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Performance Criteria, Compliance Success, and Vegetation Development in Compensatory Mitigation Wetlands

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Abstract The US Army Corps of Engineers often requires wetland creation or restoration as compensation for wetlands damaged during development. These wetlands are typically monitored postconstruction to determine the level of compliance with respect to site-specific performance standards. However, defining appropriate goals and measuring success of restorations has proven difficult. We reviewed monitoring information for 76 wetlands constructed between 1992 and 2002 to summarize the performance criteria used to measure progress, assess compliance with those criteria, and, finally, to evaluate the appropriateness of those criteria. Goals were overwhelmingly focused on plant communities. Attributes used to assess the quality of restored plant communities, including percent native species and the Floristic Quality Index, increased over time but were apparently unrelated to the number of species planted. Compliance frequencies varied depending on site goals; sites often failed to comply with criteria related to survival of planted vegetation or requirements that dominant plant species should not be exotic or weedy, whereas criteria related to the establishment of cover by vegetation or by wetland-dependent plants were often met. Judgment of a site's success or failure was largely a function of the goals set for the site. Some performance criteria were too lenient to be of value in distinguishing failed from successful sites, whereas other criteria were unachievable without more intensive site management. More appropriate goals could be devised for restored wetlands by basing performance standards on past performance of similar restorations, identifying consistent temporal trends in attributes of restored sites, and using natural wetlands as references.

Keywords Creation · Restoration · Clean Water Act, Section 404 · Performance standards · Plant community development · Floristic Quality Index

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Approximately 52% of the original wetland area in the conterminous United States (Dahl 2000) has been converted to other land uses. The extensive loss of wetlands, in addition to a growing recognition of the value of wetlands to society, led federal and state governments to switch from policies subsidizing wetland conversion to policies with the goal of preventing further loss (Brown and Lant 1999). The major piece of federal legislation regulating wetland conversion is Section 404 of the Clean Water Act, which is enforced by the US Army Corps of Engineers. Permits for regulated activities affecting wetlands often require mitigation in the form of compensation through restoration, creation, or enhancement of wetlands elsewhere. These compensatory mitigation wetlands are typically monitored for a period of 3–5 years to determine whether they meet a set of site-specific performance standards approved by the Army Corps of Engineers (NRC 2001).

The policy of compensatory mitigation assumes that both the structure and function of destroyed wetlands can be predictably recreated, an assumption questioned by several authors (e.g., Niering 1987; Race 1985; Zedler 1996), and that 5 years of monitoring is long enough to assess the progress of compensatory mitigation wetlands (Mitsch and Wilson 1996; Zedler and Callaway 1999).

Restored and created wetlands have often failed (NRC 2001), and in addition to the progressive degradation of existing natural wetlands, this has led to the continuing loss of both wetland area and wetland ecosystem function at regional scales (Whigham 1999; Zedler and Callaway 1999). Judging whether a restored or created wetland is a failure or a success, however, is a difficult task.

Judgment of success or failure in compensatory mitigation wetlands is ideally based on goals established a priori. A mitigation project is considered a "compliance success" if it meets all goals specified in a permit or agreement among the parties involved (Kentula 2000; Zedler and Callaway 2000). A site can fail to achieve compliance for two reasons: The goals were too stringent to be realistically achievable or the site is not successful as a functioning wetland. On the other hand, even if a site does meet all compliance goals, it is not necessarily a successful ecological restoration because the goals might have been too modest or otherwise inappropriate.

In a regulatory context it is important to establish measurable, realistically achievable performance standards in order to judge a site's progress with respect to stated project goals. Performance standards, measurable thresholds used to judge compliance or lack thereof, are often included as conditions in mitigation permits (Streever 1999) and determine how a site will be monitored (Ehrenfeld 2000). Performance standards are not uniform among wetland permits (Streever 1999) and are often proposed by a permittee's consultants with approval from the Army Corps of Engineers (Sudol and Ambrose 2002). Even within similar wetland types, there can be large inconsistencies in actual targets (Breaux and Serefiddin 1999), suggesting that the performance standards are often set arbitrarily, without reference to similar natural or restored wetlands. Furthermore, performance standards are often unclear, do not set measurable targets, or are poor indicators of site performance or wetland functions (Cole 2002; NRC 2001).

A lack of regional-scale studies of the past performance of compensatory mitigation wetlands has limited the ability of wetland planners to set realistic goals for new sites. Most published assessments of wetland permitting programs have focused very broadly on whether compensatory wetlands were actually created or monitored, and although informative, they necessarily lack details about site performance that might prove useful as models for setting goals. Other studies have focused in more detail on evaluating success in only one or a few sites, but the generalities that can be drawn from such site-specific studies are limited. Furthermore, there has been little discussion of whether the performance standards used to measure site progress are reasonable (but see Breaux and Serefiddin 1999; Cole 2002).

Wetland conversion has been especially extensive in the midwestern United States. In Illinois; an estimated 90% of original wetland area has been lost (Suloway and Hubbell 1994). Therefore, protection of existing wetlands and effective compensation for unavoidable losses are of great consequence in the state. The Illinois Department of Transportation (IDOT) has created and restored wetlands throughout Illinois to compensate for natural wetlands damaged during road projects. After construction, these sites are monitored annually for a period of up to 5 years. Data derived from the original site-monitoring reports provide a unique opportunity to examine, in detail, the goals and performance levels of a large number of compensatory mitigation wetlands. The specific objectives of this study were to (1) summarize the goals and performance standards set for these sites, (2) determine compliance frequencies for each goal, (3) determine whether performance levels change over time and how they compare to typical performance standards in order to judge whether standards were achievable within the time frame of monitoring, and (4) determine whether planting a greater number of herbaceous species increased performance levels.

Methods

Seventy-six compensatory mitigation wetlands, constructed between 1991 and 2002 in 38 separate project areas, were monitored annually, in late summer, for 1–5 years by scientists from the Illinois Natural History Survey (INHS). Late summer sampling maximizes the number of identifiable plant species in wetlands (Matthews 2003) but might underestimate richness of early-flowering species (e.g., *Carex* spp.). Sites included both emergent and forested wetlands. Target areas for wetland construction ranged from 0.02 to 10.7 ha (median: 0.6 ha). Sites were located throughout Illinois, from $\sim 37°17'$ to $42°27'$ latitude and $87°53'$ to $91°20'$ longitude (Figure 1). Eight sites were monitored for a single year, 17 were monitored for 2 years, 9 were monitored for 3 years, 18 were monitored for 4 years, and 24 were monitored for 5 years. For analyses focusing on the outcome of restoration, we use only the final year of monitoring data for each site, as it represents the site at its most mature state and is the final year of data upon which regulatory agencies can base decisions about site success. For analyses of trends over time, we use only sites with at least 4 years of data.

At each site, in each year, the area of the site meeting the jurisdictional criteria of a wetland was delineated; a site was determined to be a wetland if it contained dominant hydrophytic vegetation (Reed 1988), hydric soils, and wetland hydrology as described by the US Army Corps of Engineers Wetlands Delineation Manual (USACE 1987). A complete plant species list was compiled annually during a thorough search of the entire site. Additional monitoring was

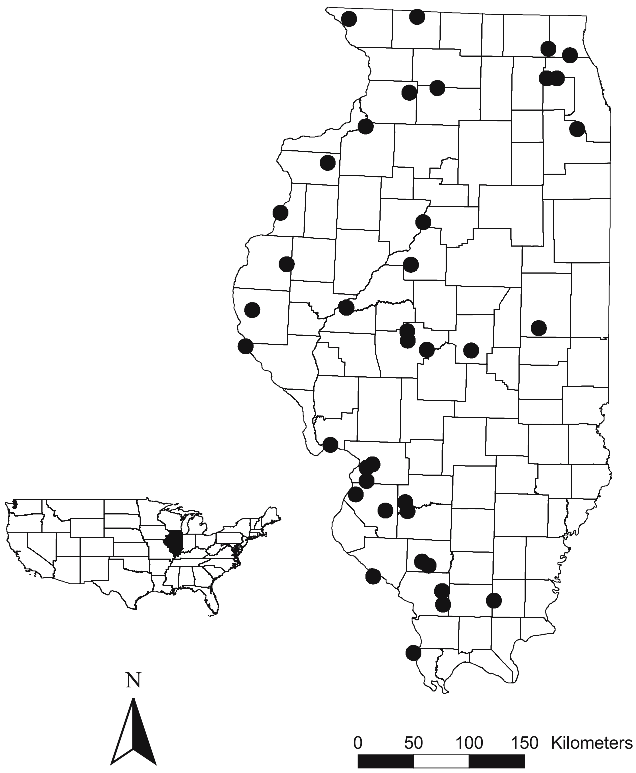

Fig. 1 Locations, within Illinois, of compensatory mitigation projects included in this study

performed based on site-specific performance standards. For example, trees were counted in restored floodplain forests when performance criteria required a measurement of the number of planted trees surviving by the end of monitoring. Goals and performance standards were specified by the permitting agency or were developed by the permittee's consultants or personnel from the INHS, with approval by the permitting agency. Several of these sites were also monitored by hydrologists from the Illinois State Geological Survey to determine areal extent of wetland hydrology.

Some sites had performance standards that required measurement of herbaceous species cover. In these sites, in addition to annual whole-site surveys that were used to generate species lists, vegetation was quantitatively sampled in square quadrats (1 m^2 or 0.25 m^2) placed systematically along transects. All vascular plant species in each quadrat were recorded, and each species was assigned a cover class (<1%, 1–5%, 6–25%, 26–50%, 51–75%, 76–95%, or 96–100%), an estimate of the amount of area within the sample quadrat that is covered by that species (Daubenmire 1959). Cover class data were used to calculate frequency (percent of quadrats in which a species is present), relative frequency, average cover per quadrat, relative cover, and importance value (the sum of relative frequency and relative cover, divided by 2) for each sampled species at each site. Species were arranged by importance value in decreasing order, and importance values were sequentially summed, starting with the most prevalent species, until the total reached 50. Those species included in the summation were considered dominant species. Additionally, any species having >20% of the total vegetation cover was considered dominant (FICWD 1989). Number of quadrats and transects, distance between transects, and distance between quadrats varied among sites, but were consistent within sites from year to year. Although the monitoring protocol varied among sites, the quantitative sampling employed should have yielded a good representation of the relative importance of species within a site. However, because of the sampling differences among sites, we avoided direct among-site comparisons based on quadrat sampling, and we restricted other analyses based on these data to a few variables (relative cover by all hydrophytic species combined and presence or absence of exotic and weedy dominant species) that were unlikely to be affected by the sampling differences.

Some sites had performance standards requiring the calculation of the mean coefficient of conservatism ($\overline{C}$) and Floristic Quality Index (FQI). Swink and Wilhelm (1994) developed these indexes as a means of rapidly assessing natural areas in the region around Chicago, Illinois, and Taft and others (1997) expanded the indexes for use throughout Illinois. Each native plant species was assigned a "coefficient of conservatism" (C), a subjective rating of species fidelity to undegraded natural communities, varying from 0 to 10, with higher values assigned to species less tolerant of degradation. The Floristic Quality Index is computed as $\mathrm{FQI} = \bar{C}\sqrt{S}$, where $\overline{C}$ is the mean coefficient of conservatism for all native plant species at a site and S is the total number of native plant species at the site.

The following approach was used to summarize the goals set for the wetlands and determine compliance frequencies: (1) Goals specified in site-monitoring reports were first categorized to determine what types of goals were set; (2) for each category of goals, we determined how success with respect to that goal has been evaluated (i.e., what specific performance criteria were established); (3) for each major category of goals, we determined what proportion of sites achieved the site-specific performance standards. A site was considered successful with respect to a given goal if it met all stated performance criteria related to that goal in its final year of monitoring. Sites were categorized as successful at meeting all goals, partially successful, or completely unsuccessful, and analyses of variance (ANOVA), followed by Scheffe tests, were used determine if these categories differed in mean wetland indicator status (Reed 1988) or in the mean number of goals originally set for sites.

Compliance success frequencies are of interest from a regulatory perspective. However, actual target levels for a given goal might vary widely among sites, so that frequencies of success, based solely on yes-or-no judgments of compliance, provide little insight into the overall level of performance across sites. Instead, performance of sites should be compared to a common standard. Therefore, the performance level for each site, in its final year of monitoring, was quantified for each category of goals, and the distribution of performance levels across all sites was compared to a common standard: the "typical" performance requirement. The typical performance requirement for a given goal was taken to be the mode of the distribution of performance requirements. For example, 53 sites had performance requirements establishing that some minimum percentage of the plant species at the site should be the desirable species. However, the definition of "desirable species," as well the percent required for success, varied among sites, making among-site comparison difficult. Therefore, we compared the distribution of percent native, nonweedy perennials across all sites (regardless of whether they specified this particular goal) to the most commonly required performance level for that goal (namely 50% native, nonweedy perennials). A similar approach was used to assess performance with respect to other site goals. Comparing the typical performance requirement to the distribution of success levels allowed for a qualitative assessment of whether the typical requirement was appropriate (i.e., not unachievably ambitious nor overly modest). Because sites were monitored annually for periods varying from 1 to 5 years, sites varied in age at their final year of monitoring.

For this study, native weeds were defined as native species that: 1) were listed as economic, noxious or colonizing weeds (Iverson and others 1999), or are typical of habitats that include waste areas, bare or disturbed ground (Mohlenbrock 2002); and 2) have coefficient of conservatism values of two or less (Taft and others 1997). Native status of species was based on Taft and others (2002). *Phalaris arundinacea*, *Typha* x *glauca*, and *Phragmites australis* were considered non-native to this region due to likely hybridization between native and non-native species or genotypes (Galatowitsch and others 1999; Saltonstall 2002).

We employed a distribution-free, randomization procedure, analogous to a repeated measures one-way ANOVA (Edgington 1995), to determine whether performance levels for common goals (planted tree survival; percent of planted herb species persisting; proportion of flora comprised of native, nonweedy, and perennial species; relative cover by hydrophytic species; number of non-native and weedy dominant species; and FQI) change over the first 4 years of monitoring. This analysis was limited to sites with at least 4 consecutive years of monitoring (n = 42). Performance levels are expected to vary widely among sites, and we were primarily interested in whether there were consistent time trends in performance levels within sites over time, rather than in among-site variability. Data were therefore permuted, 10,000 times, among years, within sites, using Resampling Procedures v. 1.3. The observed F-statistic for the effect of year was then compared to the distribution of F-statistics generated under a null hypothesis of no effect of year in order to calculate a P-value. Significance levels were adjusted using Bonferroni's method ($\alpha' = \alpha/k$, where k is the number of tests and α was set to 0.05).

Simple linear regressions were used to determine whether native species richness, FQI, mean coefficient of conservatism, or proportion of a site's flora comprised of desirable species increased with the number of herbaceous species planted at a site. Data from only the final year of site monitoring were used in these analyses. The number of species planted was $\log_{10}$-transformed prior to analyses. Some project areas consisted of multiple wetland sites in close proximity. Therefore, to ensure statistical independence, a single, randomly chosen site from each project area was included in regressions. Data were available on number of planted species for 33 independent sites.

Results

Goals and performance standards were grouped into 14 categories that were overwhelmingly focused on the plant community (see the Appendix). The most common goal, not unexpectedly, was to create or restore jurisdictional wetland as defined by the US Army Corps of Engineers (USACE 1987). Other commonly stated goals included ensuring adequate survival of planted species, specifications that the dominant species should not be exotic or weedy, specifications that a minimum proportion of the plant species at a site must be native, nonweedy, and/or perennial, and requirements for a minimum cover by vegetation or by hydrophytic plant species. With the exception of one site with a goal related to sediment accumulation rate, criteria were based on structural attributes and therefore did not require measures of dynamic processes.

Within broader categories of goals, performance standards and acceptable thresholds for success varied widely for some goals (see the Appendix). For example, acceptable levels of planted tree survival varied from 27% to 100%. Most performance standards established measurable benchmarks for success, but some were subjective and not measurable (e.g., site must have "good survival" of planted trees) and therefore were not useful for determining compliance. Some standards were site-specific and would not be applicable to other sites (e.g., standards specifying particular species that should be dominant), but most were very general and could be applied to any restored or created wetland.

Of a total of 76 sites, 8 sites failed to achieve any project goals in the final year of site monitoring, 45 sites met some, but not all, goals, and 23 sites achieved all goals. Of the sites that were partially successful, seven failed to create jurisdictional wetland and six of these also failed to comply with one or more vegetation-based standards. The remaining 38 partially successful sites did generate jurisdictional wetland but failed to meet some or all vegetation standards. Failed sites had vegetation more characteristic of upland communities (based on mean wetland indicator status) than partially successful or successful sites, reflecting a lack of appropriate wetland hydrology (ANOVA; $n = 72$; $F_{2,69} = 13.60$; $P < 0.001$; Figure 2A). Sites considered partially successful had more goals, on average, than sites considered fully successful (ANOVA; $n = 76$; $F_{2,73} = 12.87$; $p < 0.001$; Figure 2B), suggesting that one reason successful sites were considered "successful" is that they had fewer standards to achieve. It should be noted that the strict assumption of statistical independence among sites has been violated in these ANOVAs because some sites co-occurred within project areas.

Area of jurisdictional wetland created or restored was assessed at the project area level rather than the site level because jurisdictional wetland area was often summed across sites within project areas in the original monitoring reports. The total area proposed for wetland establishment was 113.6 ha in 37 projects, but the area actually established was 81.9 ha in 34 projects, based on an average area of jurisdictional wetland across all years during which a site was monitored. Thus, there was a deficit of 31.7 ha, and three projects failed to produce any wetland due to a lack of wetland hydrology. Two additional projects failed to establish wetland hydrology in a majority of years monitored. Overall, 67% of projects failed to create or restore their minimum required area. On average, projects established 70% of their required area of jurisdictional wetland. This deficit was due to failure to achieve wetland hydrology over the entire area intended for creation or restoration, rather than failure to construct sites. For 22 projects, information was available on the area of natural wetland that was originally impacted, so the mitigation ratio (ratio of area required for compensation to area of original wetland impacted) could be determined. For these projects, the proposed mitigation ratio was 1.55:1, which would result in a net gain of wetland area if all projects were successful. For this subset of projects, the actual, realized mitigation ratio was approximately 1.1:1, indicating a small net gain of wetland area.

For most goals, there were no obvious across-site trends in compliance over time (data not shown). In other words, as sites aged, the proportion of sites considered to be in compliance with permit conditions did not increase or decrease consistently.

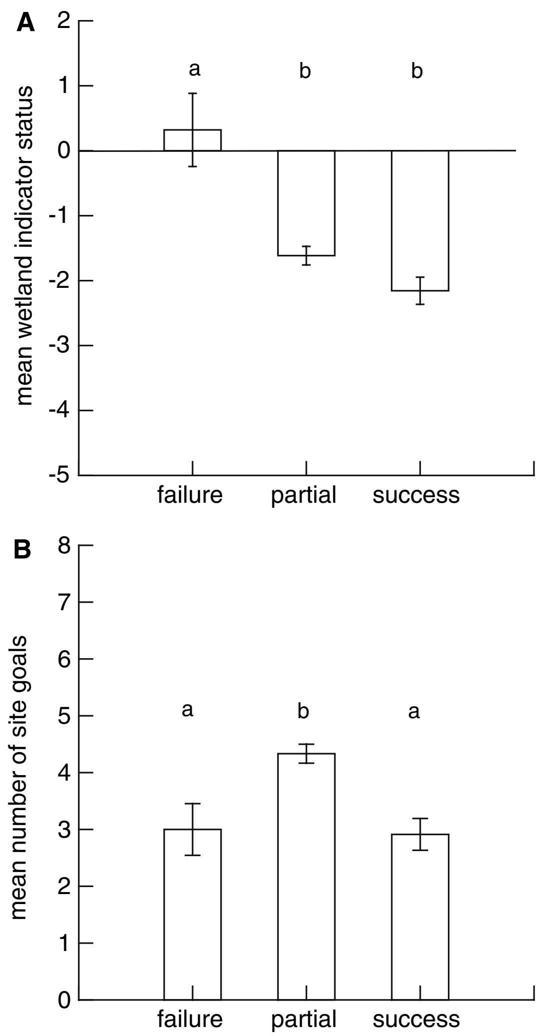

Fig. 2 **A** Mean (± standard error) wetland indicator status of failed, successful, and partially successful compensatory wetlands. **B** Mean (± standard error) number of site goals of failed, successful, and partially successful compensatory wetlands. Different letters above bars indicate significant differences ($P < 0.05$) among groups based on Scheffe test

Compliance success frequencies at the final year of site monitoring varied widely among goals (Table 1). Performance standards related to the survival of planted herbaceous species and planted trees were rarely met by the final year of site monitoring. Similarly, standards specifying a certain vegetation structure were rarely met (e.g., standards requiring some level of interspersion of emergent vegetation and open water for waterfowl habitat). A majority of sites with performance standards stating that no non-native or otherwise undesirable species could be dominant at the site failed to meet this standard. However, standards that specified a minimum vegetation cover, or cover by hydrophytic plant species, and standards that established a minimum percent native or nonweedy plant species at a site were frequently met, even in the early years of site

Table 1 Compliance frequencies for compensatory mitigation wetlands at the final year of site monitoring for major categories of site goals

Goal	No. of sites with goal assessable[a]	No. meeting goal in final year	Success rate
Create jurisdictional wetland[b]	72	58	81%
No undesirable species dominant	53	24	45%
Flora composed primarily of desirable species	53	38	72%
Site must have a minimum of total vegetation cover	31	24	77%
Survival of planted trees	19	4	21%
Goals regarding overall vegetation structure	14	2	14%
Goals regarding buffer vegetation	13	5	38%
Site must exceed a minimum FQI	11	6	55%
Site must have a minimum of cover by hydrophytes	11	10	91%
Survival of planted herbaceous species	9	1	11%
Plant species evenness or richness	1	0	0%
Sediment retention	1	1	100%
Natural regeneration of trees	1	1	100%

[a] For a given goal, the number of sites in which compliance was assessable based on information available in monitoring reports might be less than the number of sites with that goal (see the Appendix)

[b] Considered successful in final year if jurisdictional criteria were met in more than half of the years monitored

establishment. Compliance frequencies for some other goals could not be evaluated due to a lack of information in site-monitoring reports.

In order to generalize site performance across sites that had different performance standards and goals, measures of performance were compared to typical performance criteria (Figure 3). All sites (given availability of information) were included in these analyses, regardless of site goals and performance criteria. Median percent tree survival, measured as the number of planted trees surviving at the site in the final year of monitoring divided by the number originally planted at the site, was 31%, much lower than the most common criterion for percent tree survival (80%), and this typically required criterion for planted tree survival was met in fewer than 15% of sites. The typical performance criterion of no exotic or weedy dominant species was also met in fewer than 15% of sites. The most frequent exotic dominants were *Phalaris arundinacea* (among the dominants in 19% of sites), *Typha angustifolia* (14% of sites), and *Festuca arundinacea* (8% of sites). Frequent native weedy dominants were *Echinochloa muricata* (11% of sites) and *Eupatorium serotinum* (8% of sites). Typical performance criteria for planted herb persistence, proportion native, nonweedy, or perennial species, and number of exotic dominant species were met in fewer than half of the sites. However, all sites met the typical standard for percent native species, and 67% of sites met this standard for percent native or nonweedy species. The typical performance criterion of at least 75% relative cover by hydrophytic plant species was met in 74% of sites. A majority of sites also met the typical criterion for the FQI.

Randomization tests demonstrated that some, but not all, vegetation-based indicators improved over the first 4 years in sites with at least 4 consecutive years of monitoring (Table 2). Proportion of initially planted trees present in a given year was calculated as the number of individuals alive in that year divided by the number initially planted. Planted tree mortality was typically high during the first year, and in several cases, additional trees were planted in later years in response. Therefore, the ratio of living planted trees to the number initially planted could increase or decrease over time and potentially could exceed 1 in some years. However, no significant time trend (at $\alpha = 0.006$ after Bonferroni adjustment) was observed in the number of living planted trees relative to the number initially planted. The proportion of planted herb species persisting at a site tended to increase, although not significantly, over time. Based on information available in site-monitoring reports, this was likely a result of initially seeded species becoming established slowly over time, rather than as a result of subsequent plantings. The FQI and proportion of species that were native, nonweedy, and perennial increased significantly over time, although the increase in mean percent native species over 4 years was small. It should be noted that these variables are interrelated because sites with a high proportion of weedy and annual species will have a low FQI. The percent cover by hydrophytic species also increased over time, although this increase was only marginally significant after a Bonferroni adjustment. There was no significant trend, however, in the number of dominant weedy or exotic species over time.

The number of herbaceous species planted varied among sites from zero to 56 species ($n = 33$ sites). Native species richness, FQI, mean coefficient of conservatism, and proportion of a site's flora made up by native, nonweedy perennials were not significantly related to log-transformed number of species planted (native species richness: $r^2 = 0.00$, $\beta = 0.78$, $F_{1,31} = 0.01$, $P = 0.92$; FQI: $r^2 = 0.03$, $\beta = 1.76$, $F_{1,31} = 0.84$, $P = 0.37$; mean coefficient of conservatism: $r^2 = 0.07$, $\beta = 0.23$, $F_{1,31} = 2.36$, $P = 0.14$;

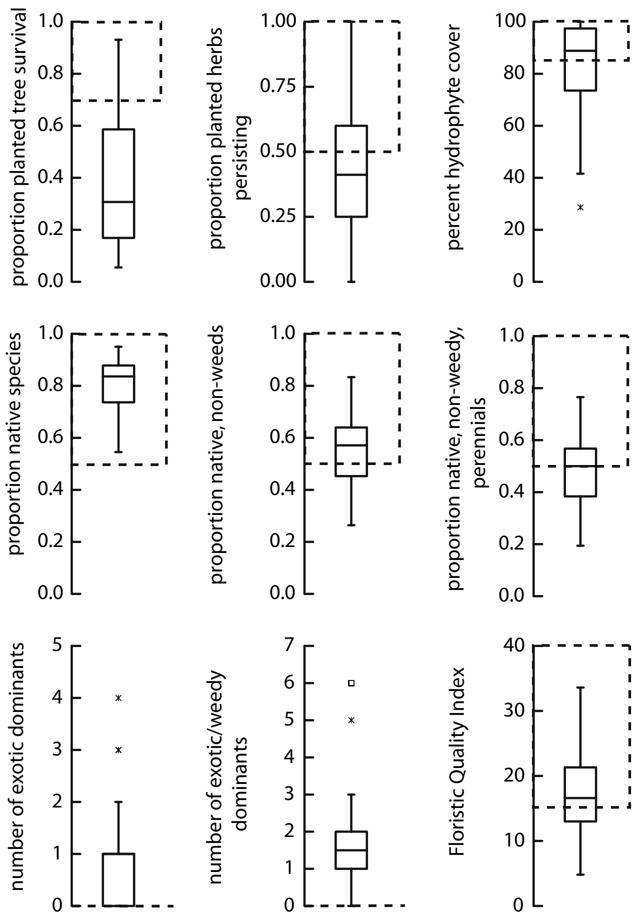

Fig. 3 Box-and-whisker plots illustrating the distribution of wetland site performance levels in comparison to typical thresholds for compliance success. Box-and-whisker plots illustrate the interquartile range (solid box), median (line in box), the range of the distribution (whiskers), and outliers (asterisks and circles). The range of values typically considered successful is represented by the dotted box. Sample sizes were 23 for tree survival, 25 for planted herb persistence, 42 for hydrophyte cover, 73 for proportion desirable species and FQI, and 72 for number of exotic and exotic plus weedy dominants

proportion native, nonweedy perennials: $r^2 = 0.07$, $\beta = 0.06$, $F_{1,31} = 2.19$, $P = 0.15$).

Discussion

Performance Standards and Compliance

Goals and performance standards reported here are similar to those reported for compensatory mitigation wetlands elsewhere in the United States. For example, in a review of 300 Section 404 permits, Streever (1999) identified 7 common approaches to performance standards: survival of planted vegetation, standards that are phased in over time, the use of reference sites to set standards, methods that are based on delineation of jurisdictional wetlands, the use of indexes to condense information, requirements for vegetation cover or plant density, and requirements limiting the occurrence of undesirable species. Six of these approaches were employed in the sites reviewed here. No sites in the present study had performance criteria based on an explicit reference to natural wetlands, however. As in the present study, other studies have reported that the most commonly measured characteristic of compensatory wetlands was vegetation, with performance standards often requiring a certain level of vegetation cover or percent survival of planted vegetation (Breaux and Serefiddin 1999; Spieles 2005).

Most sites reviewed here can be considered partially successful from a compliance standpoint, meeting some, but not all, project goals. Herbaceous vegetation planting was often unsuccessful in the sites reviewed here. Planted tree survival also failed to meet required goals in a majority of sites. Dominance by exotic and weedy species, most notably *Phalaris arundinacea*, was an additional barrier to compliance. Most sites, however, complied with standards related to percent desirable plant species and, as reported in other studies (Brown and Veneman 2001; Cole and Shafer 2002; Spieles and others 2006), standards for total vegetation cover and cover by hydrophytic plant species.

Very few projects were completely unsuccessful at creating or restoring at least some wetland area, but for a majority of projects, the area of wetland actually constructed was less than the area planned for the project. These results call into question the effectiveness of the Section 404 permitting process with respect to the national goal of no-net-loss of wetland area. However, because this study considered only sites constructed by a single permittee and included sites that ultimately were not accepted as successful by the US Army Corps of Engineers, this study cannot fully address this issue. Previous studies, however, that have reviewed national or state wetland permitting programs have invariably found low success rates for the compensatory mitigation process. Often, required sites are never installed or are never monitored after installation (Brown and Veneman 2001; Hornyak and Halvorsen 2003; NRC 2001; Race and Fonseca 1996; Robb 2002; Sudol and Ambrose 2002). The area of wetland actually created or restored, on a regional or statewide basis, is less than the area required, often leading to a net loss of wetland area at regional scales (Breaux and Serefiddin 1999; Brown and Veneman 2001; Morgan and Roberts 2003; Kentula and others 1992; NRC 2001; Race 1985; Sifneos and others 1992). When restoration or creation is attempted, compliance with permit conditions is often low (Morgan and Roberts 2003; Sudol and Ambrose 2002; Wilson and Mitsch 1996). A recent review of several studies by the National Research Council (NRC 2001)

Table 2 Results of repeated measures one-way ANOVA via randomization, testing for an effect of monitoring year on commonly used measures of compensatory wetland performance, over the first 4 years of site monitoring

Measure of success	*n*	Mean in year 1	Mean in year 4	Observed *F*	*P*
No. of trees alive, relative to number initially planted	14	0.54	0.45	1.21	0.33
Proportion of planted herb species persisting	17	0.31	0.41	3.64	0.01
Proportion of flora made up by native species	41	0.79	0.82	6.75	0.0003
Proportion of flora made up by native, nonweedy species	41	0.51	0.56	6.16	0.0005
Proportion of flora made up by native, nonweedy perennials	41	0.41	0.49	9.56	<0.0001
No. of exotic dominants	41	0.85	0.66	0.73	0.54
No. of exotic and weedy dominants	41	2.10	1.71	1.17	0.33
Relative percent cover by hydrophytic plant species	19	82.1	90.7	4.30	0.006
Floristic Quality Index	41	14.7	19.4	27.99	<0.0001

estimated that about half of projects fail to meet their requirements.

Compliance Versus Success

Compliance with permit conditions is a poor indication of a site's success at replacing the functions of a destroyed natural wetland; therefore, a distinction must be made between compliance success (a regulatory issue) and ecological or functional success (Kentula 2000; Wilson and Mitsch 1996; Zedler and Callaway 2000). Site functional failure has been attributed to a lack of knowledge of wetland ecology among regulators and restoration practitioners (Mitsch and Wilson 1996; Zedler 2000), poor site location relative to the surrounding landscape (Simenstad and others 2006), poor vegetation establishment (Brown and Veneman 2001; Morgan and Roberts 2003; Race 1985), and failure to establish appropriate hydrologic regimes (Brown and Veneman 2001; Galatowitsch and van der Valk 1996; Loucks 1992; Mitsch and Wilson 1996; Morgan and Roberts 2003; Race 1985; Zampella and Laidig 2003; Zedler 2000).

Some of the sites reviewed here were clearly functional failures, largely due to inappropriate hydrology and dominance by exotic species. These functional failures resulted in failure to achieve permit compliance. However, this study demonstrates that a judgment of compliance success or failure is also a function, to a large extent, of the standards chosen to measure site performance. Not unexpectedly, sites with fewer goals were more likely to be considered successful. Furthermore, some standards were apparently either unrealistically stringent or too modest to be of value in assessing site performance. Unrealistically high expectations might reflect overconfidence in restoration technology and our ability to compensate for lost wetland functions, which might ultimately result in an overreliance on restoration and creation as a form of mitigation. Standards that are too lenient result in the acceptance of poorly performing compensation sites as mitigation for destroyed natural wetlands.

Comparing the site performance from a number of sites to typical goals can help distinguish between situations where goals were not appropriate from situations where sites are not performing. Among sites with planted trees or herbaceous species, survival of planted stock was usually lower than typical standards required. This suggests that if a certain number of planted species or individuals is desired, more individuals, and perhaps a wider variety of species, must be planted with a lowered expectation for establishment.

The typical performance standard for percent native species at a site (>50%) is too low to be of value in distinguishing heavily invaded sites from noninvaded sites. Natural wetlands in this region have, on average, much greater than 50% native species. A set of 551 wetlands sampled throughout Illinois during jurisdictional wetland delineations had an average of 82.4% native species per site (J. Matthews, unpublished data), which is comparable to the average for the compensatory sites in this study (81.3%). Benchmarks for native species presence as well as benchmarks based on indexes like FQI should be based on reference to natural wetlands of similar size, community type, and region as the compensatory wetland so that there is true ecological compensation rather than arbitrary regulatory accomplishment.

Although most sites failed to meet the often-required performance standard specifying that exotic and or weedy species should not be dominant at a site, this standard does not seem inappropriate or overly stringent. However, based on the observed poor performance with respect to this standard, more intensive management is needed to control undesirable species, especially given the high levels of exotic invasion in natural wetlands that act as seed sources for constructed sites (Spyreas and others 2004; Zedler and Kercher 2004). Some weedy and exotic species are likely to decline in dominance over time (e.g., *Echinochloa muricata* in the present study), and their presence is not necessarily indicative of functional failure in recently restored sites. Other, more invasive, species can form stable communities in restorations, preventing the recruitment of desired, native species (Kulmatiski 2006; Stylinski and Allen 1999). Because of the often inhibitory effect of early invaders on further vegetation change (Connell and Slatyer 1977), restoration practitioners should not assume that invasive species will be replaced by desired native communities via succession (Klötzli and Grootjans 2001; Suding and others 2004). We found no evidence that the number of exotic and weedy dominants declined over 4 years in these sites (see Table 2).

Most sites met the typical performance standard requiring greater than 75% cover by hydrophytic species. It is not clear, however, why a site with more cover by hydrophytic species should be considered more successful. Wetland designers have often erred on the side of greater depth or duration of flooding, creating wetlands that are wetter than the natural wetlands they are meant to replace (NRC 2001). This type of performance standard could have the undesirable effect of encouraging this practice. Given that the primary goal is to create jurisdictional wetland, which requires the establishment of dominant hydrophytic vegetation, wetland hydrology, and hydric soils, this additional performance standard requiring some minimum cover by hydrophytes is redundant and unnecessary as long as the site has an acceptable level of overall vegetation cover.

Improving Predictability in Wetland Compensation

Ultimately, setting appropriate, scientifically valid performance standards will require improved prediction of restoration outcomes and, thus, an understanding of restoration site development over time. Results of this study suggest that vegetation indicators generally improved over the first 4 years of monitoring. Other studies of restored and created freshwater wetlands have reported increases in plant species richness over time (Campbell and others 2002; Moore and others 1999; Reinartz and Warne 1993), higher FQI in older wetlands (Balcombe and others 2005), and decreases in the presence of exotic species over time (Spieles 2005). However, many studies have reported increases in the abundance or cover of particularly invasive species as restored and created wetlands age (Garde and others 2004; Noon 1996; Moore and others 1999; Reinartz and Warne 1993), suggesting that restored and created wetlands might become biologically simplistic over longer timescales. The timescale of the present study was too short to determine if increasing dominance of exotic species will eventually lead to a decline in other measures of site performance.

Planting restored wetlands with native species might discourage the establishment of unwanted, highly dominant species and increase the diversity of native species (Armitage and others 2006). Restored wetlands in Wisconsin were found to have lower cover by cattails (*Typha* spp.) and higher diversity of native wetland plants when planted than when unplanted (Reinartz and Warne 1993). Other studies, however, suggest that planting restored wetlands is unnecessary (Kellogg and Brigham 2002; Mitsch and others 1998). Although we found no effect of number of planted species on native species richness, or on other site-scale indicators of floristic quality, planting native species that would not otherwise colonize a site might still increase the site's contribution to local and regional biodiversity (Galatowitsch 2006).

Recommendations

Two recommendations, not unique to this study but supported by its findings, can be made to improve the establishment of performance criteria. First, the range of performance criteria used to evaluate compliance should be expanded. Performance is most commonly measured by quantifying properties of the vegetation, but such structural properties do not necessarily reflect ecosystem function (Mitsch and Wilson 1996; NRC 2001; Parker 1997). The range of site attributes measured could be expanded to include topography, soils, hydrology, and wildlife, as well as functional attributes of sites (NRC 2001, Ruiz-Jean and Aide 2005; Zedler 1996, Zedler and Callaway 2000). Site-specific goals could be based on wetland functions lost as a result of the permitted activities (NRC 2001; Streever 1999) or based on functions found to be lacking at a watershed scale (Bedford 1999; Brooks and others 2006). Second, more realistic benchmarks for compliance should be set based on reference to the surrounding landscape, natural reference sites, and performance over time in previously restored sites. Permitting agencies will be able to make more informed decisions regarding permit approvals, mitigation site locations, mitigation ratios, performance criteria, and postconstruction monitoring protocols if they can more accurately predict the outcomes of restoration.

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Appendix

Goals and Performance criteria for 76 Compensatory Mitigation Wetlands Sites in 38 Illinois Project Areas

Goal	Sites	Projects	Goal	Sites	Projects
Create jurisdictional wetland	73	37	Total vegetation cover	31	11
Dominance	56	29	20% vegetation coverage in emergent zone	3	1
No exotic or noxious dominants	3	1	30% vegetation coverage	4	2
No exotic or invasive dominants	4	1	50% vegetation coverage	1	1
No exotic or weedy dominants	1	1	50% vegetation coverage in emergent zone	9	3
None of 3 most dominant exotic	5	3	75% vegetation coverage in zones other than emergent	8	2
None of 3 most dominant exotic or *Typha* spp.	18	9	75% vegetation coverage in wet prairie zone	1	1
None of 3 most dominant exotic or weedy	11	7	75% vegetation coverage	16	6
None of 3 dominants exotic, weedy, or nonhydrophytic	2	1	Vegetation coverage should be dominant	2	1
None of 3 most dominant in any stratum exotic	1	1	Planted herb persistence or cover	19	8
None of 3 most dominant in any stratum exotic or weedy	4	2	50% of planted herb species persist	14	5
50% of dominants native and nonweedy	5	2	70% of planted herb species should establish	2	1
Dominated by native herbaceous species in ground layer	1	1	50% areal coverage by planted herbs	2	1
Dominated by tall graminoids	1	1	70% of herbaceous cover must be planted species	2	1
Woody species must be dominant	1	1	Good survival of planted herbs	2	1
No woody dominants	2	1	Cover by hydrophytic species	11	7
Sparganium eurycarpum must be a dominant species	1	1	50% of area with hydrophyte cover	5	2
Planted trees should dominate	1	1	75% of area with hydrophyte cover	2	2
Certain planted tree species specified as dominant	1	1	25-80% of area with hydrophyte cover	1	1
Planted tree survival	24	19	Yearly goal for hydrophyte cover (75% by 5 years)	3	3
100% planted tree survival	3	1	Mean native wetness rating of 0 or less	1	1
80% planted tree survival	6	6	Overall vegetation structure/composition	14	6
75% planted tree survival	1	1	Hemimarsh of 50% open, 30% emergent, 20% sedge	8	1
50% planted tree survival	3	3	Establish a floodplain forest	1	1
1500 live trees after 5 years (100% survival)	1	1	Should resemble natural aquatic emergent composition	1	1
60 trees alive after 5 years (92% survival)	1	1	Should resemble natural wet prairie composition	1	1
300 stems/acre (27% survival)	1	1	Less than 40% open water	1	1
100 stems/per acre after 5 years (89% survival)	1	1	Less than 30% open water	1	1
Survival rates specified by seedling type (36% overall)	1	1	High interspersion of vegetation and open water	1	1
Planted trees account for 70% of woody cover	1	1	No planted or volunteer should exceed 40% density	1	1
50% survival of each species	2	1	Floristic quality	11	4
70% of planted species represented by live individuals	1	1	FQI > 20 and mean coefficient of conservatism > 3.5	1	1
50% of planted species represented by live individuals	2	2	FQI > 15	8	2
Good survival of planted trees	2	1	FQI > 7, mean coefficient of conservatism > 2	2	1
Nativeness/nonweediness of flora	53	26	FQI must increase each year	1	1
50% of species native	4	2	Buffer goals	13	4

continued

Goal	Sites	Projects	Goal	Sites	Projects
50% of species native and nonweedy	9	4	Buffer should have 75% vegetation cover	8	1
50% of species native, nonweedy perennials	15	9	No evidence of erosion in the buffer	11	2
50% of species native, nonweedy hydrophytes	2	1	Planted species should establish in the buffer	11	2
70% of species native and nonweedy	1	1	Native perennials persist in buffer	1	1
90% of species native and nonweedy	1	1	Buffer dominated by native, non-weedy perennials	9	2
50% cover by native, nonweedy species	8	1	Good survival of planted trees in buffer	1	1
50% cover by native, nonweedy perennials	8	2	Natural regeneration of trees should occur	1	1
75% cover by native, nonweedy perennials	1	1	Sediments should accumulate at a rate of 0.3–1.1 in/year	1	1
Relative importance of native species increases yearly	1	1	State threatened/endangered birds should be present	8	1
Yearly goal for percent native species (50% after 5 years)	3	3	State EPA water quality standards should be met	8	1

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