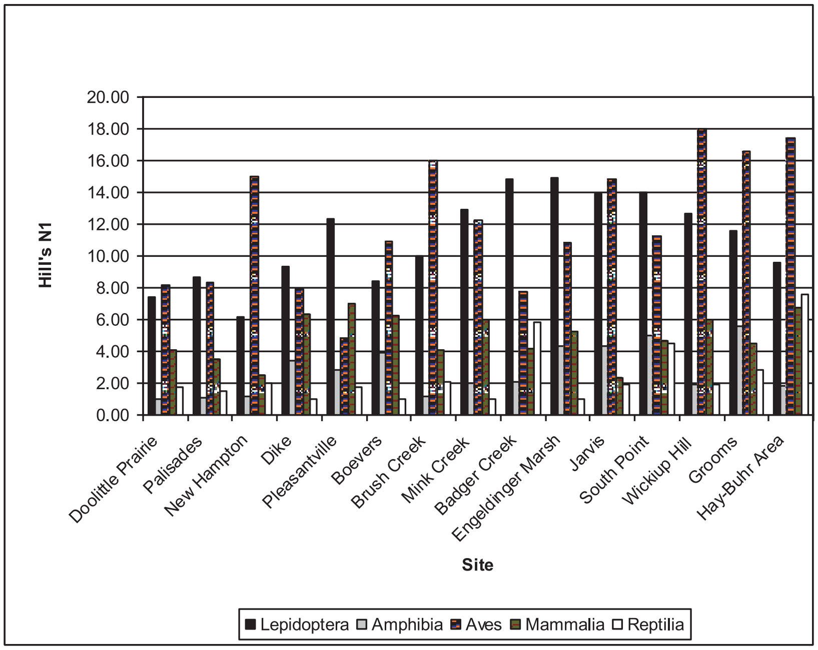

Figure 3. Biodiversity of terrestrial organisms as estimated by effective number of species at 15 wetland study sites (12 mitigation and 3 reference) located in Iowa, USA (2005-2006).

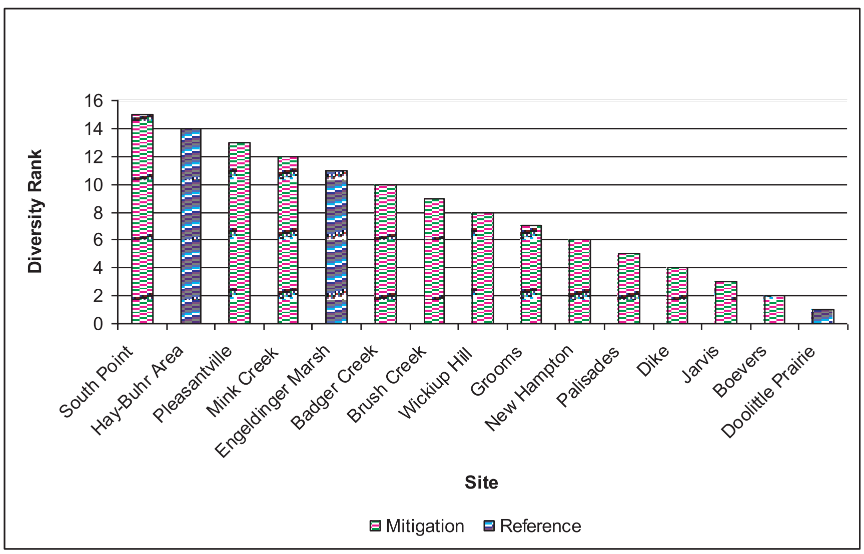

Figure 4. Overall species diversity found at 15 wetland study sites (12 mitigation and 3 reference) located in Iowa, USA (2005-2006).

The highest ranking site in terms of overall diversity is South Point, a large (40 acre), created mitigation site that was one year post construction at the time it was surveyed. South Point had the highest diversity of algae and aquatic invertebrates of any site (table 3 and figure 2), the second highest amphibian diversity and the third highest diversity of butterflies (table 3 and figure 3). Along with South Point, two of the reference sites (Hay-Buhr Area and Engeldinger Marsh) were in the top five in overall diversity.

The third reference site, Doolittle Prairie, ranked the lowest in overall diversity. Doolittle Prairie is a small (26 acre) native tallgrass prairie remnant with a series of small prairie potholes located across the site that was dedicated as one of Iowa's State Preserves in 1980. Portions of the site have never been plowed. Doolittle Prairie had the lowest amphibian diversity and the second lowest butterfly diversity (table 3 and figure 3). With respect to protozoa and aquatic invertebrates, the only sites with lower diversity than Doolittle Prairie were sites that were dry all, or a large portion, of the year in which they were sampled.

When the effective number of species (Hill's N1) by species group at mitigation sites is compared to that found at reference sites, no significant differences are found within any of the groups (table 3). Because the effective number of species is a measure of the number of common species at a site, this result suggests that the number of common species within each species group is approximately equal between mitigation and reference sites. In an effort to further explore the question of whether mitigation sites are performing differently than reference sites, the species richness of mitigation sites versus reference sites was compared using expected species accumulation curves (figures 5a–5h).

The species accumulation curves for algae, protozoa, and aquatic invertebrates all show similar patterns (figures 5a–5c). Based on the numbers of individuals recovered, the 95 percent confidence intervals for the mitigation sites overlap those of the reference sites for all three groups of organisms. This indicates that insufficient evidence exists to reject the null hypothesis of no significant difference in species richness between the two types of sites given comparable sample sizes. In addition, as more individuals are recovered, the number of species for both mitigation and reference sites do not appear to be converging to an asymptote, indicating that many additional species remain to be recovered. For algae, rarefaction of the mitigation site curve to a sample size of about 2000 individuals (the total for the pooled reference sites) suggests that when the number of individuals recovered is taken into account, "rarefied" species richness at the two types of sites is approximately equal at 200. For aquatic invertebrates at a sample size of about 110 individuals (the total for the pooled reference sites) it is approximately equal at 29 species. Based on a sample size of about 60 individuals (the total for the pooled reference sites), "rarefied" species richness for protozoa ranges from approximately 63 to 69 species at the two types of sites.

Among vertebrate taxa, the species accumulation curves for birds (figure 5d) exhibit patterns similar to those noted for algae, protozoa, and aquatic invertebrates. No significant difference in species richness was detected between the two types of sites given comparable sample sizes, and many additional species probably remain to be recovered. Rarefaction of the mitigation site curve to a sample size of about 575 individuals (the total for the pooled reference sites) suggests that "rarefied" avian species richness ranges from approximately 54 to 62 species between the two types of sites.

The species accumulation curves for mammals (figure 5e) exhibit a slightly different pattern than that noted for birds. No significant difference in species richness was detected between the two types of sites given comparable sample sizes, but the curve for mammals at the mitigation sites appears to be converging to an asymptote of about 25 species, thereby suggesting that all common and most rare species have been recovered. The curve for reference sites does not appear to converge to an asymptote, indicating that many additional species probably remain to be recovered. Rarefaction of the mitigation site curve to a sample size of about 330 individuals (the total for the pooled reference sites) suggests that "rarefied" mammalian species richness ranges from approximately 14 to 16 species between the two types of sites.

For reptiles, the species accumulation curves are somewhat similar to those for mammals (figure 5f). No significant difference in species richness was detected between the two types of sites given comparable sample sizes. The curve for reptiles at the mitigation sites appears to be converging to an asymptote, thereby suggesting that most species have been recovered. The curve for reference sites is not converging to an asymptote, indicating that most likely only the most common species have been found and that many additional species probably remain to be recovered. In addition, the 95 percent confidence intervals for the reference sites are very wide, ranging from five to 15 species at a sample size of 21 individuals (the total number recovered from all of the reference sites). This reflects both the small sample size and the high variability in observed reptilian species richness at the reference sites (one species at Engeldinger Marsh, nine at Hay-Buhr, and two at Doolittle Prairie). Rarefaction of the mitigation site curve to a sample size of 21 individuals (the total for the pooled reference sites) suggests that "rarefied" reptilian species richness ranges from approximately seven to 10 species between the two types of sites.

The species accumulation curve for amphibians (figure 5g) at mitigation sites is noteworthy because beginning at a sample size of about 1,000 individuals it converges to an asymptote of 13 species, suggesting that all available species have been found at this group of sites. The 95 percent confidence intervals for the mitigation sites overlap those of the reference sites, indicating that insufficient evidence exists to reject the null hypothesis of no significant difference in species richness between the two types of sites. However, at a sample size of about 190 individuals, the curve for reference sites shows signs of beginning to converge to an asymptote at an undefined level lower than that noted for the mitigation sites. This suggests that although additional species remain to be recovered at the reference sites, additional

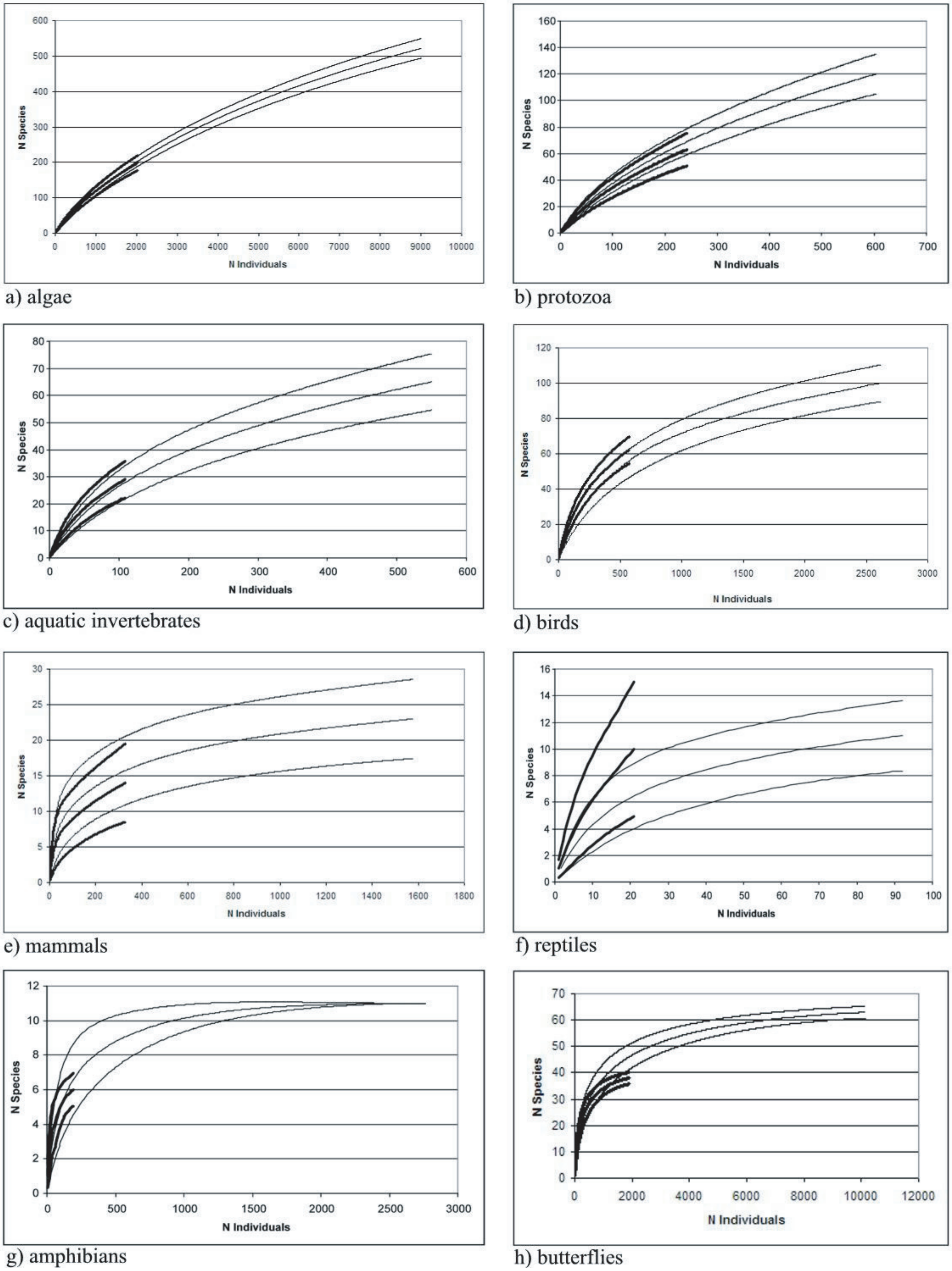

Figure 5. Species accumulation curves. Thin line = mitigation site; thick line = reference site. The middle line in each curve represents the mean. The outer two lines represent the 95% confidence intervals. If the 95% confidence intervals for the two curves overlap, this indicates there is no significant difference in species richness between the two groups.

sampling at the reference sites could cause the curves to diverge, with the reference sites possibly being less diverse than the mitigation sites. Rarefaction of the mitigation site curve to a sample size of about 190 individuals (the total for the pooled reference sites) suggests that "rarefied" amphibian species richness ranges from approximately six to seven species between the two types of sites.

The species accumulation curves for butterflies (figure 5h) indicate that "rarefied" species richness is significantly higher at the mitigation sites than it is at the reference sites. The 95 percent confidence intervals for the two groups of sites diverge at about 1,800 individuals, providing evidence sufficient to reject the null hypothesis of no significant difference in species richness between the two types of sites. The curves for both groups of sites appear to converge to asymptotes (approximately 65 species at mitigation sites and approximately 40 species at reference sites, a difference of 63 percent). Rarefaction of the mitigation site curve to a sample size of about 1,900 individuals (the total for the pooled reference sites) suggests that "rarefied" butterfly species richness ranges from approximately 38 species at reference sites to approximately 46 species at mitigation sites, a difference of 21 percent. This result, in combination with the finding of no difference in the effective number of species between the two groups of sites, suggests that the difference in species diversity is due to the presence of significantly more rare species at the mitigation sites.

Discussion

Using Section 404 permit acreage requirements as the criteria for measuring success, 58 percent of the wetland mitigation sites evaluated for regulatory compliance are successful. Using net gain/loss as the measure of success, wetland mitigation has resulted in a net increase of nearly 44 acres of wetland over what was required by permits. While the program as whole has been marginally successful at meeting permit requirements, individual sites have done exceptionally well, which has resulted in the large overall net increase.

These results are in contrast to those of previous studies in Massachusetts, where over 50 percent of the study sites failed to meet regulatory requirements (Brown and Veneman 2001), and Tennessee where 75 percent of the study sites failed to meet acreage requirements (Morgan and Roberts 2003). Percent success in meeting acreage requirements in this study was similar to the 56 percent found by Robb (2002) in Indiana. However, in the Indiana study, the 44 percent of the sites that did not meet the acreage requirements resulted in a net loss of wetlands, as opposed to this study which found an overall net gain in wetland acreage.

When the age of the sites is taken into consideration, the data suggest that sites that have been constructed in the last five years are more successful than sites constructed five or more years ago. Of the sites constructed in the last five years, 75 percent meet or exceed permit requirements. Only 33 percent of the sites constructed five or more years ago meet or exceed permit requirements, suggesting that the Iowa Department of Transportation's Compensatory Wetland Mitigation Program has been improving with time. In all likelihood, this is due to improved site selection criteria and better site design.

This improvement in the success of meeting regulatory requirements may reflect the development and growth of wetland programs within Departments of Transportation in many states. In the past, wetland mitigation design was often done as an afterthought by civil engineers with little or no ecological training. Wetland mitigation was commonly located in borrow sites with that hope that some cattails would grow satisfying the wetland requirement. Many of these sites resulted in nothing more than sterile ponds.

Within the last 15 years or so, many Departments of Transportation have begun staffing their wetland and water resources departments with individuals trained in ecology or wetland science. In addition, outside environmental consultants with expertise in wetland science and design are often brought in as part of the design team. The result has been the development of mitigation sites that are designed to function as wetlands.

Not only are these better designed sites more successful at meeting Section 404 permit requirements, they no doubt function ecologically better as well. Data from this study suggest that ecologically, mitigation sites in Iowa are functioning similarly to reference sites. However, the lack of convergence to an asymptote in many of the species accumulation curves suggests that for the most part sampling for many of the sites/species groups (particularly the reference sites) is effectively incomplete, which may explain the inability to demonstrate differences in the effective number of species (Hill's N1) at mitigation versus reference sites. A true difference in species diversity may exist between the two groups of sites; however, due to small sample size and/or a lack of a sufficiently powerful statistical test, a true difference may have gone undetected.

Even though an overall difference in species diversity between mitigation and reference sites was not detected, differences between individual mitigation and reference sites are apparent from the data. The starkest contrast is between the newly constructed South Point with the highest overall species diversity and Doolittle Prairie State Preserve, which had the lowest overall species diversity. One possible explanation for the difference in diversity between the newly constructed South Point and the remnant wet prairie at Doolittle is the connectivity of each site to other suitable habitat. South Point has a direct connection to a 6,500 acre wildlife area located along the Skunk River, which is home to a diverse collection of woodland, wetland and prairie wildlife. In contrast, Doolittle Prairie is located in a highly agricultural part of the state and is surrounded by intensively cropped agricultural land. The fencerows that formerly bordered the site have been removed and the adjacent fields are plowed right to the edge of the prairie. No direct connection to any large area of natural habitat exists.

Within species groups, a significant difference in species richness between mitigation and reference sites was found only with the butterflies (figure 5h). No significant difference in the number of effective butterfly species between the mitigation and reference sites was found (table 3), indicating that both groups contain approximately equal numbers of common species. The 21 percent difference seen in "rarefied" butterfly species richness between mitigation and reference sites therefore suggests that the difference in species diversity is the result of more rare species being found at the mitigation sites. The underlying reason(s) for why mitigation sites may be able to harbor a larger assemblage of butterfly species is beyond the scope of this study, but may be related to such factors as plant species diversity, plant community types, connectivity to other suitable habitat and management.

Many factors can influence whether a site is successful at meeting its regulatory requirements, including site selection, site design and construction. Even with the best site location and design, an improperly constructed site may result in an acreage shortfall. Although a site may be unsuccessful from a regulatory standpoint, it still may be successful from an ecological standpoint and therefore may still be replacing the functional values lost with the impacted wetland.

The Brush Creek mitigation site in this study is an example of a site that is unsuccessful in meeting its Section 404 requirements, but is performing well ecologically. The Brush Creek site is only 85 percent compliant with its permit requirements, resulting in a net loss of 2.49 acres of wetland (table 2). Ecologically, it ranks ninth out of 15 in overall species diversity (figure 4), had the fourth highest diversity of birds and a higher diversity of protozoa, aquatic invertebrates, butterflies, reptiles and birds than two of the three reference sites (table 3; figures 2 and 3).

Likewise, a site can be successful in meeting its regulatory obligations, but perform poorly ecologically, such as the Dike mitigation site, which is 141 percent compliant with its permit requirements, resulting in a net increase of 4.11 acres of wetland (table 2). However, the site ranks fourth out of 15 in overall species diversity and on the low end of the diversity for many of the species groups (table 3; figures 2 and 3). These examples serve to illustrate that the success/performance of a wetland mitigation site should be evaluated on both regulatory compliance and ecological performance.

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References

APHA (American Public Health Association, American Water Works Association, and Water Environmental Federation). 1998. Standard methods for the examination of water and wastewater. 20th edition. American Public Health Association, Washington, DC.

Brown, S.C. and P.L.M. Veneman. 2001. Effectiveness of compensatory wetland mitigation in Massachusetts, USA, Wetlands, 21(4): 508-518.

Christiansen, J. L. and T. J. VanDeWalle. 2000. Effectiveness of three trap types in drift fence surveys. Herpetol. Rev. 31(3):158-160.

Colwell, R. K., C. X. Mao, & J. Chang. 2004. Interpolating, extrapolating, and comparing incidence-based species accumulation curves. Ecology 85, 2717-2727.

Colwell, R.K. 2006. *Estimate* S: Statistical estimation of species richness and shared species from samples. Version 8. Persistent URL <purl.oclc.org/estimates>.

Cowardin, L.M., V. Carter, F.C. Golet, and E.T. LaRoe. 1979. "Classification of Wetlands and Deepwater Habitats of the United States," FWS/OBS-79/31, U.S, Fish and Wildlife Service, Office of Biological Services, Washington, DC.

DeBlase, A.F. and R.E. Martin, 2000. A Manual of Mammology with keys to families of the world, 3rd ed.

Environmental Laboratory. 1997. "Corps of Engineers Delineation Manual," Technical Report YR-87_1, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Fairbairn, S. E., and J. J. Dinsmore. 2001. Local and landscape-level influences on wetland bird communities of the prairie pothole region of Iowa, USA. Wetlands 21:41-47.

Gotelli, N., and R. K. Colwell. 2001. Quantifying biodiversity: Procedures and pitfalls in the measurement and comparison of species richness. Ecology Letters 4, 379-391.

Heyer, W.R., M.A. Donnelly, R.W. McDiarmid, L.C. Hayek, M.S. Foster (Eds.). 1994. Measuring and monitoring biological diversity: Standard methods for amphibians. Smithsonian Institution Press, Washington, D.C.

Hill, M.O. (1973). Diversity and evenness: a unifying notation and its consequences. Ecology 54:427-431.

Legler, J. M. 1960b. A simple and inexpensive device for trapping aquatic turtles. Utah Acad. Proc. 37:63-66.

Jost, L. 2006. Entropy and diversity. Oikos 113:2, 363-375.

MacArthur, R.H. 1965. Patterns of species diversity. Cambridge Philosophical Society Biological Review 40: 510-533.

Mann, H. B. and D.R. Whitney. 1947. On a test of whether one of two random variables is stochastically larger than the other. Annals of Mathematical Statistics 18, 50-60.

Morgan, K.L. and T.H. Roberts. 2003. Characterization of wetland mitigation projects in Tennessee, USA, Wetlands, 23(1): 66-69.

National Research Council. 2001. Compensating for Wetland Losses Under the Clean Water Act, National Academy Press, Washington, DC, USA.

Peet, R.K. 1974. The measurement of species diversity. Annual Review of Ecology and Systematics 5:285-307.

Pollard, Ernest. 1991. Monitoring Butterfly Numbers, Monitoring for Conservation and Ecology, Barrie Goldsmith Ed., Chapman and Hall, London.

Pollard, E. and T.J. Yates. 1993. Monitoring Butterflies for Ecology and Conservation. Chapman & Hall, London.

Robb, J.T. 2002. Assessing wetland compensatory mitigation sites to aid in establishing mitigation ratios. Wetlands. 22(2): 435-440.

Simmons, J.E. 2002. Herpetological Collecting and Collections Management. Society for the Study of Amphibians and Reptiles Herpetological Circular No. 31. pp. vi + 1-153.

Storm, L. and J. Stellini. 1994. Interagency follow-through investigation of compensatory wetland mitigation sites. Joint Agency Staff Report, U.S. Environmental Protection Agency, Region 10, Water Division, Wetlands Section, Seattle, WA, USA and U.S. Fish and Wildlife Service, Ecological Services. Washington, DC, USA. EPA 910-R-94-013.

U.S. EPA. 2002a. Methods for Evaluating Wetland Condition: Using Algae to Assess Environmental Conditions in Wetlands. Office of Water, U.S. Environmental Protection Agency, Washington, DC. EPA/822-R-02-021.

--------2002b. Methods for Evaluating Wetland Condition: Using Amphibians in Bioassessments of Wetlands. Office of Water, U.S. Environmental Protection Agency, Washington, DC. EPA/822-R-02-022.

--------2002c. Methods for Evaluating Wetland Condition: Biological Assessment Methods for Birds. Office of Water, U.S. Environmental Protection Agency, Washington, DC. EPA/822-R-02-023.

Wilson, D.E., F.R. Cole, J.D., Nichols, R. Rudran, M.S. Foster (Eds.). 1996. Measuring and monitoring biological diversity: Standard methods for mammals. Smithsonian Institution Press, Washington, D.C.

Winter, William D. Jr. 2000. Basic Techniques for Observing and Studying Moths and Butterflies, The Lepidopterists Society, Natural History Museum, 900 Exposition Blvd., Los Angeles, CA.

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