Environmental Management (2012) 50:97–105
DOI 10.1007/s00267-012-9861-2

Compliance with Wetland Mitigation Standards in the Upper Peninsula of Michigan, USA

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Received: 23 November 2010 / Accepted: 30 March 2012 / Published online: 29 April 2012
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Abstract The United States has lost about half its wetland acreage since European settlement, and the effectiveness of current wetland mitigation policies is often questioned. In most states, federal wetland laws are overseen by the U.S. Army Corps of Engineers, but Michigan administers these laws through the state's Department of Environmental Quality (MDEQ). Our research provides insight into the effectiveness of the state's implementation of these laws. We examined wetland mitigation permit files issued in Michigan's Upper Peninsula between 2003 and 2006 to assess compliance with key MDEQ policies. Forty-six percent of files were out of compliance with monitoring report requirements, and forty-nine percent lacked required conservation easement documents. We also conducted site assessments of select compensatory wetland projects to determine compliance with MDEQ invasive plant species performance standards. Fifty-five percent were out of compliance. We found no relationship between invasive species noncompliance and past site monitoring, age of mitigation site, or proximity to roads. However, we found wetland restoration projects far more likely to be compliant with performance standards than wetland creation projects. We suggest policy changes and agency actions that could increase compliance with wetland restoration and mitigation goals.

Keywords Wetlands · Mitigation · Restoration · Invasive species · Compensatory

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Introduction

Wetlands are often considered among the most valuable ecosystems on earth. Efforts to conserve or protect wetlands, however, did not gain international momentum until the 1960s. This movement was led both by governments and non-governmental organizations, and featured notable international treaties such as the 1971 Ramsar Convention on Wetlands (Erwin 2009; O'Connell 2003; Turner and others 2000; Zedler and Kercher 2005). Despite progress in many areas, wetlands remain a globally threatened resource characterized by misunderstanding, ineffective policies, and difficult valuation (BenDor and others 2008; Turner and others 2000). Since 1900, about half of the world's wetlands have been destroyed (Barbier 1993).

Most global wetland losses are driven by human population growth and economic motives such as expansion for urban areas or agriculture. In developing nations with scarce water resources, wetland losses from human activities can be particularly devastating (Brock and others 1999; Kingsford 2000; Schuyt 2005; Wang and others 2008). Developed nations with abundant water resources and well-developed environmental policies also suffer losses of wetlands (Rundcrantz and Skarback 2003; Wende and others 2005). For instance, Canada is wetland-rich and has a very low population density, yet struggles with wetland losses due to an incomplete wetland inventory, jurisdictional conflicts, and ineffective policy enforcement (Rubec and Hanson 2009; Schulte-Hostedde and others 2007).

The United States has lost about half its wetland acreage since European settlement (Dahl 1990; Mitsch and Gosselink 1993). To minimize wetland losses, Section 404 of the 1972 U.S. Clean Water Act (CWA) and its amendments regulate activities impacting wetlands. A permit must be obtained for these activities, and the permit applicant must first demonstrate that avoidance of wetland impacts has been explored and is not a feasible option. Next, any unavoidable impacts must be minimized to the greatest extent possible. Finally, wetland impacts must be compensated for by the restoration or creation of new wetlands (US EPA 1990). This multi-step process is known as wetland mitigation, and the human-made wetlands that result are commonly referred to as "compensatory wetlands."

In most states, U.S. federal wetland protection laws are administered by the U.S. Army Corps of Engineers (ACE), in conjunction with the U.S. Environmental Protection Agency (EPA). However, in 1984 Michigan became the first state to assume responsibility for Section 404 administration, which entails day-to-day oversight of wetland permitting and mitigation (Hornyak and Halvorsen 2003). "No net loss" continues as the central objective of federal wetland policy, despite widely-reported difficulties associated with the compensation process (Bies 2006; Gaddie and Regens 2000; National Academies 2001; Squillace 2006; Zedler 1996).

Wetlands are inherently complex ecosystems and their study involves a substantial degree of uncertainty that is often difficult for management agencies to evaluate (Breaux and Serefiddin 1999; Smith and others 2008). Challenges may also result from jurisdictional disputes, limited agency funding, a lack of accurate records, or limited ecological knowledge (Dale and Gerlak 2007; Krogman 1999). Wetland management also includes a range of management objectives that extend beyond traditional ecosystem science, further challenging the management abilities of agencies with limited resources (Euliss and others 2008; Kaplowitz and Kerr 2003; Krogman 1999; Smith and others 2008). Many restoration ecologists agree that U.S. wetland mitigation policies are often based on unclear or unrealistic goals (Ehrenfeld 2000; Euliss and others 2008; Matthews and Endress 2008; Smith and others 2008; Zedler and Callaway 1999).

Some agencies have difficulty enforcing relatively simple permit requirements. For instance, one study found that 48 % of mitigation permit files in one Michigan region were missing at least one piece of required paperwork (Hornyak and Halvorsen 2003). This problem was particularly common among mitigation projects involving county road agencies, as only 15 % of their files contained site monitoring reports (Hornyak and Halvorsen 2003). This study only involved inspections of file contents, so any possible linkages between monitoring and site conditions were unanswered.

The reliance on compensation in the mitigation process has led to the profusion of replacement wetlands that may not provide equivalent functions and values to the wetlands they replace (Burgin 2010; Dale and Gerlak 2007; Reiss and others 2009). Compensatory wetlands are often constructed far from the wetlands they were intended to replace, resulting in negative watershed impacts (Brown and Lant 1999; Zedler 1996). This is typically the case with mitigation banks, where large, off-site wetlands are built to compensate for multiple, smaller wetland impacts elsewhere—a strategy which tends to result in poor quality replacement wetlands (Bies 2006; Brown and Lant 1999; Burgin 2010; Zedler 1996). Mitigation policies emphasize performance standards that do not necessarily protect ecosystem functions and services (Bies 2006; Zedler 1996). Compensatory wetlands in the U.S. are often deemed a success when they actually pale in comparison to the wetlands they replace (Dale and Gerlak 2007; Euliss and others 2008; Krogman 1999; Zedler and Callaway 1999).

Hydrologic conditions are typically considered one of the most important wetland characteristics, influencing fauna, soils, and vegetation (Falk and others 2006; Mitsch and Gosselink 1993; Stolt and others 2000). In many studies of U.S. compensatory wetlands, sites have been found to possess serious design flaws that limit their functions and values, including unsuitable hydrology and a lack of topographic variability (Brown and Veneman 2001; Campbell and others 2002; Cole and Shafer 2002; Morgan and Roberts 2003; Stolt and others 2000). These flaws may result in the creation of the wrong wetland type, a wetland smaller than specified in the permit, or no wetland at all.

The composition of plant communities in compensatory wetlands often differs from those of natural wetlands. In many cases, total plant cover is comparable to natural wetlands but diversity is not. These sites often have higher rates of pioneer and non-native species, and fewer species of higher value to wildlife (Balcombe and others 2005; Spieles 2005; Spieles and others 2006). This problem has been noted in mitigation banks that rely on the creation of wetlands versus the restoration of them (Burgin 2010; Spieles 2005; Spieles and others 2006). Undesirable species may decline over time as compensatory wetlands age, but developers are often not required to monitor them long enough to see these changes (Spieles and others 2006). Inadequate additions of organic matter can also result in increased invasive plant species (Mitsch and Gosselink 1993; Pennala, 2008, personal communication).

All wetlands are vulnerable to negative impacts from nearby roads, but the disturbance patterns associated with wetland construction make roadside compensatory sites particularly vulnerable to invasive plant species (Moore and others 1999). In many cases nitrogen and chloride levels are higher in roadside compensatory wetlands than natural wetlands, leading to a reduced ability to process roadway runoff (Moore and others 1999). Although roadside compensatory wetlands may provide sediment retention or water storage, ecological values could be greatly increased by design and construction improvements. However, many highway construction projects appear to be carried out with minimal concern for ecological consequences (Cuperus and others 1999; Moore and others 1999).

Michigan's Wetland Regulations

Most wetland management decisions in Michigan are made at the state level. Part 303 of Michigan's Natural Resources and Environmental Protection Act of 1994 (NREPA) details the state's wetland regulation policies (Michigan PA 451 Part 303, 1995). Part 303 of NREPA largely resembles Section 404 of the CWA. Consequently, the MDEQ's wetland permit documents are referred to as "joint permits" that meet both state and federal requirements. Michigan wetlands are subject to protection if they are: (1) connected to or within 1,000 ft of a Great Lake or Lake St. Clair; (2) connected to or within 500 ft of any inland water body; (3) >5 acres in size; or (4) otherwise deemed ecologically critical by the MDEQ (Michigan PA 451 Part 303, 1995).

Applicants whose permits are approved receive permission to go forth with their wetland-impacting project as long as they construct, restore, or preserve wetlands of a size and type prescribed by the MDEQ (Michigan PA 451 Part 303, 1995). This process mirrors the EPA's avoid-minimize-compensate objectives described previously (US EPA 1990). If compensation is required, the size of the compensatory wetlands is determined primarily by the ecological characteristics of the impacted wetlands. The compensation ratio typically ranges from 1:1 to 5:1 (Michigan PA 451 Part 303, 1995; Pennala, 2008, personal communication). The MDEQ may determine that some wetlands possess particularly high ecological value (e.g., coastal wetlands) and therefore require compensation at a 10:1 or higher ratio (Pennala, 2008, personal communication). The compensatory wetlands should be located in the same watershed as the impacted wetlands, preferably adjacent to them if site conditions allow (Pennala, 2008, personal communication). The MDEQ may also assist in construction design, including specifying soil, vegetation, and hydrologic characteristics. For compensation, the MDEQ prefers restoration over creation when conditions allow (Pennala, 2008, personal communication).

When issued, wetland-impact permits clearly describe the construction and performance standards that are to be met. Permittees are also required to monitor the sites and submit comprehensive annual reports to the MDEQ for at least five years after site construction (Michigan PA 451 Part 303, 1995). Wetland-impact permits describe in detail what is to be monitored, how it is to be monitored, and what is to be included in annual reports. These can include documentation of hydrology, soils, organic cover, wildlife sightings, and vegetation (Michigan PA 451 Part 303, 1995).

All compensatory wetland sites must have, on average, <10 % invasive plant species cover (Michigan PA 451 Part 303, 1995). Noncompliant sites must be corrected as described in a plan to be added to the file by the permittee. The agency often provides technical advice and recommendations to permittees (e.g., herbicide selection and use, burning, or manual removal) before action is taken. The results of such efforts are to be included on subsequent monitoring reports (Pennala, 2008, personal communication). If these actions do not fix the problem, the MDEQ may require that the site be re-constructed or re-vegetated (Pennala, 2008, personal communication).

Michigan road agencies must adhere to the same wetland mitigation policies, procedures, and site performance standards as individual (private) permittees. However, because road agencies tend to be repeat applicants due to their frequency of wetland-impacting projects, they often compensate for numerous wetland impacts at a single site. These sites therefore resemble mitigation banks, where wetland acreage "credits" are created or restored to offset "debits" at far-away projects. The MDEQ and the Department of Transportation (MDOT) created this arrangement in the 1990s in an effort to reduce paperwork, increase project efficiency, and create larger and fewer mitigation sites, which can have greater ecological value than smaller ones (Pennala, 2008, personal communication; Pennington, 2009, personal communication). In rural northern Michigan, road agencies frequently hold a large proportion of mitigation permits (Pennala, 2008, personal communication).

Most wetland mitigation studies focus on one of two areas, which can be described as "policy analysis" or "condition assessment." Policy analyses tend to characterize effectiveness by examining permit file compliance, ultimately to offer insight on wetland management from a bureaucratic perspective (Dale and Gerlak 2007; Hornyak and Halvorsen 2003; Krogman 1999). In contrast, condition assessments typically involve direct biophysical comparisons between compensatory and natural wetlands, involving vegetation, soil, or hydrologic characteristics (Campbell and others 2002; Morgan and Roberts 2003; Stolt and others 2000). The typical objective of this type of research is to characterize gains and losses of wetland functions resulting from the process of mitigation. Others yet discuss the human-related values of preserving natural wetlands (Bendor 2008; Burgin 2010; Johnson and Pflugh 2008; Kaplowitz and Kerr 2003; Lupi and others 2002).

Little work combines these multiple perspectives, leaving uncertainties about linkages between policy compliance and long-term ecological outcomes. Few have examined relationships between long-term site monitoring and ecological conditions (Brown and Veneman 2001; Cole and Shafer 2002; Matthews and Endress 2008). This is an important gap because quality wetland development takes years, yet rates of site monitoring and agency follow-up are frequently low (Spieles and others 2006). Comprehensive national reports have also identified flaws in the compensatory strategy of the "No net loss" objective, despite its very frequent implementation (National Academies 2001). Therefore our primary research objective was to examine compliance-monitoring-condition relationships at compensatory wetland sites.

Research Design

We selected recent compensatory wetland projects in Michigan's western Upper Peninsula (U.P.) and assessed their performance linking permit file compliance, long-term site monitoring, and ecological conditions. We focused on three key MDEQ policies: (1) Site monitoring reports must have been conducted by permittees and submitted to the MDEQ annually for 5 years; (2) wetland acreage must have been placed into conservation easement; and (3) invasive plant species must be limited to 10 % of total vegetative cover (Michigan PA 451 Part 303, 1995). We formulated four hypotheses based on a literature review and our early discussions with relevant MDEQ officials:

H_1 Permit files in 2008 will be more likely to include monitoring reports than they did in 2003.

H_2 Sites with monitoring reports in the permit files will be more likely to be in compliance with the maximum 10 % invasive plant species coverage requirement than sites for which the monitoring report had not been filed.

H_3 Compensatory wetland sites built recently or located close to roads will have higher predominance of invasive plant species than older sites or sites farther from roads.

H_4 Restored wetlands will have fewer invasive species than created wetlands.

In early 2008 we accessed the MDEQ's computerized CIWPIS system to identify all relevant mitigation permits that had been issued in the region between 2003 and 2006. Before inspecting files, we sorted all permits into the following four classes: (1) Michigan Department of Transportation (MDOT); (2) county road commissions; (3) other/public; and (4) private. Physical inspection of permit files occurred in June 2008 at the two regional MDEQ offices in Gwinn and Crystal Falls, Michigan. This search resulted in 57 wetland-impact permits issued in the study area during this period. The 57 permits corresponded to 37 actual compensatory wetland projects, because many projects were compensated together at a single location (as described previously). According to MDEQ policies, all 37 of these files were expected to contain annual site monitoring reports and conservation easement documentation. We found permittees noncompliant if files lacked either of these documents.

Of the 37 compensatory wetland projects across the U.P. during this period, road agencies combined to represent by far the largest class of permittees (20 of 37). Considering the previously-documented problems with road-related compensatory wetlands, we focused our site assessments exclusively on cases from this class. These compensation projects were conducted by either the state MDOT or by county road commissions operating in the region. All cases represent "permittee-responsible mitigation", where the permittee retains full responsibility for the outcome of the project even if subcontractors are used. Of these 20 sites, our field assessments included all 11 located in the western half of the peninsula (limited by time, scope, and travel costs). The 11 sites were distributed over eight counties (Fig. 1).

We conducted assessments of the compensatory wetland sites between June and September of 2008. At each site we visually estimated the total percent cover of all invasive species of trees, woody vines, shrubs, forbs, grasses, sedges, and rushes. We defined "invasive species" as those non-native plants identified as problematic by Michigan State University's Natural Features Inventory (2007). Our objective at this step was to estimate each site's compliance or non-compliance with the DEQ's limit of 10 % invasive cover.

We used releve sampling to document and estimate cover-abundance for each invasive species (Mueller-Dombois and Ellenberg 1974). Each releve was 10 by 10 m. The number of releves used at each site was determined by the number of homogenous stands of vegetation, and the placement of the releve was random within each stand (Chimner and others 2010). To increase efficiency and avoid oversampling at any site, we utilized one releve per homogenous stand. Thus, the total amount of releves at each site varied based on site characteristics. Some small, homogenous wetlands had a single releve while larger, diverse ones had as many as five.

All invasive species in each releve were documented. The total cover of each species within the releve was visually estimated into one of the following six categories: 0–1, 1–5, 5–25, 25–50, 50–75, or 75–100 %. We later used the midpoint value of each category for our analyses, to provide a simple method to estimate total percent cover for all invasive species found within the releve (Brown and Veneman 2001).

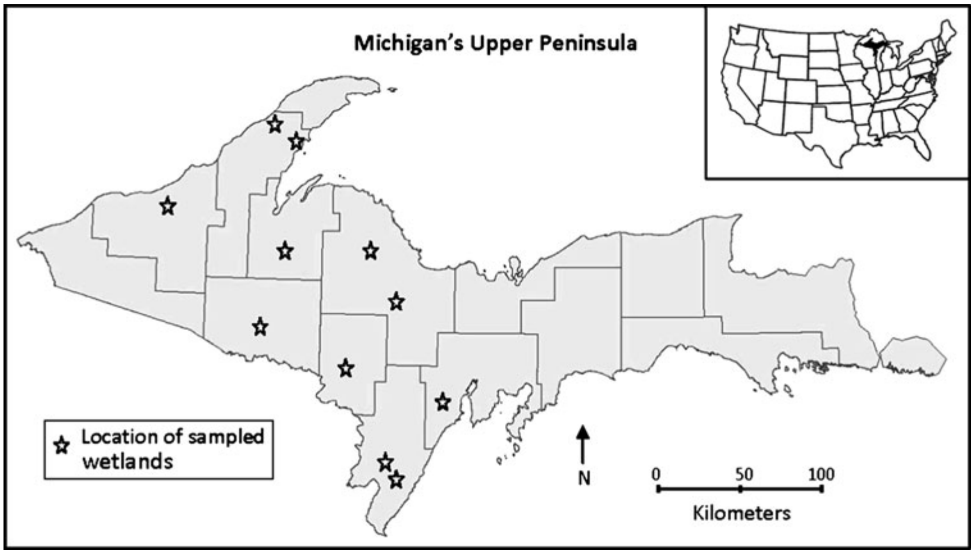

Fig. 1 Michigan's Upper Peninsula, and the 11 sampled wetland locations

For example, values for category 1 (0–1 %) became 0.5 %, values for category 2 (1–5 %) became 3 %, and so forth. Total percent cover for all invasive species was calculated by summing the respective midpoint values for all invasive species found. This method provided a characterization of plant communities suitable for the scope of our research, as our intent was to simply estimate whether each site's total invasive cover was likely above or below the MDEQ's 10 % limit. Sites with total invasive cover above 10 % would therefore be assessed as noncompliant for invasive species. We described each site's compliance status as "likely in compliance" (<10 % total cover) or "likely out of compliance" (>10 % total cover).

For additional insight, we photocopied pre-construction photographs and construction site plans from permit files to infer conditions at each site prior to wetland construction. This also allowed us to compare pre-project design specifications to post-project results. At each site we quantified distances in meters from the wetland boundary to the nearest road. We then utilized GIS land-cover and National Wetland Inventory datasets to help characterize the features of the surrounding landscape immediately adjacent to each project (and to supplement photographs and qualitative observations). We used a dichotomous variable to describe whether each site was directly adjacent to a natural wetland or not. These data was proved valuable in our analyses, since factors such as road proximity and adjacent landscape features can influence seed dispersal and species composition regardless of efforts made by permittees.

Results

H_1 Permit files in 2008 will be more likely to include monitoring reports than they did in 2003.

Results from analyses of H_1 reflect our examinations of MDEQ permit files ($n = 37$). The overall monitoring compliance rate for all permittee classes was 54 %, as 20 of 37 permit files contained monitoring reports. In the 2003 study, 31 % (11 of 35) of files contained monitoring reports. Although the percentage of compliant cases increased between 2003 and 2008 studies, a chi-square test of independence determined that the difference is not significant ($\chi^2 = 3.755$; df = 1; $\alpha = .05$). Therefore, we reject H_1 and conclude that monitoring compliance has not significantly increased.

File document compliance rates varied widely by permittee class. The MDOT was most compliant with regard to monitoring (9 of 10), while county road commissions were the least compliant (3 of 10). Monitoring compliance rates for other/public and private permittee classes were comparable, at 45 and 50 % respectively. We found 19 of 37 files (51 %) compliant for conservation easement documents, with no discernable trends across permittee classes. The 2003 study did not single out rates for compliance with conservation easement documents, so we can offer no comparison in this regard.

H_2 Sites with monitoring reports in the permit files will be more likely to be in compliance with the maximum 10 % invasive plant species coverage requirement than sites for which the monitoring report had not been filed.

Results from this hypothesis reflect our findings from file examinations ($n = 37$) and our field sample of corresponding compensatory wetland sites ($n = 11$). A chi-square test of independence determined that the difference in invasive species compliance between monitored and unmonitored sites was not significant ($\chi^2 = .110$; df = 1; $\alpha = .05$). Therefore, our findings did not support H_2 and we reject the hypothesis. Agencies that were in compliance with monitoring requirements were not more likely to be in compliance with invasive species limits, although this conclusion must be stated with caution due to our small sample size.

The MDOT submitted monitoring reports for 90 % (9 of 10) of their compensatory wetland projects whose files we examined. We sampled five of these sites for compliance with invasive species standards and found 60 % (3 of 5) of sites compliant. County road commissions filed monitoring reports for 30 % (3 of 10) of their sites, and we found 40 % (2 of 6) of the sampled sites compliant for invasive species. Ultimately, we assessed 45 % (5 of 11) of all compensatory sites sampled "likely in compliance" with the MDEQ's invasive species standard (Table 1).

Estimated total invasive cover ranged from 4 to 25 % across the 11 sites. Although we observed invasive species at every site, no site featured an individual species in abundance greater than cover-class 3 (5–25 % cover). Some species appear particularly problematic in the region. For instance, reed canary-grass (*Phalaris arundinacea*) was present at all sites and spotted knapweed (*Centaurea maculosa*) was present at 9 of 11 sites. Many sites had additional invasive species growing in the areas just beyond the wetland perimeter, which we noted in our records but did not include in our calculations of total cover.

H_3 Compensatory wetland sites built recently or located close to roads will have higher predominance of invasive plant species than older sites or sites farther from roads.

Our findings led us to reject H_3, as invasive species levels varied little across site-ages or proximity to roads for the 11 compensatory sites sampled. Average site age was 3.6 years for compliant sites and 4.0 years for non-compliant sites. Average distance from wetland boundary to the nearest road was 420 m for compliant sites and 576 m for non-compliant sites (Table 1). Regression analyses for both of these variables support our rejection of the hypothesis (in both cases, $R^2 < .007$ and $P > .4$).

H_4 Restored wetlands will have fewer invasive species than created wetlands.

Our findings clearly support H_4, as the restored wetlands we sampled were more likely than created wetlands to be in compliance with the MDEQ's invasive species standard. A χ^2 test determined that the differences between the invasive species cover of these groups is significant to the 0.01 level ($\chi^2 = 7.639$; df = 1). Further, because all restored wetlands in our sample were constructed adjacent to natural wetlands, we can infer a relationship between invasive species abundance and characteristics of adjacent ecosystems. However, as mentioned previously, conclusions must be considered cautiously due to the small sample size in this aspect of our study ($n = 11$).

Of wetland restoration projects, 83 % (5 of 6) were compliant with the MDEQ's invasive species limit. These sites were all constructed in areas where wetlands are known to have once existed. Indeed, we found these sites all constructed directly adjacent to natural wetlands. By contrast, none of the wetland creation projects ($n = 5$) were compliant with the invasive species limit. These compensatory wetlands were all constructed adjacent to upland forests or grasslands where no wetlands were known to historically exist (Table 1).

We also found a relationship between invasive species and the size of compensatory wetlands, as smaller sites generally had lower cover and fewer numbers of invasive species than larger sites. Compliant sites averaged 0.6 ha in size, with three invasive species per site and an average total invasive cover of 6.2 %. Non-compliant sites averaged 1.8 ha in size, with six invasive species per site and an average total invasive cover of 21.6 %. Because this

Table 1 Site details and compliance rates for sampled mitigation wetlands

Size (ha)	Project type	Permittee agency	Adjacent to wetland?	Distance to road (m)	Age (years)	Number of invasive species	Percent cover of invasive species	Compliant for invasive species?	Compliant for monitoring?
0.20	Restoration	County	Yes	16	3	2	6.0	Yes	No
0.46	Restoration	State	Yes	12	4	4	7.5	Yes	Yes
0.63	Restoration	County	Yes	1535	2	3	4.0	Yes	No
0.65	Restoration	State	Yes	9	5	4	7.0	Yes	Yes
1.04	Creation	County	No	307	4	7	25.5	No	No
1.21	Restoration	State	Yes	530	4	3	6.5	Yes	Yes
1.62	Restoration	County	Yes	382	4	5	19.0	No	Yes
1.75	Creation	County	No	394	4	5	22.0	No	No
2.14	Creation	State	No	1580	5	7	16.0	No	Yes
2.56	Creation	County	No	218	3	7	25.5	No	Yes
3.83	Creation	State	No	230	5	4	10.5	No	Yes

relationship between area and numbers of invasive species is common in most landscapes, our findings are not surprising (Connor and McCoy 1979).

Discussion

The underlying rationale of the U.S. "No net loss" philosophy is that if wetland impacts are unavoidable, minimization and compensation are generally acceptable strategies as long as the area of the nation's wetland base is maintained. Between 2003 and 2006, a total of 28.8 ha of naturally-occurring wetlands in Michigan's Upper Peninsula were lost due to permitted activities. To offset these losses, 75.1 ha of wetlands were created or restored through compensation. This equates to a compensation ratio of approximately 2.6:1, or a 260 % increase in wetland area. Our research suggests, however, that a significant number of these compensatory wetlands may not be meeting vegetation standards. Of the 9.1 ha of compensatory wetlands we sampled, only 3.4 ha appear to be meeting the MDEQ's limit for invasive species.

Although we found an increase in monitoring report compliance since 2003, the difference was not significant and the MDEQ still appears to have difficulties achieving compliance with site monitoring requirements. Further, about half of the compensatory sites we examined had not yet been placed into conservation easement as required by the MDEQ. These wetlands are potentially at risk of future development without the permanent legal protection ensured by the conservation easement. If conservation easements are to be a useful mechanism to attain "No net loss" of wetlands, state and federal agencies should be concerned about the lack of permanent legal protection we revealed. In all, we found low compliance rates with all three mitigation policies we examined, indicating the ongoing challenges facing the MDEQ. Staff we spoke with suggested that their resources remain limited, particularly regarding personnel to inspect and follow-up on problem cases (Pennala, 2008, personal communication).

Prior research found low monitoring rates of compensatory wetlands in the region and suggested that a relationship might be found between site monitoring and ecological conditions (Hornyak and Halvorsen 2003). This led directly to the formulation of our second hypothesis. We expected to find higher rates of invasive plant species in un-monitored compensatory wetlands, but results from our site examinations did not support this hypothesis. Sites that had been monitored were not significantly more likely to be in compliance with invasive species standards than sites that had not been monitored. This finding was particularly intriguing, because we found some road agencies very adept at preparing and submitting monitoring documents to the MDEQ. Despite these efforts, their sites were no less likely to violate invasive species requirements than those constructed by other road agencies that were regularly negligent in meeting monitoring requirements. Although our results are limited by a relatively small sample size, these findings add to the literature by addressing a previously unanswered question about the apparent effectiveness of site monitoring. Surprisingly, our findings refute prior suggestions that there might be a link between monitoring and site conditions (Hornyak and Halvorsen 2003).

Our third hypothesis was that compensatory wetlands with the greatest invasive species problems would be those constructed most recently or located closest to roads. Such relationships have been reported by prior research (Cuperus and others 1999; Moore and others 1999; Spieles 2005; Spieles and others 2006). Our findings did not support this hypothesis, which contradicts much of the literature. However, we believe that the expected relationship between invasive species and site age was not observed due to our small sample size and the limited variation in site age in our sample. We also believe that the sites we sampled closest to roads did not exhibit the expected invasive species problems because these sites were restoration projects, with pre-existing natural wetland hydrology that was easier to re-establish than is typical of creation projects. Therefore, we suspect that the establishment and success of invasive plant species in wetlands may be determined more by hydrologic conditions than road proximity.

Where conditions are suitable the MDEQ prefers on-site compensatory projects that are essentially wetland restoration projects because they are constructed adjacent to existing wetlands. In our sample, the on-site projects tended to be the smaller ones. By contrast, the larger, off-site projects we examined were wetland creations (and essentially mitigation banks), constructed to compensate at a single location for numerous, smaller wetland-impacting activities. Off-site compensation can decrease costs and increase construction and monitoring efficiency. However, results of our site examinations support our fourth hypothesis that wetland restorations tend to have fewer invasive species problems than wetland creations. This finding supports the literature regarding the importance of compensatory wetland type (Brown and Lant 1999; Burgin 2010; Dale and Gerlak 2007; Mitsch and Gosselink 2000; Reiss and others 2009; Zedler 1996). The off-site compensation projects we examined were constructed in areas possessing fewer suitable wetland conditions. In such cases the sites' prospects for development into a viable wetland appear limited. The MDEQ appears to be approving off-site compensatory wetland projects in areas that are simply not suitable for wetland development. This pattern has been reported in numerous nations and, considering the reliance upon compensation as a mitigation tool, presents an ongoing threat to the ecological quality of global wetland resources (Burgin 2010; Krogman 1999; Zedler and Kercher 2005).

Staff at the MDEQ suggested that lower water levels in the Great Lakes over recent years have exacerbated difficulties with vegetation of some compensatory sites (Pennala, 2008, personal communication). Drier-than-expected conditions appear likely to make invasive establishment more likely (Falk and others 2006). Uncertainties associated with global climate change render modeling difficult, but long-term hydrologic disturbances could make wetland compensation an even more challenging proposition. Regulatory agencies may need to consider policy modifications such as an emphasis on impact avoidance, increased compensatory acreage, or a longer monitoring period.

Despite decades of international attention, wetlands remain a globally threatened resource. The patterns of permittee noncompliance, invasive species, and regulatory failures we reported are consistent with international findings on wetland management. Our determination that compensatory wetlands are not meeting performance standards for invasive species should be of particular concern to policy-makers. Our results support the findings of others who suggest the “No net loss” approach to wetland management is likely resulting in gains of wetland area but losses of wetland quality (Balcombe and others 2005; Brown and Lant 1999; Brown and Veneman 2001; Campbell and others 2002; Cole and Shafer 2002; Dale and Gerlak 2007; Euliss and others 2008; Kaiser 2001; Krogman 1999; Morgan and Roberts 2003; Moore and others 1999; Smith and others 2008; Stolt and others 2000; Zedler and Callaway 1999).

The MDEQ staff explained that repairs to problematic sites will likely involve re-vegetation or complete site reconstruction (Pennala, 2008, personal communication). Some invasive plant problems could be avoided by selecting compensation project locations with more suitable wetland conditions. In keeping with EPA directives, regulators should pursue all other options first (avoid/minimize), then view wetland restoration as a much better last resort than creation. Ongoing problems with site monitoring compliance, however, appear unlikely to change without drastic improvements in agency resources.

Future research could add to this study by examining wetland sites in other parts of the state. Despite our limited sample size, however, we believe the wetland sites we examined are representative of the greater population of compensation projects in our region for the permittee classes we included. In fact, our site examinations reflect a 100 % sample for such projects conducted in the western half of the Upper Peninsula during a four-year period. Further, compensatory wetlands in the eastern half of the peninsula may contrast in ecological characteristics due simply to the considerable differences in topography, hydrology, and land cover between the two halves of the peninsula. Finally, our site examinations included invasive species cover as an indicator of ecological condition, but follow-up efforts would be enhanced by the inclusion of additional indicators such as soils, hydrology, and organic cover.

Acknowledgments The authors express appreciation to the anonymous reviewers whose assistance greatly improved this paper. We also thank Rod Chimner, Catherine Tarasoff, and Hugh Gorman of Michigan Technological University; Virginia Pennala and Ann Sullins of the MDEQ, Michael Pennington of the MDOT, and the supervisors of Michigan’s Upper Peninsula county road commissions who assisted us with our research. We thank the Michigan Technological University Department of Social Sciences for financial assistance with this research.

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