Great Lakes Basin Evaluation of Compensation Sites Repot

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I. Introduction

Annually more than 40,000 acres of wetlands are restored, established, enhanced, and preserved to compensate for the approximately 20,000 acres of losses permitted through the federal wetlands regulatory program. It is not clear, however, whether this compensation is yielding projects that successfully replace lost wetland acres and functions. There is a great need to comprehensively evaluate the ecological success of compensatory mitigation across the country and to develop effective ecological guidelines for designing sustainable mitigation sites in the future. The study described in this report attempted to assess the regulatory and ecological outcomes of two compensatory mitigation mechanisms—permittee-responsible mitigation and mitigation banking—in a manner that would enable comparisons of the two mechanisms.

I.A Background

Permittees under the Clean Water Act (CWA) section 404 wetland permitting program may use two primary mechanisms to satisfy their compensatory mitigation requirements: (1) performing project-specific or permittee-responsible mitigation (PRM) and/or (2) purchasing credits from a mitigation bank (MB). Mitigation banking is referred to as "third-party" mitigation because liability for completing the compensatory mitigation project and ensuring its success transfers from the permittee to a third party (e.g., a mitigation banker or in-lieu fee program sponsor). Each year nearly 60 percent, by acre, of the mitigation demand nationwide is satisfied through permittee-responsible compensation (USACE 2008). The use of mitigation banks, however, has expanded in recent years and currently about one-third of compensation is accomplished through banking annually. With PRM, the permittee (or an authorized agent or contractor) undertakes an aquatic resource restoration, establishment, enhancement, and/or preservation activity to provide compensatory mitigation, for which the permittee retains full responsibility. With an MB, a site or suite of sites (e.g., wetlands, streams, riparian areas) are restored, established, enhanced, and/or preserved for the purpose of providing compensatory mitigation for impacts. In general, a mitigation bank sells compensatory mitigation credits to permittees, whose obligation to provide compensatory mitigation is then transferred to the MB sponsor. The operation and use of an MB are governed by a mitigation banking instrument.

Wetland compensatory mitigation projects built to replace wetlands impacted through CWA permit authorizations have been on the ground for many years. Numerous evaluations of these mitigated wetlands have been conducted over the years, and most have reported low levels of success in replacing either natural wetland condition or function (Zedler 1996; Turner et al. 2001; Robb 2002; Sudol and Ambrose 2002; Minkin and Ladd 2003; Fennessy et al. 2004; Ambrose et al. 2006; Kihslinger 2008; Burgin 2010; Teal and Peterson 2011). The Committee on Mitigating Wetland Losses was established by the National Research Council to evaluate whether the compensatory mitigation required of section 404 permit recipients was contributing to achieving the CWA's overall objective of restoring and maintaining the quality of the nation's waters (NRC 2001). The National Research Council's report (NRC 2001) was instrumental in pointing out many of the shortcomings of compensatory mitigation and showing that wetland mitigation was not achieving the no net loss goal. The report provides a number of recommendations, including the need to consider the siting and location of the wetland, the timing of wetland establishment, and the need to provide for financial assurances and long-term management. The report also calls for the development of ecological performance standards to plan and measure the success of wetland mitigation projects.

Because many have recognized the widespread shortcomings of wetlands developed as compensatory mitigation, numerous recommendations for improving wetland compensatory mitigation projects have been made. One common theme of those recommendations is a call to develop reliable wetland assessment tools that are calibrated to the conditions of natural reference wetlands and provide quantifiable results. The recommendations also call for using such tools to establish corresponding measurable ecological performance standards for mitigation wetlands (Kentula 2000; Mack et al. 2004; Faber-Langendoen et al. 2008; Matthews and Endrew 2008).

During 2011, data were collected on 1,258 natural wetlands across the country using the National Wetlands Condition Assessment (NWCA) monitoring protocol. It is anticipated that the NWCA data will be analyzed and used to develop indexes of biotic integrity (IBIs; Karr and Chu 1999) or other condition assessments that will allow accurate measurements of the ecological condition of the nation's natural wetlands. One of the main purposes of the NWCA is to inform decision-making on how to better protect, maintain, and restore water-quality to the Nation's aquatic resources (EPA NWCA website). The NWCA goals are consistent with the theme of using reference wetland standards when making evaluations of mitigation wetlands. Therefore, it is expected that the assessment tools developed as part of the NWCA will also be used to monitor and establish quantifiable ecological performance standards for mitigation wetlands constructed to compensate for natural wetland losses that occur through CWA permit issuance.

II.B Study Purpose

The Great Lakes Basin Evaluation of Compensatory Sites (GLBECS) project was designed to collect data concurrently and with the same methods as those used for the NWCA survey effort. Using the NWCA protocols, the GLBECS project reports results from a randomly selected set of 60 wetland mitigation projects (30 MB projects and 30 PRM projects) in the Lake Erie watershed of Ohio. Using the NWCA protocols for the GLBECS study will help EPA to assess the regulatory and ecological outcomes of compensatory mitigation mechanisms and thus enable basin-wide and national comparisons. However, because indices or other measures of wetland condition based on the NWCA data are in the process of being developed, interim measures of performance was desired both to allow for more immediate reporting of the results and to provide an example of how Level 3 tools can be used in evaluating mitigation wetlands with data collected using the NWCA protocols.

The GLBECS study was performed in Ohio, which has in place Level 3 wetland assessment tools that can identify ecologically quantifiable condition levels. The assessment tools were developed using data from a reference set of natural wetlands studied in previous years throughout Ohio. Because the GLBECS mitigation wetlands were located in the same area as where some of the assessment tools developed, specifically the Vegetation Index of Biotic Integrity (VIBI; Mack 2004a) and the Landscape Development Intensity (LDI) index (Micacchion et al. 2010), those tools were used to evaluate the performance of the mitigation wetlands monitored. Once assessment tools based on the NWCA data collected have been developed, further evaluation of GLBECS and other mitigation wetlands can occur, including comparing their performance to that of natural wetlands.

II. Methods

Generally, the protocols for the NWCA were used as the basis for the methods used for implementing the GLBECS study. The NWCA protocols are specified in the following documents:

- *National Wetland Condition Assessment Field Operations Manual* (USEPA 2011a) (hereinafter referred to as the NWCA FOM)
- *National Wetland Condition Assessment: Laboratory Operations Manual* (USEPA 2011b) (hereinafter referred to as the NWCA LOM)
- *National Wetland Condition Assessment: Quality Assurance Project Plan* (USEPA 2011c).

Each of the above documents should be accessed for detailed information related to the protocols used for the study. Due to the focus of this study, modifications or variations to the NWCA protocol were made. The remainder of this section describes these modifications and variations.

II.A Site Selection and Access

The 60 wetland mitigation project points in this study, representing 30 MB and 30 PRM projects located in the Lake Erie watershed of Ohio, were randomly selected to provide an unbiased representation of the performance of compensatory wetland mitigation. As a quality assurance measure, one MB and one PRM site were sampled twice. The 62 individual monitoring events for this study occurred between June 1 and September 15, 2011. The second monitoring events occurred at least two weeks after the initial visits, and all data were collected using the same protocols.

Eighteen of the 19 existing wetland banks in the Lake Erie watershed of Ohio were used in selecting sampling points. The one bank eliminated from the draw was a large wetland preservation site that contained no areas of wetland restoration. In an effort to sample the required minimum of 30 sites per mitigation mechanism outlined as a goal for the project, additional sampling points were randomly selected from the total pool of MB sites using a random number generator. Using ArcGIS, a 10-meter by 10-meter grid was created on top of each MB site polygon using XTools (i.e., fishnet). Each grid square was sequentially numbered, and then the MB sampling points were selected using a random number generator.

Based on desktop reviews, some of the original selections did not meet the study criteria because they fell on areas of wetland preservation, existing upland buffers, or other locations where no active mitigation activities had been undertaken. New random selections were made to replace those grid points using the procedures described above. In other cases, points were systematically moved (e.g., two grid cells down and two grid cells over) in an effort to fit the sample point characteristics defined in the NWCA protocols (i.e., sample capable area is at least 0.1 hectare, no more than 10 percent of the assessment area (AA) is non-target). This process continued until 30 MB points meeting the study criteria had been selected. In the end, 17 of the 18 mitigation banks in the draw had sample points.

The PRM sites were randomly selected from the Ohio Environmental Protection Agency's (Ohio EPA) database of Section 401 Water Quality Certification and Isolated Wetland Permits. Only those permits that involved wetland impacts and required the submittal of wetland mitigation monitoring reports were included. Each file was sequentially numbered, and the PRM sampling points were then selected using a random number generator and reviewed in that sequence. Projects not in the Lake Erie drainage were rejected and replaced by the next targeted file based on an overdraw list provided by EPA. Office reviews of the selected project files were performed. Only those that appeared to have wetland restoration or creation as components of their compensatory mitigation obligations were included, and rejected projects were replaced by the next pick from the overdraw. As with the MB sites, each PRM wetland footprint was divided into 10-meter by 10-meter grids associated with the latitude and longitude at their center point. A simple random selection was made to determine the point to be used in the study.

Landowners of PRM sites were contacted to arrange for site access prior to the monitoring events. This process usually required intensive investigative work, including Internet searches and reexamination of project files to determine current landowners and their appropriate contact information. The mitigation banks were less labor-intensive in terms of the number of contacts needed before gaining permission to access the properties. When necessary, public land permits were applied for and received prior to monitoring.

Only three of the originally selected PRM projects could not be monitored because of access constraints. Two property owners directly denied access, and despite numerous attempts, contact could not be made with a third. During the scheduled monitoring visit, one project was found to be too small to accommodate five vegetation plots, and therefore it was excluded. These four projects were replaced by the next four from the overdraw list. All 60 of the GLBECS points—30 PRM and 30 MB points—were able to be sampled in 2011.

II.B Sampling Methods

The NWCA is a component of the National Aquatic Resource Surveys (NARS), which are nationwide assessments of the condition of the waters the United States using probability-based sampling design. Part of adding wetlands to the NARS process was selecting the range of information that would be collected about each wetland. The intent was to gather the types of commonly shared data that could be best used to report on the health of the entire range of wetland types from across the country. The data selection process for the NWCA chose parameters that were thought to best provide the data needed to develop wetland assessment tools that would provide quantifiable measurements of natural wetland ecological conditions.

Data were collected using the protocols found in the NWCA FOM, with the exception of the soil monitoring protocols. Refer to the NWCA FOM for descriptions and types of sampling methods performed for the GLBECS project, including: assessment area and vegetation plot establishment, buffer plot characterization, vegetation, soils, hydrology, water chemistry, algal taxonomic identification and algal toxins, chlorophyll-a, and USA Rapid Assessment Methodologies. All algal, water chemistry and soil samples were shipped and analyzed at independent laboratories. A description of the modified soil monitoring protocols is provided below.

II.B.1 Soil Monitoring Protocols

The soil monitoring protocols were modified from the NWCA methods to address the unique circumstances of soils associated with wetland mitigation projects, where recent disturbances to the soil profile are commonplace. In addition, because only a three-person crew was used for this study, it was determined that using a modified soil field protocol similar to those used previously by Ohio EPA (Mack et al. 2004), while providing all the important soil data, would reduce some of the labor requirements, making field data collection with a three-person crew feasible.

Soil sample locations were placed just outside the southeast (SE) corners of the four vegetation plots farthest from the center of the AA. These four locations were evaluated for hydric soil indicators present and Munsell soil colors at 12, 20, and 30 centimeters (cm). At each of the four sample locations, a core was taken with a soil probe at the three depths from the same hole. Soil colors and any redoximorphic, organic, or mottle features present were recorded at each of the three depths. An additional core sample was collected to the depth of 30 cm, or as near to the depth of 30 cm as soil compaction would allow, at each of the four SE corner sample locations for hydric soil indicator evaluation.

Soil chemistry and bulk density samples were collected from one sample location inside the AA that was most representative of the overall soil conditions at the site. For soil chemistry, a sample was collected from the soil surface to a recorded depth, typically 15.5 cm, using either a large-diameter corer or an 8.25-cm by 25-cm stainless steel bucket auger (AMS Soil Recovery Sampler), and transferred to a heavy-duty plastic bag. The bulk density sample was taken to a recorded depth, typically 15.5 cm and adjacent to the chemical sample location, using a large-diameter corer, taking care not to compact the soil sample. The corer was driven into the ground using hand power or a block of wood and a hammer to a specified depth in order to provide a known volume of soil. The bulk density sample was used to determine percent solids and the percentage of particle sizes.

The set location for each hydric soil determination was used unless there were water depths and/or soft substrates more than 0.25 meters (m) deep or large wood or rock was present. When such impediments occurred, an alternative location was attempted as close to the SE corner of the vegetation plot as possible, and that location was recorded on the data forms. All soil sample locations were at least two meters away from the edge of the re-established, established, or rehabilitated wetland mitigation project boundaries. If a soil sample had to be relocated, a minimum of 10 meters was maintained between sample locations.

Soil samples were shipped to an independent laboratory, which performed analyses for the following parameters in accordance with the NWCA LOM and NWCA QAPP, or methods specified in *Recommended Chemical Soil Test Procedures for the North Central Region*, North Central Research Publication No. 221 (Brown, Revised January 1998):

- Total organic matter
- Available phosphorus (P_1 Weak Bray and P_2 Strong Bray extractions)
- Exchangeable potassium (K), magnesium (Mg), calcium (Ca), sodium (Na)
- Nitrate-N, iron (Fe_2 and Fe_3), manganese (Mn_2 and Mn_4), sulfur, zinc, copper, boron
- pH
- Cation exchange capacity (Ca, Mg, K, Na, H)

- Total carbon (C), total nitrogen (N), C/N ratio
- Bulk density
- Soil texture (percentage of sand to silt to clay and soil type classification).

II.C Success Criteria

In Ohio one success criterion used for all wetland mitigation projects is their ability to meet a "good" level of ecological condition based on VIBI scores. The good level is based on Ohio's Wetland Antidegradation Rule (Ohio Administrative Code 3745-1-54), which assigns any wetland to one of three antidegradation categories. In the Ohio Rule, wetlands are defined as demonstrating minimal, moderate, or superior functional and ecological levels and are assigned to Category 1, 2, or 3, respectively. In practice, scores generated using wetland assessment tools (i.e. the VIBI) calibrated to equate to the corresponding levels of ecological conditions are used to place wetlands into the appropriate antidegradation categories (Mack 2001, 2004a; Micacchion 2004).

On an ecological condition scale, the classification of Ohio wetlands is better characterized by a four-tiered structure of "poor", "fair", "good", or "excellent" rather than the three tiers provided by Ohio's Wetland Antidegradation Rule. Using the four tiers, poor equates to Category 1; fair to good to Category 2, which encompasses a broad range of ecological conditions; and excellent to Category 3.

Setting the standard at the "good" ecological condition level ensures that the resulting mitigation wetlands meet all the rule requirements for mitigating Category 1 and 2 wetlands so they are of a high enough quality to be environmentally resilient and require minimal adaptive management. For these reasons, the VIBI performance standard developed for Ohio wetlands were incorporated into the GLBECS evaluation of wetland mitigation bank (MB) and permittee-responsible mitigation (PRM) projects.

II.D Data Analysis Methods

The two assessment methods selected to analyze the data from the 2011 GLBECS project are the Vegetation Index of Biotic Integrity (VIBI; Mack 2004) and the Landscape Development Intensity (LDI) index (Vivas and Brown 2005). The results in this GLBECS study are reported using VIBI and LDI scores; doing so allows evaluation of ecological conditions and success rates. It also allows comparisons to sets of natural and other mitigation wetlands in an effort to measure whether MB projects or PRM projects are providing better compensation for impacts on wetlands due to CWA section 404 permit recipients.

II.D.1 Vegetation Index of Biotic Integrity Methods

The VIBI is a reliable Level 3 evaluation tool because, as an IBI (Karr and Chu 1999), it reflects the status of the physical, chemical, and biological conditions of the wetlands being measured. The VIBI was developed with data collected from a large set of natural wetlands from across Ohio. The natural wetlands selected include the best remaining examples of least disturbed wetlands, the most disturbed, and every level of condition in between (Mack 2007). These considerations make the VIBI a robust assessment tool able to accurately characterize the ecological condition of wetlands.

The tool also correlates strongly with other measures of resource integrity including the Ohio Rapid Assessment Method for Wetlands (Mack 2001) and other human disturbance gradients.

Some Ohio mitigation wetlands—those created through wetland MBs (Mack and Micacchion 2006) and PRMs (Micacchion et al. 2010)—have been studied in the past, and their ecological conditions have been reported using the VIBI as one of the evaluation tools. Furthermore, the VIBI has been used as a performance standard for all new Ohio wetland MB and PRM projects for the past five to eight years (Mack et al. 2004; Ohio IRT Section 8. 2011). Using the VIBI as an assessment tool for the mitigation wetlands in this study, as well as characterizing their ecological condition, provides a gauge of their functional capacity and gives an indication of which mitigation type has typically been more successful.

As stated in the NWCA FOM, vegetation was characterized by collecting data describing vegetation structure, presence of individual plant species, predominate heights, and percent cover in each of the five 10-meter by 10-meter vegetation plots that were placed systematically in the AA. In addition, counts, cover by height class, diameter at breast height (dbh) sizes of woody vegetation, and cover values of various biotic and abiotic surface materials were collected in each vegetation plot. Data used for the VIBI analysis included species present, cover values, dbh of woody vegetation, and relative bryophyte cover. The plant species coefficient of conservation scores and groupings according to wetland indicator status, life-form, habit, and taxonomic class from Andreas et al. (2004) were used in this analysis. This information, along with transformation of some shrub and small tree cover values into shrub clump and dbh class counts, was used to calculate Forest VIBI scores and scores for nine of the 10 metrics of the Emergent VIBI (Mack 2004a, 2004b, 2007, 2009).

Forest VIBI scores were calculated as the sum of the 10 metrics. Information on primary productivity is used for calculating the Biomass metric for the Emergent VIBI (Mack 2004b). However, NWCA vegetation monitoring protocols do not include clipping vegetation to determine primary productivity. As such, only nine of the 10 metrics could be calculated for those sites dominated by emergent vegetation. To allow comparisons for the sites dominated by emergent vegetation, an average score for their nine metrics, rounded to the nearest whole number, was added to the sum of their nine metrics to generate their VIBI scores. Results of the VIBI analysis are listed in **Tables 1a and 1b.** Note that all Tables are located in Section VI of this report.

II.D.2 Landscape Development Intensity Index Methods

One possible factor affecting the condition and success of a wetland could be the level of development on adjacent lands. Human-dominated land uses and especially the intensity of the uses can affect adjacent ecological communities through direct, secondary, and cumulative impacts (Brown and Vivas 2005). To better understand the effects of adjacent land use on the relative ecological condition of mitigation wetlands, an assessment of the level of development being experienced in landscapes surrounding each assessment area (AA) can be performed.

In addition to using the Level 3 VIBI assessment, a Level 1 tool, the Landscape Development Intensity (LDI) index, was developed for each mitigation site sampled in 2011. The LDI index score is based on land use data and land use intensity coefficients developed by Micacchion et al. (2010). Under this analysis method, land uses in the area surrounding surveyed mitigation wetlands are assessed and assigned an LDI index score, which can be compared to surveyed sites and assist in determining what influence the adjacent areas have on the overall ecological condition of the mitigation wetlands.

Each of the 62 sites sampled in this study were assigned a Landscape Development Intensity (LDI) index score. A digital wetland boundary of each site was created in ArcGIS based on the shape of the AA. Wetland AA digital boundaries were created using "heads up" digitizing techniques, and utilized high-resolution orthophotography, aerial imagery, field survey data, and ArcInfo editing tools.

Once the AA boundary was produced, a 100-meter polygon buffer was created outside the AA using the ArcInfo buffer tool in ArcGIS. The resulting polygon was then overlaid with the United States Geological Survey's 2006 "National Land Cover Dataset" (NLCD), and the total area of each land use category within the polygon buffer was determined (**Figure 6**) (Brown and Vivas 2005). The number of raster cells falling within each 100-meter polygon for each 2006 NLCD land use category was multiplied by the associated LDI coefficient, as shown in **Table 2**. The sum of all LDI/land use calculations was then divided by the total number of raster cells associated with each 100-meter polygon. The resulting LDI scores are listed in **Tables 1a and 1b**.

III. Results

The results from this study show, based on VIBI scores for the 30 PRM sites, that with respect to ecological condition, nine PRM sites (30 percent) are poor, 17 (57 percent) are fair, and four (13 percent) are good. VIBI scores for the 30 MBs show that with respect to ecological condition, eight MB sites (27 percent) are poor, 13 (43 percent) are fair, five (17 percent) are good, and four (13 percent) are excellent (**Tables 1a and 1b**) (Mack 2004). The mean VIBI score for the PRMs is 33.5, and that for the MBs 42.3, with median values of 36.0 and 47.0, respectively (**Figures 1 and 2**). Note that all Figures are provided in Section VII of this report. The VIBI scores for the MBs were, on average, higher than the PRM scores, but not significantly different ($p>0.05$) (**Figure 3**). Two sites, one MB and one PRM, were monitored twice for a quality assurance measure as part of the NWCA protocol. The results of the VIBI analysis placed both wetlands in the same condition class each time (**Tables 1a and 1b**). Overall, 30 percent of the MBs met the performance standard of good or better ecological condition compared to 13 percent of the PRMs.

The MB and PRM VIBI scores from the GLBECS study were compared to VIBI scores from a set of 154 natural Ohio reference wetlands used by Mack and Micacchion (2006). In the Ohio reference wetland study, the natural wetlands were divided into three groups (tertiles) based on equal divisions of the range of Ohio Rapid Assessment Method (ORAM) scores (human disturbance gradient), while mitigation wetlands from the GLBECS study were grouped into MB and PRM. The three groupings for the natural wetlands, are based on ORAM scores, and equate to the divisions between poor, fair-good, and excellent ecological conditions (**Figure 3**).

The GLBECS analysis found that the means of the three groupings of natural wetlands described above are significantly different from each other. The VIBI means for MBs and PRMs are not significantly different from each other. However, the VIBI mean for PRMs is significantly different from the means for all three groupings of natural wetlands, and the VIBI mean of the MBs is significantly different from those for the first and third ORAM groupings of the natural wetlands after analysis of variance followed by Tukey's multiple comparison test ($df = 213$, $F = 73.7$, $p < 0.001$) (**Figure 3**).

Comparisons between VIBI and LDI scores for the mitigation wetlands show little association, and the resulting correlations are not statistically significant ($p > 0.05$) (**Figure 4**). Though moderate, there is a statistically significant correlation between VIBI scores and the percent coverage of invasive species as calculated from the vegetation plot data ($S = 16.4200$, $P < 0.001$, R – Sq = 27.3 percent) (**Figure 5**). As such, sites with higher VIBI scores exhibited lower percentages of invasive species, while sites with lower VIBI scores had a higher percentage of invasive species. Eighteen (60 percent) of the MBs and 10 (33 percent) of the PRMs had less than 10 percent coverage of invasive species.

Water depth measurements in each of the five vegetation plots were collected as part of the NWCA protocol. Eight of the MB sites and 15 of the PRM sites had standing water in all five of the vegetation plots at the time of the survey. The number of vegetation plots with standing water at the time of sampling showed no correlation to the overall ecological condition of the mitigation wetlands.

IV. Discussion

IV.A Comparisons from Previous Ohio and GLBECS Mitigation Bank Performance Studies

An earlier study of Ohio wetland mitigation banks (MBs) found overall low success rates for achieving VIBI scores equating to good or better ecological condition (Mack and Micacchion 2006). The study, conducted in 2003 and 2004, evaluated 34 subareas of 12 MBs located throughout Ohio using data from both randomly selected and targeted plots for assessments of the vegetation communities. The banks in the study were from Ohio's first generation of MBs, with most of their plans or instruments approved between 1992 and 2000.

Overall that study found 25 percent of the developed bank areas did not meet wetland criteria and were instead primarily shallow, unvegetated ponds. As part of the study, 103 VIBI scores were calculated—41 from the larger (20-meter by 50-meter) targeted plots and 62 from aggregations of the 331 smaller (10 meter by 10-meter) random plots. Fifty-one of the VIBI scores (49.5 percent) were for bank subareas in the Ohio River watershed, and 52 (50.5 percent) were for bank subareas in the Lake Erie watershed.

The bank areas that met wetland criteria predominantly demonstrated low levels of ecological condition. The most common reason for failure was determined to be issues with controlling the water level of the wetland bank. The bank designs, which were often designed to maximize the footprint of wetland credits, typically had no maintenance of water levels and were kept at maximum inundation. Other reasons for failure included poorly defined goals, poor site selection, extreme soil disturbance, no planting or seeding of desirable wetland species, dominance by invasive plants, drowning of mature trees, and lack of effective buffers. Much has been learned and incorporated into the bank approval process based on the results of this study.

For the 2003–2004 study, the mean VIBI scores of 36.5 for MBs and 27.8 for permittee-responsible mitigation projects (PRMs) were significantly different from the mean VIBI scores for the three groups of natural reference wetlands—17.5, 49.6, and 77.5, respectively. The PRMs sampled in this GLBECS study are similar to those results, with a mean VIBI score of 33.5 and, therefore, also significantly different. Although the GLBECS study MBs (42.3) are not significantly different from the PRMs, they are also not significantly different from the natural reference wetlands, which have fair to good quality ($p < 0.001$) (**Figure 3**).

The VIBI evaluation from the 2003–2004 study found that, of the randomly selected bank plots monitored, 25.8 percent were of poor, 64.5 percent were of fair, and 9.7 percent were of good ecological condition (Mack and Micacchion 2006). None of the bank plots monitored in 2003–2004 demonstrated excellent ecological condition. Since both the GLBECS and 2003-2004 studies were probability-based and representative of the entire population, the jump from 9.7 percent of MB sites meeting VIBI performance standards in the earlier study to 30 percent of the MB sites in the GLBECS study (of which 13 percent are of excellent quality) is a large increase, potentially indicating an improvement in wetland bank quality.

IV.B Measurable Ecological Performance Goals

There has been a movement to require quantifiable ecological performance standards for mitigation wetlands, both to ensure they are replicating natural reference conditions as closely as possible and to document whether they have met these goals (NCR 2001; Mack et al. 2004; Fennessy et al. 2004; Mathews and Endress 2005; Faber-Langendoen et al. 2008; Kihslinger 2008; Reiss et al. 2009). The Ohio Interagency Review Team (IRT) has been requiring quantifiable ecological performance standards for wetland mitigation banks since 2003. These standards are specified in the recently established *Ohio Wetland Mitigation Banking Guidance* (Ohio IRT 2011) as well as the *Federal Rules on Compensatory Mitigation for Losses of Aquatic Resources* , which state that ecological performance goals should be used with a strong preference for quantifiable standards where and when they exist (USACE and USEPA 2008).

In the past, credit releases for Ohio mitigation banks were generally granted for all areas meeting wetland criteria as defined by U.S. Army Corps of Engineers (Corps) guidelines for soils, hydrology, and vegetation (USACE 1987). With the otherwise broad, vague, and unmeasurable performance goals of earlier banks, it was almost impossible to determine whether those standards had been met. In addition, although some of those goals appeared to have a relationship with ecological performance and functional replacement, no strong evidence linking the two existed. As a result, many credits were being released on the specified schedule even when performance, from an ecological and functional perspective, was less than good (Mack and Micacchion 2006). Therefore, it is important to establish robust, measurable, and enforceable performance standards for all mitigation projects.

Currently for Ohio banks, only the first 30 percent of credits are released without prior demonstration of meeting performance standards at the time of the bank instrument signing. Bank construction must occur within one year of the signing. After that, additional credits are not released until 30 percent of the credits meet performance standards and all other credits proposed for release also meet their performance goals (Ohio IRT 2011). Tying credit releases to measurable ecological standards has certainly resulted in better bank proposals in addition to the fact that more attention has been spent on replicating natural systems in site selection, restoration design, implementation practices, and adaptive management components. Establishing repercussions, by not allowing credit releases for less than high-functioning systems and implementing more stringent requirements on credit releases, has proven to be effective. This might be reflected in the higher levels of success seen in the MBs monitored in this study, and it is anticipated that increased levels of success can be expected on that basis.

It is the responsibility of the IRT to (1) encourage an atmosphere that leads to the development of adequate credits to accommodate the regulatory demands of its area; (2) develop banking agreements that are fair to all involved in the process, including the bankers, the long-term managers, and the public; and (3) ensure that what is developed through the review process is high-quality wetlands that can compensate for the natural wetlands being lost through permitting (Ohio IRT 2011). The incorporation of measurable performance standards of ecological and functional conditions into banking agreements appears to meet these three criteria. For example, the GLBECS study found that 30 percent of bank sites monitored, of which almost half are in excellent ecological condition, did meet some of the performance goals that have been established for wetland mitigation banks in individual Mitigation Banking Instruments (**Table 1a**). These successful projects can be used as models for future proposals and adaptive management of existing, underachieving projects.

IV.C Permittee-Responsible Mitigation Site Performance

A 2007 study of randomly selected Ohio PRM projects found a predominance of wetlands demonstrating low ecological conditions (Micacchion et al. 2010). The percentages of PRM wetlands in the GLBECS study that exhibited low levels of performance was slightly higher than the results of the 2007 study of 26 randomly selected Ohio PRM wetlands. The VIBI analysis from the 2007 study found 10 (38.5 percent) of the wetlands were of poor, 11(42.3 percent) of fair, and five (19.2 percent) of good ecological condition (Micacchion et al. 2010). Results from the PRM wetlands in the GLBECS study found 87 percent were of poor to fair ecological condition (**Table 1b**), which is even higher than the 80.8 percent failure rate from the earlier Ohio study (Micacchion et al. 2010). In addition, the mean VIBI score for the GLBECS PRM wetlands (33.5) was significantly lower than natural reference wetland VIBI scores of fair to good (49.6) and excellent (77.5) quality; but was significantly higher than poor-quality (17.5) natural wetlands ($p < 0.001$)(**Figure 3**). Low levels of ecological performance have also been reported in other PRM studies from around the country (Robb 2002; Sudol and Ambrose 2002; Minkin and Ladd 2003; Ambrose et al. 2006). These results highlight a great need to increase the performance levels of PRM projects; an 87 percent failure rate, as measured in the GLBECS project, should not be left unaddressed.

IV.D Forested Sites

Nine (30 percent) of the MB points and three (10 percent) of the PRM points were located in preexisting wetland forest. In many of the non-forested sites sampled for the GLBECS study, it was apparent what mitigation activities had been performed at the site. For the forested sites, it was often difficult to determine what modifications had been undertaken and were being considered as compensatory mitigation activities, which often complicated the site layout and post analysis process for those points. In most cases, it was assumed that drainage had been reduced or eliminated by tile decommissioning, ditch plugging, or other methods to convert a transitional community to a more wetland community. For the nine bank sites in preexisting forest, one (11 percent) was of poor, six (67 percent) were of fair, one (11 percent) was of good, and one (11 percent) was of excellent ecological condition (**Table 1a**). The three PRM bank sites in preexisting forest were all (100 percent) in fair ecological condition (**Table 1b**). Overall, the majority of the MB and PRM sites in preexisting forest were wetlands in fair or worse ecological condition.

IV.E Comparison of the 2011 GLBECS Data to Natural Wetland Data Sets

The results from the two sets of randomly selected mitigation wetlands, both MBs and PRMs, was compared to available sets of previous assessment data on randomly selected natural Ohio wetlands from the Cuyahoga River watershed in northeastern Ohio and urban wetlands. The data on populations of natural Ohio wetlands should provide an overview of the types and percentages of differing ambient ecological conditions that exist, and allow direct comparisons to sites in this study. Comparisons of percentages of wetland populations in differing ecological conditions show that both the MBs and PRMs in this study are demonstrating much lower levels of ecological integrity than the ambient conditions of populations of natural Ohio wetlands.

In a study of wetlands in the Cuyahoga River watershed of northeastern Ohio, wetlands were evaluated using the Ohio Rapid Assessment Method for Wetlands Version 5.0 (ORAM) (Mack 2001). VIBI scores and ORAM scores from a subset of the Cuyahoga River watershed wetlands correlated strongly and validated the use of ORAM scores alone for most of the large number of wetlands (243) being assessed (Fennessy et al. 2007). On that basis, 22 (9.1 percent) were in poor, 32 (13.2 percent) in fair, 124 (51.0 percent) in good, and 65 (26.7 percent) in excellent ecological condition (Fennessy et al. 2007). Overall, 77.7 percent of the wetlands randomly selected in the Cuyahoga River watershed were of good to excellent ecological condition, a far higher percentage than that reflected by the MBs (30 percent) or PRMs (13 percent) in this study. It should be noted that high levels of development in the urbanized parts of the watershed have resulted in few remaining wetlands. Therefore, a random sample of wetlands from across the watershed would display a skewed representation by wetlands in undisturbed parts of the watershed.

Although ORAM correlates strongly with VIBI scores, as stated in the ORAM User's Manual, it was not designed to be used as a tool to assess wetland mitigation projects (Mack 2001). Many of the ORAM metrics award more points when wetland components (i.e., soils, hydrology, habitat, buffers) have experienced no or few disturbances in the recent past. Therefore, the disturbances associated with mitigation wetland establishment make ORAM a biased and inappropriate assessment tool for mitigation wetlands. Level 3 tools like the VIBI are the preferred and more precise assessment tools for natural wetlands. ORAM correlates strongly with VIBI scores in natural wetlands, however, and it can be used in lieu of the VIBI in studies like that in the Cuyahoga River watershed, or in other instances where large numbers of wetlands are being assessed and the reduced resources involved in Level 2 assessments make the studies feasible. Even then, a significant percentage (≥ 10 percent) of the population should be monitored with the Level 3 tool to provide a quality assurance check.

In a study of central Ohio urban wetlands, the overall ecological condition of wetlands reported was much different from that of the Cuyahoga watershed. VIBI score results from 28 randomly selected wetlands showed that four (14.3 percent) were of poor, 15 (53.6 percent) of fair, five (17.8 percent) of good, and four (14.3 percent) of excellent ecological condition (Mack and Micacchion 2007). In urban central Ohio, the loss of wetlands was also high at 42.3 percent in the previous 25 years. The representative levels of wetland ecological condition were also much lower than those from the Cuyahoga watershed. The lower level of performance for urban wetlands illustrates the findings of Brooks et al. (2005) and others that wetland populations in areas of high levels of environmental stressors tend to be predominately of moderate to low quality.

Overall, 32 percent of the urban central Ohio wetlands studied were found to be of good or better condition (Mack and Micacchion 2007), which is much higher-performing than the GLBECS study's PRM sites, but about on par with the results from the GLBECS study's MB sites. This may suggest that it is reasonable to expect replacement of urban wetland levels of performance at wetland mitigation banks if a representative cross section of urban wetlands (mostly low-quality) were being impacted. However, most wetland mitigation banks are in rural areas, more akin to the upper portions of the Cuyahoga River watershed, where the landscape is less developed indicating a higher level of quality should be achievable. The associated lower intensity surrounding land uses predominant in those areas, reflected in the higher levels of ambient ecological condition in the natural wetlands (Fennessy et al. 2007), makes expectations for mitigation banks in these settings higher as well. In addition, banks must be able to compensate for losses of all wetlands likely to be impacted, including at times those of good to very good quality.

IV.F Landscape Development Intensity Index

The VIBI scores from natural sets of Ohio wetlands have demonstrated strong correlations to the relative intensity of land uses, as reflected in LDI scores (Mack 2006; Fennessy et al. 2007; Micacchion et al. 2010). These correlations were characterized by little or no difference in VIBI scores until wetlands experienced uniformly high levels of landscape development intensity (i.e., urbanization, row cropping), beyond which achievement of high VIBI scores was limited. This association indicates that for Ohio's natural wetlands, the level of intactness of the surrounding landscape is an important factor in the ability to achieve and maintain high ecological integrity.

Because there is little correlation between LDI scores and VIBI scores for the mitigation wetlands in this study, it appears that other factors affect the LDI index scores for mitigated areas. One factor could be the year the land use layer was developed versus the year the wetland and the area surrounding the wetland were developed. The latest released land use database during this analysis was from a 2006 National Land Cover Dataset (NLCD) land use layer. Some of the variability between LDI and VIBI scores could be attributed to a few of the mitigation sites being placed in a "developed" land use category in 2006 because of ongoing site development activities, resulting in high LDI scores (**Table 2**).

Another factor that could affect the LDI scores is the amount of invasive plant species within the mitigated wetland. Some large, established mitigation sites with little or no adjacent land use disturbance in 2006 had low LDI scores (good), but the mitigation sites were sometimes found to have low VIBI scores (poor or fair) due to vegetation indicators (i.e., high relative cover of invasive graminoid species, no or few *Carex* species, high relative cover of tolerant plant species, low floristic quality assessment index (FQAI) scores) reflecting high levels of disturbance within the project footprint. Given the dynamics of disturbance levels and timing of wetland and adjacent buffer development, the LDI might not be the most effective predicator of ecological conditions on mitigation sites.

IV.G Coverage of Invasive Plant Species

Native plants can compete equally as well as invasive species provided that the appropriate growing medium is provided. However, nonnative invasive plant species are able to out-compete native species where there has been soil and hydrologic disturbances resulting in altered levels of nutrients, light, and water or other disturbance-driven effects. Invading plants species typically have higher amounts of leaf area and require less energy to develop new tissue, which can be beneficial under high light and nutrient conditions. The invasive plants also have great ability to adapt to changing environmental conditions, which is particularly advantageous in disturbed environments (Daehler 2003). Although there might be no clear connection between mitigation wetlands' levels of performance and the condition of their surrounding landscapes, it appears the disturbance level of the land occupied by the wetland project itself, as determined from the soil profiles and other observable on-site factors, plays a large role in determining wetland ecological condition. Those projects with higher levels of disturbance within their wetland footprints had higher percent coverage of invasive plant species and were demonstrating overall lower ecological conditions.

In the GLBECS study, 18 (60 percent) of the MBs had ≤ 10 percent coverage of invasive species, which suggests this common mitigation performance standard may be a reasonably attainable goal. Because invasive coverage correlates with VIBI scores, it appears that continued use of this goal can facilitate attainment of higher ecological conditions. While a high percentage of invasive species coverage is not the only indicator of impediments to meeting success criteria, it seems to be reliable in a majority of the cases when both MBs and PRMs are considered. Only 10 (33 percent) of the PRMs had ≤ 10 percent coverage of invasive species, which appears to be consistent with their overall lower achievement of success criteria, although it is not clear what other limitations could affect their success given that only four (13 percent) of the PRMs met performance standards. Only three of the sites meeting good or better ecological condition, based on VIBI scores, (all MBs) had >10 percent coverage of invasive species. Two of those sites were only a few percentage points above the 10 percent threshold, which again demonstrates the correlation between high percent coverage of invasive species and low VIBI scores ($S = 16.4200$, $P < 0.001$, R–Sq = 27.3%) (**Figure 5**).

Based on observations during the monitoring, it was evident that a high percentage of the MBs were receiving or had received adaptive management. Some of the field crew in this study had visited many of the MB sites in the past and had observed areas that had received or were receiving adaptive management. In addition, most of the MBs were in areas that receive regular visits by the banker or the long-term manager. Since most of the banks sampled were located in a park or conservation area with large amounts of land over which the banker or long-term manager has control, most disturbances appeared to be absent or present at low levels. Conversely, based on the higher prevalence of invasive species and often more isolated settings, many of the PRMs appeared to receive little human visitation, and a large percentage were in need of adaptive management. The lack of regular monitoring and maintenance activities as well as ongoing disturbances at many of the PRMs appeared to be contributing to the large coverage of invasive species observed.

All the forested sites monitored had ≤ 10 percent coverage of invasive species. This result is likely a function of the shade provided by the tree canopies serving as a limiting factor to the growth of the predominantly sun-loving invasive species. Although areas with young trees require more management for invasive species during canopy development, the resulting shade once developed could be an important management tool in reducing the establishment of invasive species.

A large coverage of invasive plant species, as observed in many of the mitigation sites with low VIBI scores, likely indicates that a high level of disturbance has been experienced within the footprint of wetland establishment. In these cases it can be inferred that the disturbances, most often related to construction but sometimes to maintenance practices, contribute to the inability of the resulting wetland to attain higher levels of ecological performance. Invasion by nonnatives is most easily achieved in wetlands located in large landscapes that are experiencing high levels of disturbance, where their spread requires migrations of short distances. However, invasive plant species also have a strong ability to adapt to local conditions and out-compete other wetland plant species. For instance, a study of invasive plant species growing in open disturbed habitats found that plants, on average, experienced higher levels of self-pollination and cloning rates than those in undisturbed habitats (Ecker et al. 2010). The ability of invasive plant species to become established in smaller and more isolated areas of environmental disturbance illustrates the importance of minimizing disturbances when constructing compensatory mitigation projects and keeping the plans as close to a true restoration project as possible.

Adaptive management involving the removal of invasive species as they become established is important. However, the adaptive management must also include the needed restoration of the growing medium to ensure that the desired native plant species' habitat requirements are met. This could mean increasing soil organic carbon levels, augmenting or reducing soil or water nutrient levels, adjusting water levels, or a combination of these. Once the appropriate conditions are established, seeding at high rates and/or planting at high densities appears to be the best method to limit reinvasion. The site should then be monitored routinely and invasive species problems dealt with immediately. It appeared these steps were being taken at some of the MBs; in fact, some of the same sites that had been underperforming that were monitored in the 2003 and 2004 study (Mack and Micacchion 2006) had undergone substantial adaptive management and were meeting their performance standards (i.e. VIBI, native perennial hydrophyte coverage, and invasive species coverage).

V. Conclusions

Wetland mitigation efforts have been formally required by the CWA section 404 permit process for more than three decades. In that time many wetland projects have been undertaken to compensate for the permitted losses of natural wetlands. A small percentage of those projects have been successful in replacing wetland functions or reaching required levels of ecological integrity (Zedler 1996; Turner et al. 2001; Robb 2002; Sudol and Ambrose 2002; Minkin and Ladd 2003; Fennessy et al. 2004; Ambrose et al. 2006; Mack and Micacchion 2006; Kihslinger 2008; Burgin 2010; Teal and Peterson 2011). While the need to avoid wetland impacts cannot be overstated, especially when high-functioning systems are at risk, there has also been a focus on improving the results of wetland compensatory mitigation projects.

A prime mover in raising the bar on the performance of wetland mitigation projects has been the National Research Council's report *Compensating for Wetland Losses under the Clean Water Act*, which reviewed the federal mitigation program and found the national goal of "no net loss" of wetlands was not being met (NRC 2001). Other measures to improve wetland mitigation on a national level have included the *National Wetlands Mitigation Action Plan* (U.S. Government 2002) and the *Federal Rules on Compensatory Mitigation for Losses of Aquatic Resources* (USACE and EPA 2008).

Common threads in the findings, recommendations, and rules in these documents, as well as the results from many other wetland mitigation studies, correspond with our thoughts on improving wetland mitigation in the Lake Erie Basin of Ohio. Specifically, we recommend:

- Placing projects in the appropriate hydrogeomorphic settings for the types of wetlands proposed to be restored.
- Making adequate buffers a prime consideration in site selection and project design. Constructed and natural wetlands need significant buffers—at least 50 meters on all sides—and more is better.
- Developing designs that involve as little disturbance to the existing landscape as possible, and avoidance of any structures that require regular management or maintenance if possible.
- Replicating natural wetland hydrographs; some seasonal fluctuations of water levels should occur, and for many wetland types seasonal dry-downs are regular events.
- Allowing soil profiles to remain intact and select or amend them to provide high levels of organic matter and appropriate amounts of nutrients to encourage establishment and growth of robust and diverse plant communities.
- Seeding at high volumes and planting at high densities to develop plant communities that will mimic the species diversity and cover values of nearby natural wetlands of the project type. This should also assist rapid development, thereby minimizing the opportunity for invasive plant species establishment.
- Starting monitoring and adaptive management at the same time construction is initiated, maintaining constant observations, and addressing any obstructions to development of high-quality wetlands as they occur.
- Designing projects to replicate high-performing natural wetlands.
- Monitoring mitigation wetlands using Level 3 assessment tools like those developed in Ohio and for the NWCA, which can be successfully used to assess natural wetlands.

- Setting performance goals for wetlands that include measurable ecological goals that can be generated from analysis of data collected using Level 3 assessment tools like those used in Ohio and those being developed for the NWCA.
- Mitigation performance standards that equate to a good or better level of ecological condition.

GLBECS researchers believe close attention to these details will result in wetlands of high ecological condition. If the goals are embraced from the beginning and focused on throughout the process, such conditions can be achieved.

VI. Tables

Table 1a. VIBI and LDI Results for Mitigation Bank (MB) Sites Sampled during the Great Lakes Basin Evaluation of Compensation Sites Survey (2011)

	Assessment Area (AA) Information								Results		
Site	Sample Date	Vegetation Class	HGM Class[1]	% NPH Spp.[2]	% Invasive Cover[3]	% H_20 Cover	% Buffer Plots w/ Invasive Spp.	VIBI	Ecological Condition	LDI
MB01	8/28/2011	Emergent	Impound	50	47	50	69	29	Fair	2.9
MB02	6/21/2011	Emergent	Depress	56	1	30	23	79	Excellent	2.8
MB03	6/24/2011	Forest	Riv-MS	63	13	4	92	75	Excellent	1.0
MB04	7/22/2011	Forest	Slope	36	9	0	8	47	Fair	1.5
MB05	8/2/2011	Emergent	Impound	63	34	0	92	24	Poor	4.6
MB06	6/29/2011	Forest	Depress	85	0	35	23	26	Poor	1.0
MB07	8/2/2011	Emergent	Impound	0	100	1	100	0	Poor	4.3
MB08	7/17/2011	Emergent	Impound	49	43	0	85	56	Good	3.6
MB09	7/15/2011	Emergent	Depress	32	56	0	69	10	Poor	4.5
MB10	8/4/2011	Emergent	Depress	59	3	3	77	49	Fair	4.5
MB11	8/22/2011	Emergent	Impound	52	45	5	85	21	Poor	5.1
MB12	7/16/2011	Emergent	Impound	34	65	0	92	21	Poor	2.3
MB13	8/7/2011	Emergent	Impound	94	0	2	0	64	Good	2.3
MB14	8/7/2011	Emergent	Depress	83	14	5	62	44	Fair	3.2
MB15	6/27/2011	Emergent	Depress	63	3	22	15	53	Fair	4.2
MB16	7/20/2011	Emergent	Impound	83	2	0	38	56	Good	3.8
MB17	7/20/2011	Forest	Impound	67	1	8	15	23	Poor	1.2
MB18	7/23/2011	Forest	Impound	86	2	0	46	26	Fair	2.8
MB19	6/20/2011	Emergent	Impound	71	6	55	8	53	Good	1.1
MB20	6/22/2011	Emergent	Depress	80	8	30	38	78	Excellent	4.6
MB21	7/22/2011	Forest	Slope	72	2	0	8	47	Fair	1.5
MB21(2)	8/30/2011	Forest	Slope	55	2	0	15	44	Fair	1.5
MB22	6/29/2011	Forest	Depress	49	3	0	69	47	Fair	1.0
MB23	8/1/2011	Forest	Impound	99	1	0	8	30	Fair	1.1
MB24	6/23/2011	Emergent	Depress	52	16	65	15	71	Excellent	2.6
MB25	8/23/2011	Emergent	Impound	51	49	85	92	26	Poor	1.0
MB26	8/23/2011	Emergent	Impound	98	1	65	100	29	Fair	1.0
MB27	8/3/2011	Emergent	Impound	90	10	100	46	51	Fair	3.5
MB28	6/28/2011	Emergent	Depress	76	9	70	31	52	Fair	4.1
MB29	7/18/2011	Forest	Impound	65	1	0	0	55	Good	1.0
MB30	7/23/2011	Emergent	Depress	21	66	0	15	26	Fair	3.0
			MB Average[4]:	**63**	**20**	**21**	**47**	**42**		**2.7**

Notes:
[1]Hydrogeomorphic wetland classification for assessing wetlands function; based on Brinson et al. (1995)
[2]Percent of plant species in the AA that are native perennial hydrophytes (NPH)
[3]Percent coverage of invasive species in the AA
[4]MB Averages based on 30 sampled sites; does not include re-visit site MB21(2)

Table 1b. VIBI and LDI Results for Permittee Responsible (PR) Sites Sampled during the Great Lakes Basin Evaluation of Compensation Sites Survey (2011)

	Assessment Area (AA) Information						% Buffer	Results		
Site	Sample Date	Vegetation Class	HGM Class[1]	% NPH Spp.[2]	% Invasive Cover[3]	% H_20 Cover	Plots w/ Invasive Spp.	VIBI	Ecological Condition	LDI
PR01	6/7/2011	Emergent	Riv-HW	46	8	4	62	48	Fair	3.5
PR02	8/10/2011	Emergent	Impound	15	39	85	85	3	Poor	1.5
PR03	6/6/2011	Emergent	Impound	88	9	75	54	59	Good	5.9
PR04	6/8/2011	Emergent	Riv-MS	26	69	8	69	51	Fair	2.9
PR05	8/27/2011	Forest	Riv-MS	94	0	10	62	32	Fair	2.8
PR06	9/13/2011	Emergent	Impound	49	7	70	0	18	Poor	1.0
PR07	6/9/2011	Emergent	Riv-MS	19	69	35	62	33	Fair	1.5
PR08	8/8/2011	Emergent	Impound	9	90	100	100	11	Poor	4.6
PR09	6/10/2011	Emergent	Impound	86	13	90	69	40	Fair	1.0
PR10	6/3/2011	Emergent	Impound	99	0	30	15	22	Poor	4.3
PR12	6/1/2011	Emergent	Impound	82	13	37	69	48	Fair	3.6
PR13	6/2/2011	Emergent	Impound	77	6	30	38	56	Good	4.5
PR14	9/14/2011	Emergent	Depress	12	88	5	62	11	Poor	4.5
PR15	9/15/2011	Emergent	Depress	91	8	0	15	51	Good	5.1
PR16	8/8/2011	Forest	Depress	73	9	3	23	36	Fair	2.3
PR17	8/6/2011	Emergent	Impound	6	93	60	77	36	Fair	2.3
PR18	8/12/2011	Emergent	Impound	70	29	85	62	43	Fair	3.2
PR19	9/12/2011	Emergent	Impound	11	87	95	46	7	Poor	4.2
PR22	8/31/2011	Emergent	Depress	56	35	85	31	43	Fair	3.8
PR23	8/5/2011	Emergent	Impound	74	26	90	77	19	Poor	1.2
PR23(2)	8/25/2011	Emergent	Impound	67	31	90	92	11	Poor	2.8
PR24	8/29/2011	Emergent	Impound	2	64	50	92	0	Poor	1.1
PR26	6/30/2011	Emergent	Impound	68	31	60	69	56	Good	4.6
PR27	6/26/2011	Emergent	Impound	66	22	70	15	39	Fair	1.5
PR28	8/9/2011	Emergent	Impound	88	12	86	77	48	Fair	1.5
PR29	6/25/2011	Forest	Depress	0	0	5	85	34	Fair	1.0
PR30	8/24/2011	Emergent	Impound	59	26	22	38	48	Fair	1.1
PR31	8/25/2011	Emergent	Impound	37	60	5	46	29	Fair	2.6
PR32	8/26/2011	Emergent	Impound	54	0	95	31	14	Poor	1.0
PR33	9/1/2011	Emergent	Impound	39	45	40	15	33	Fair	1.0
PR34	8/11/2011	Emergent	Depress	27	61	2	38	37	Fair	3.5
			PR Average[4]:	**51**	**34**	**48**	**53**	**34**		**2.7**

Notes:

[1]Hydrogeomorphic wetland classification for assessing wetlands function; based on Brinson et al. (1995)

[2]Percent of plant species in the AA that are native perennial hydrophytes (NPH)

[3]Percent coverage of invasive species in the AA

[4]PR averages based on 30 sampled sites; does not include re-visit site PR23(2)

Table 2. 2006 National Land Cover Dataset (NLCD) Land Use Categories and Corresponding Landscape Development Intensity (LDI) Coefficients (derived from Micacchion et al. 2010)

Land Use Category	LDI Coefficient
11 (Open Water)	1.00
21 (Developed, Open Space)	6.92
22 (Developed, Low Intensity)	7.47
23 (Developed, Medium Intensity)	7.55
24 (Developed, High Intensity)	9.42
31 (Barren Land)	8.32
41 (Deciduous Forest)	1.00
42 (Evergreen Forest)	1.00
43 (Mixed Forest)	1.00
52 (Shrub/Scrub)	2.02
71 (Grasslands/Herbaceous)	3.41
81 (Pasture/Hay)	3.74
82 (Cultivated Crops)	4.54
90 (Woody Wetlands)	1.00
95 (Emergent Herbaceous Wetlands)	1.00

VII. Figures

Figure 1. Population distribution and statistics for mitigation bank VIBI scores from GLBECS study (2011).

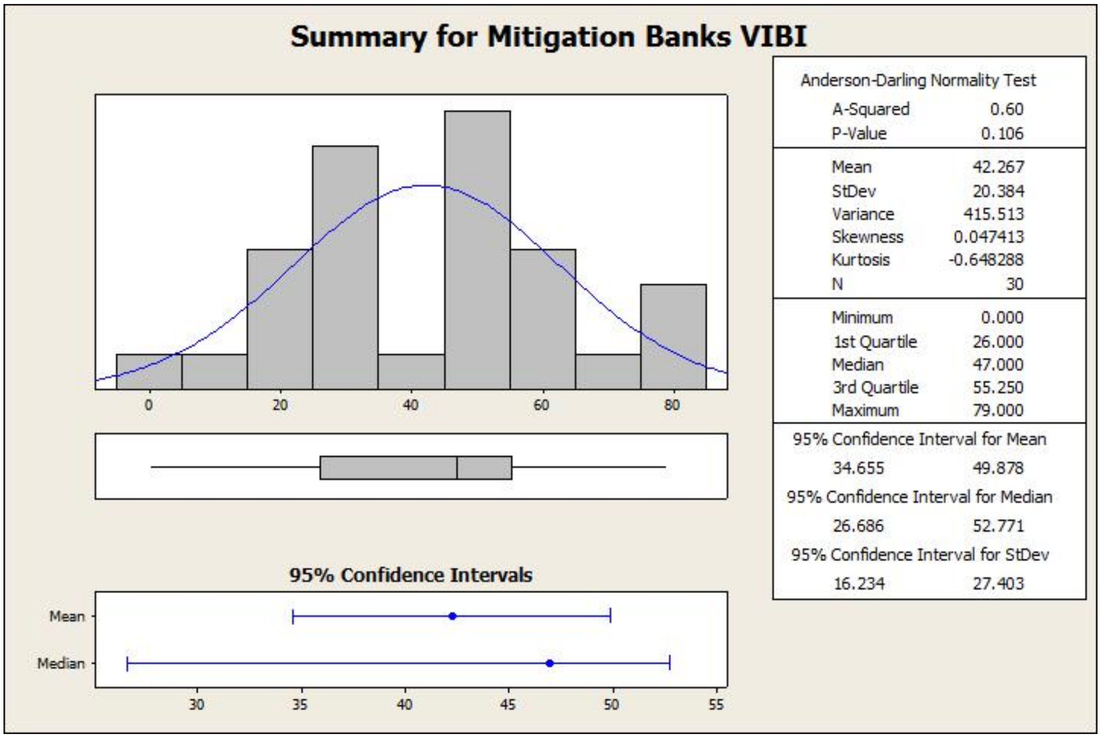


Figure 2. Population distribution and statistics for permittee-responsible mitigation VIBI scores from GLBECS study (2011).

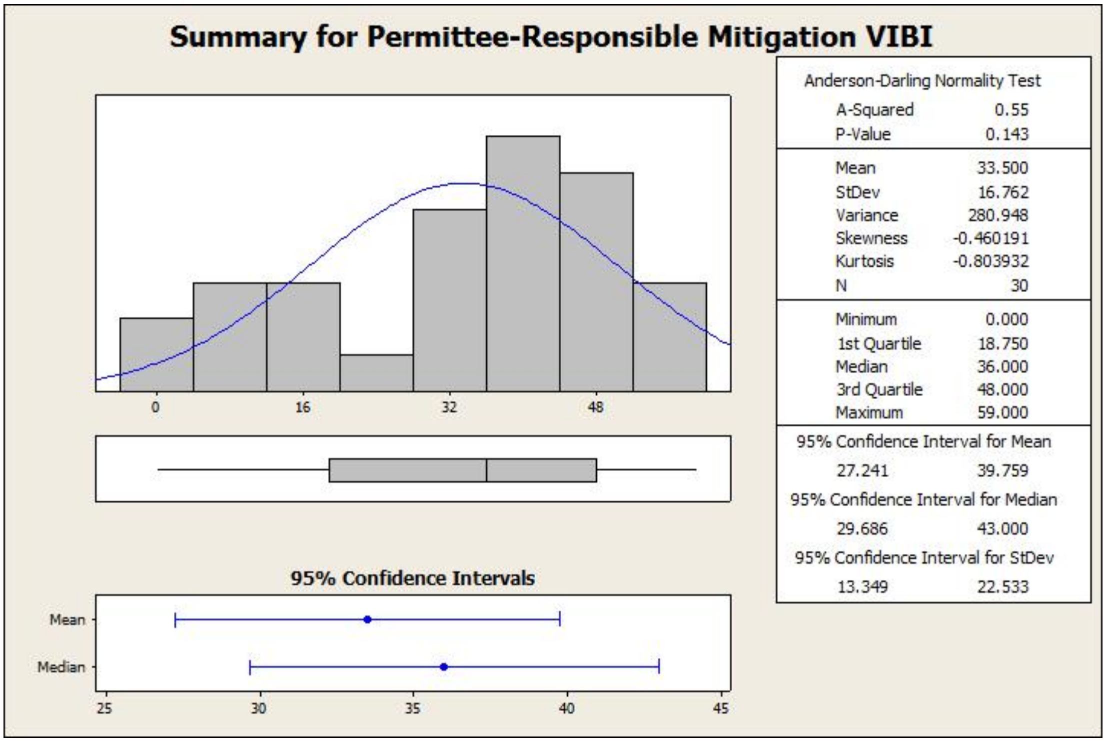


Figure 3. Vegetation IBI scores by Ohio Rapid Assessment Method (ORAM) score tertiles for natural reference wetlands, mitigation banks (MB), and permittee-responsible mitigation (PRM). 1st tertile = 0 to 33 (poor quality/Category 1/LQWLH), 2nd tertile = 34 to 65 (fair to good quality/Category 2/RWLH and WLH), 3rd tertile = >65 (excellent quality/Category 3/SWLH). Scores from permittee-responsible mitigation are not siginificantly different from mitigation bank scores but are significantly different from 1st, 2nd, and 3rd tertiles. Scores for mitigation banks are significantly different from 1st and 3rd tertiles. All comparisons were made after conducting an analysis of variance followed by Tukey's multiple comparison test (df = 213, F = 73.7, $p < 0.001$). Box = 25th and 75th percentile, crossed circle = mean, bar = median.

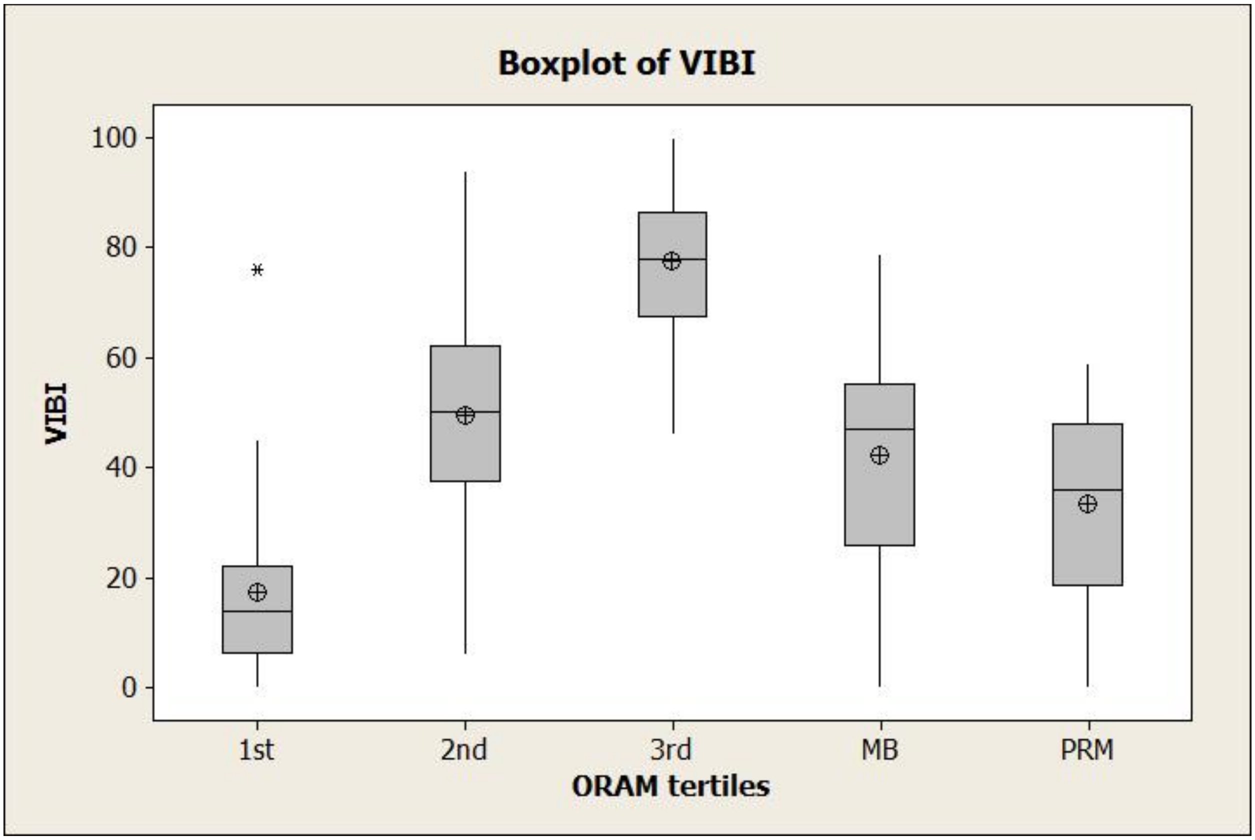


Figure 4. Scatterplot and regression line for VIBI scores vs. LDI scores from GLBECS study (2011).

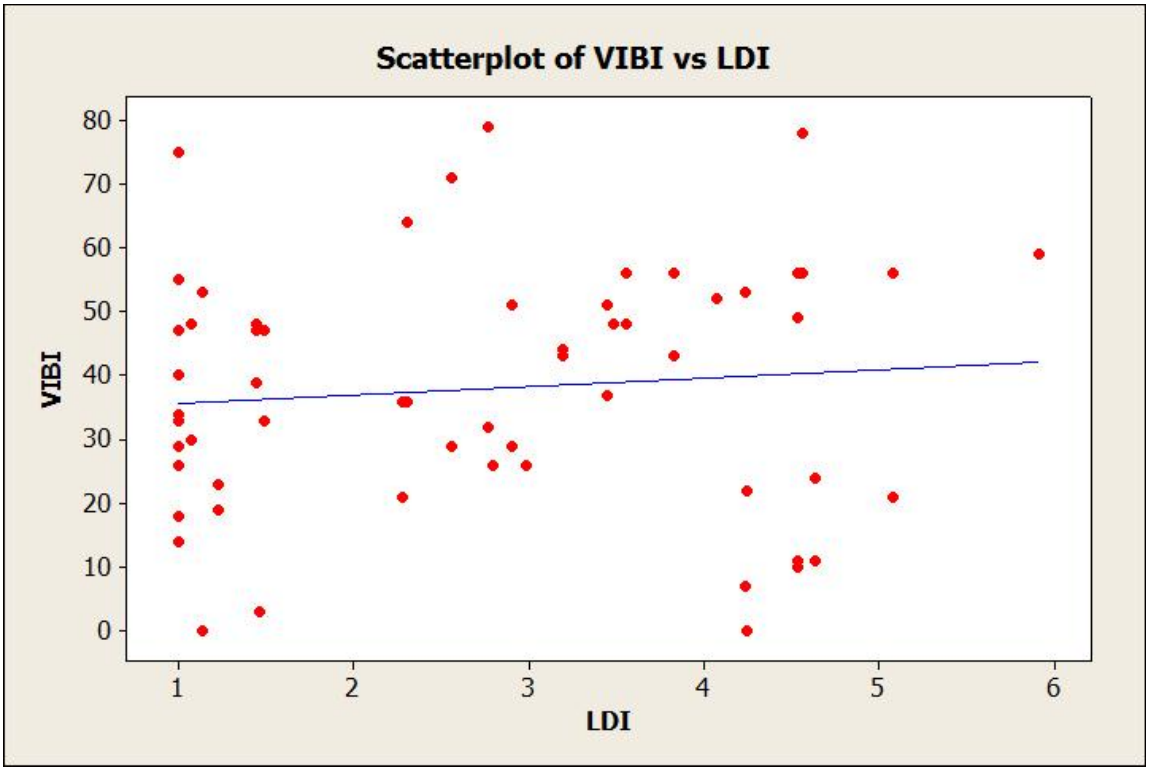
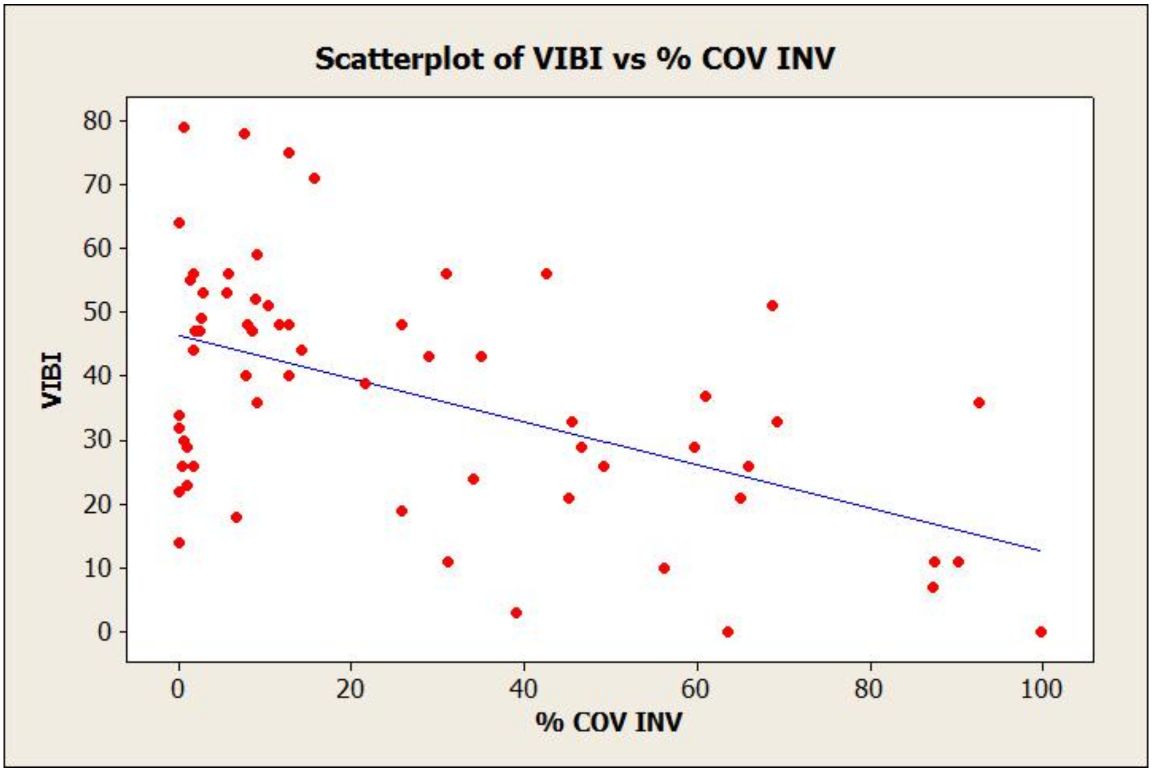


Figure 5. Scatterplot and regression line for VIBI vs. percent cover of invasives (COV INV) from GLBECS study (S = 16.4200, $P < 0.001$, R–Sq = 27.3%) (2011).



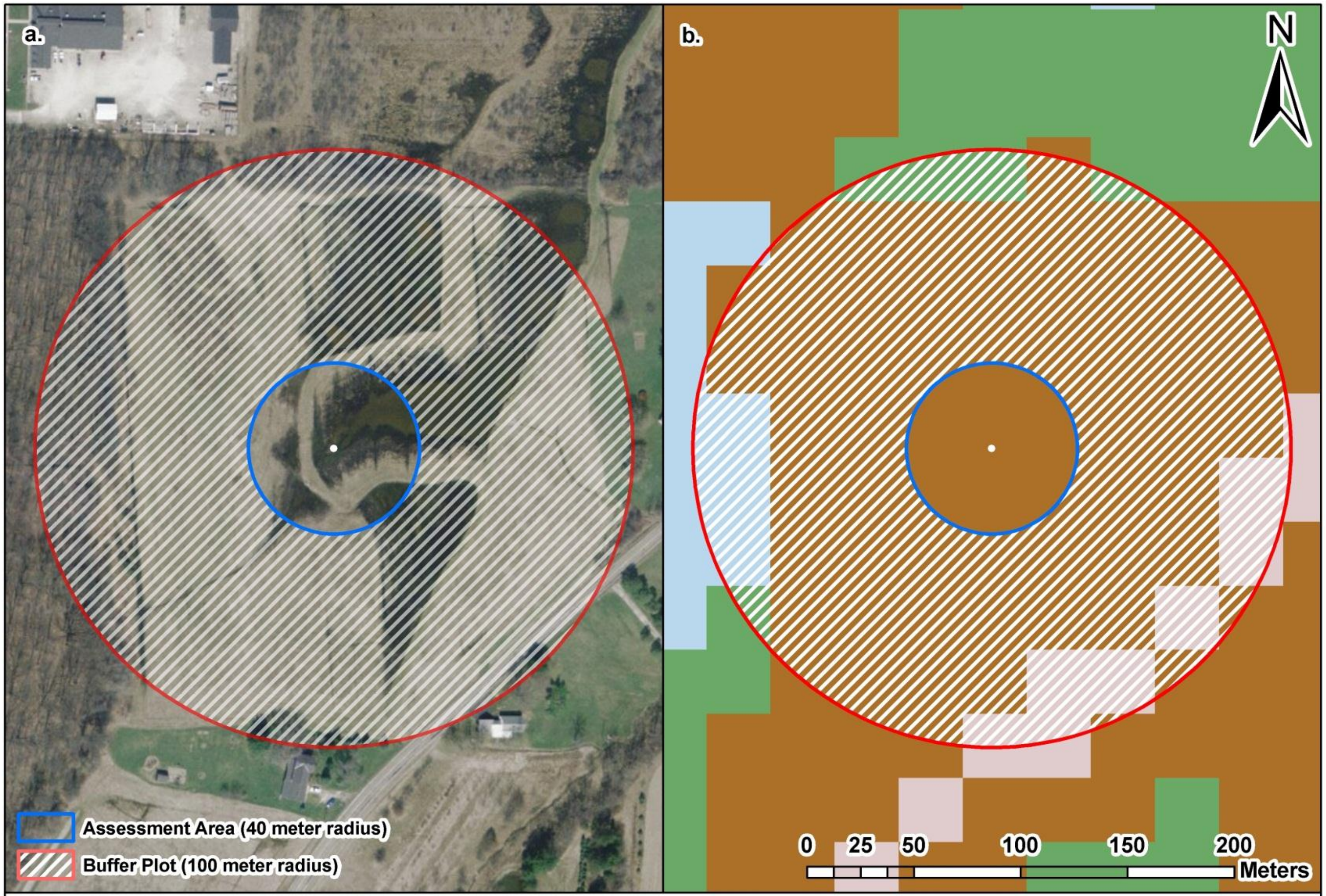


Figure 6. Standard Assessment Area (AA) and buffer plot of a representative GLBECS sample site (2011). a. AA/ buffer with aerial background; b. same AA/buffer with land use layer overlay. Each colored pixel in the buffer area of b. represents a different land use type (Table 2), which is calculated into the LDI score.

VIII. References

Ambrose, R.F., J.C. Callaway, and F.F. Lee. 2006. *An Evaluation of Compensatory Mitigation Projects Permitted under Clean Water Act Section 401 by the California State Water Quality Control Board, 1991–2002*. 03-259-250-0. California Environmental Protection Agency, California State Water Resources Control Board, Los Angeles, Calif.

Andreas, B.K., J.J. Mack, and J.S. McCormac. 2004. *Floristic Quality Assessment Index (FQAI) for Vascular Plants and Mosses for the State of Ohio*. Ohio Environmental Protection Agency, Division of Surface Water, Wetland Ecology Group, Columbus, Ohio.

Brown, M.T., and M.B. Vivas. 2005. Landscape Development Intensity index. *Environmental Monitoring and Assessment* 101: 289–309.

Burgin, S. 2010. "Mitigation banks" for wetland conservation: A major success or an unmitigated disaster? *Wetlands Ecology and Management* 18(1): 49–55.

Brooks, R.P., D. Heller Wardrop, C.A. Cole, and D.A. Campbell. 2005. Are we purveyors of wetland homogeneity? A model of degradation and restoration to improve wetland mitigation performance. *Ecological Engineering* 24 (2005): 331–340.

Brown, J.R. (ed.). 1998. *Recommended Chemical Soil Test Procedures for the North Central Region.* North Central Regional Research Publication Bull. No. 221 (revised). Missouri Agricultural Experiment Station SB 1001, University of Missouri, Columbia, MO. 72pp. <http://extension.missouri.edu/explorepdf/specialb/sb1001.pdf> Accessed 11/22/2011.

Daehler, C.C. 2003. Performance comparisons of co-occurring native and alien invasive plants: Implications for conservation and restoration. *Annual Review of Ecology, Evolution and Systematics* 34: 183-211.

Ecker, C.G., S. Kalisz, and M.A. Geber. 2010. Plant mating systems in a changing world. *Trends in Ecology and Evolution* 25: 35-43.

Faber-Langendoen, D., G. Kudray, C. Nordman, L. Sneddon, L. Vance, E. Byers, J. Rocchio, S. Gawler, G. Kittel, S. Menard, P. Comer, E. Muldavin, M. Schafale, T. Foti, C. Josse, and J. Christy. 2008. *Ecological Performance Standards for Wetland Mitigation: An Approach Based on Ecological Integrity Assessments*. NatureServe, Arlington, Va.. 72 pp.

Federal Guidance for the Establishment, Use and Operation of Mitigation Banks. 1995. *Federal Register* 60(228): 58605-58614.

Fennessy, M.S., J.J. Mack, E. Deimeke, M.T. Sullivan, J. Bishop, M. Cohen, M. Micacchion, and M. Knapp. 2007. *Assessment of Wetlands in the Cuyahoga River Watershed of Northeast Ohio*. Ohio EPA Technical Report WET/2007-4. Ohio Environmental Protection Agency, Division of Surface Water, Wetland Ecology Group, Columbus, Ohio. 123 pp. plus appendices.

Fennessy, M.S. J.J. Mack, A. Rokosch, M. Knapp, and M. Micacchion. 2004. *Integrated Wetland Assessment Program.* Part 5. *Biogeochemical and Hydrological Investigations of Natural and Mitigation Wetlands*. Ohio EPA Technical Report 2004-5. Ohio Environmental Protection Agency, Wetland Ecology Group, Division of Surface Water, Columbus, Ohio. 103 pp.

Gunsch, Marilyn S. 2008. The Effect of Wetland Size and Surrounding Land Use on Wetland Quality along an Urbanization Gradient in the Rocky River Watershed. <http://hdl.handle.net/2374.OX/104916>. Accessed 11/15/2011.

Karr, J.R., and E.W. Chu. 1999. *Restoring Life in Running Waters: Better Biological Monitoring.* ISBN 1–55963–674–2. Island Press, Washington, D.C. 206 pp.

Kentula, M.E. 2000. Perspectives on setting success criteria for wetland restoration. *Ecological Engineering* 15: 199–209.

Kihslinger, R.L. 2008. Success of wetland mitigation projects. *National Wetlands Newsletter* 30(2): 14–16.

Mack, J. J. 2001. *Ohio Rapid Assessment Method for Wetlands: Manual for Using Version 5.0.* Ohio EPA Technical Bulletin Wetland/2001-1. Ohio Environmental Protection Agency, Division of Surface Water, 401 Wetland Ecology Unit, Columbus, Ohio.

Mack, J.J. 2004a. *Integrated Wetland Assessment Program.* Part 4. *Vegetation Index of Biotic Integrity (VIBI) for Ohio Wetlands*. Ohio EPA Technical Report WET/2004-4. Ohio Environmental Protection Agency, Division of Surface Water, Wetland Ecology Group, Columbus, Ohio. 91 pp.

Mack, J.J. 2004b. *Integrated Wetland Assessment Program*. Part 9. *Field Manual for the Vegetation Index of Biotic Integrity for Wetlands v. 1.3*. Ohio EPA Technical Report WET/2004-9. Ohio Environmental Protection Agency, Division of Surface Water, Wetland Ecology Group, Columbus, OH. 44 pp. + appendices.

Mack, J.J. 2006 Landscape as a predictor of wetland condition: An evaluation of the Landscape Development Index (LDI) with a large reference wetland dataset from Ohio. Environmental *Monitoring and Assessment* 120(1-3): 221–241.

Mack, J.J. 2007. Developing a wetland IBI with statewide application after multiple testing iterations. *Ecological Indicators* 7: 864–881.

Mack, J.J. 2009. Development issues in extending plant-based IBIs to forested wetlands in the Midwestern United States. *Wetlands Ecological Management* 17(2): 117–130.

Mack, J.J., and M. Micacchion. 2006. *An Ecological Assessment of Ohio Mitigation Banks: Vegetation, Amphibians, Hydrology, and Soils*. Ohio EPA Technical Report WET/2006-1. Ohio Environmental Protection Agency, Division of Surface Water, Wetland Ecology Group, Columbus, Ohio. 152 pp.

Mack, J. J., and M. Micacchion. 2007. *An Ecological And Functional Assessment Of Urban Wetlands In*

Central Ohio. Volume 1. *Condition of Urban Wetlands Using Rapid (Level 2) and Intensive (Level 3) Assessment Methods*. Ohio EPA Technical Report WET/2007-3A. Ohio Environmental Protection Agency, Wetland Ecology Group, Division of Surface Water, Columbus, Ohio. 113 pp.

Mack, J. J., M. S. Fennessy, M.Micacchion, and D. Porej. 2004. Standardized Monitoring Protocols, Data Analysis and Reporting Requirements for Mitigation Wetlands In Ohio, v. 1.0. Ohio EPA Technical Report WET/2004-6. Ohio Environmental Protection Agency, Division of Surface Water, Wetland Ecology Group, Columbus, Ohio. 106 pp.

Matthews, J.W., and A.G. Endress. 2008. Performance criteria, compliance success, and vegetation development in compensatory mitigation wetlands. *Environmental Management* 41: 130–141.

Micacchion, M., B.D. Gara, and J. J. Mack. 2010. Assessment of wetland mitigation projects in Ohio. Volume 1: An Ecological Assessment of Ohio Individual Wetland Mitigation Projects. Ohio EPA Technical Report WET/2010-1A. Ohio Environmental Protection Agency, Wetland Ecology Group, Division of Surface Water, Groveport, Ohio.

Minkin, P., and R. Ladd. 2003. *Success of Corps-required Mitigation in New England*. U.S. Army Corps of Engineers, New England District.

NRC (National Research Council). 2001. *Compensating for Wetland Losses under the Clean Water Act*. National Academy of Sciences, Washington, D.C. 322pp.

Ohio Interagency Review Team. March 2011. Guidelines for Wetland Mitigation Banking in Ohio. <http://www.lrh.usace.army.mil/downloadfile.cfm?file=4CB321D0-E7F2-1C13-9C3D295D3B884662>. Accessed 11/17/2011.

Reiss, K.C., E. Hernandez, and M.T. Brown. 2009. Evaluation of permit success in wetland mitigation banking: A Florida case study. *Wetlands* 29(3): 907–918.

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

Sudol, M.F., and R.F. Ambrose. 2002. The U.S. Clean Water Act and habitat replacement evaluation of mitigation sites in Orange County, California, USA. *Environmental Management* 30: 727–734.

Turner, R.E., A.M. Redmond, and J. Zedler. 2001. Count if by acre or function—Mitigation adds up to net loss of wetlands. *National Wetlands Newsletter* 23(6): 5

USACE (U.S. Army Corps of Engineers). 1987. *Corps of Engineers Wetlands Delineation Manual*. Wetlands Research Program Technical Report Y-87-1. Department of the Army, U.S. Army Corps of Engineers, Waterways Experiment Station, Environmental Laboratory, Vicksburg, Miss.

USACE and USEPA (U.S. Army Corps of Engineers and U.S. Environmental Protection Agency). 2008a. Compensatory Mitigation for Losses of Aquatic Resources: Final Rule. April 10, 2008. *Federal Register* 73(70):19593–19705.

USACE and USEPA (U.S. Army Corps of Engineers and U.S. Environmental Protection Agency). 2008b. Rules on Compensatory Mitigation for Losses of Aquatic Resources. 33 CFR parts 325 and 332 and 40 CFR part 230.

USEPA (U.S. Environmental Protection Agency). 2011a. *National Wetland Condition Assessment: Field Operations Manual*. EPA-843-R-10-001. U.S. Environmental Protection Agency, Washington, D.C.

USEPA. 2011b. *National Wetland Condition Assessment: Laboratory Operations Manual*. EPA-843-R-10-002. U.S. Environmental Protection Agency, Washington, D.C.

USEPA. 2011c. *National Wetland Condition Assessment: Quality Assurance Project Plan*. EPA-843-R-10-003. U.S. Environmental Protection Agency, Washington, D.C.

U.S. Government. 2002. National Wetlands Mitigation Action Plan. <http://www.usace.army.mil/CECW/Documents/cecwo/reg/Mit_Action_Plan.pdf>

Zedler, J.B. 1996. Ecological issues in wetland mitigation: An introduction to the forum. *Ecological Applications* 6(1):33–37.