State of Ohio
Environmental Protection Agency

Wetland Ecology Group
Division of Surface Water

# 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

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VOLUME 1: CONDITION OF URBAN WETLANDS USING RAPID (LEVEL 2)
AND INTENSIVE (LEVEL 3) ASSESSMENT METHODS

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ABSTRACT

Wetlands are well known for their "kidney-on-the-landscape" functions even though these services are rarely assessed quantitatively and usually not in urban contexts. The problem of "kidney failure", by exceeding the capacity of a wetland to assimilate additional hydrologic, nutrient, or sediments, is almost never addressed. We assessed a simple random sample of 100 wetland sites (out of 649) mapped wetlands in Franklin County (Columbus), Ohio. Sites selected ranged in size from 0.04 to 3.6 ha (0.1 to 8.9 acres) with an average size of 0.77 ha (1.9 ac). The average depressional wetland was half as small as a riverine wetland, averaging 0.45 ha (1.1 ac) versus 1.0 ha (2.5ac), respectively. The 100 points evaluated were ultimately determined to include 104 assessment units. Of the 104 wetlands, Level 2 and Level 3 assessments were able to be performed at 40.4% of the sites. A large percentage of the sites mapped as wetlands ca1980s by the National Wetland Inventory (NWI) or Ohio Wetland Inventory (OWI) (42.3%) were determined to have been filled or converted to non-wetland land uses. Depressional (47%) and riverine (41%) hydrogeomorphic classes accounted for nearly all of the wetlands evaluated. Over two-thirds of urban wetlands were forested (69%) with the remainder dominated by emergent vegetation (31%). No good examples of shrub dominated wetlands were found in this study. Based on our Level 2 assessment, nearly 60% of the urban wetlands assessed were in poor (26%) or fair (33%) condition, but over one-third were in good (31%) to excellent (10%) condition. There were significant differences in average condition between depressional and riverine wetlands and observable differences in percentages of wetlands by condition class and HGM class. On average, urban depressional wetlands appeared to be in poorer condition than urban riverine wetlands. Percentages of stressors declined from Category 1 (>30%) to Category 3 (<10%) with high quality wetlands having low percentages of hydrologic (8%) and habitat (7%) disturbances. The most common hydrologic disturbances were ditching, stormwater, filling, and roads/RR beds; the most common habitat disturbances were mowing, clearcutting, sedimentation, toxic pollutants, shrub removal and nutrient enrichment. Depression and riverine wetlands had similar percentages of hydrologic and habitat disturbances but forested wetlands had substantial higher numbers of disturbances than emergent wetlands for hydrologic (67% to 33%, respectively) and habitat (62% to 38%, respectively) although these differences were not significant for hydrologic. All of the wetland's amphibian communities represented poor quality associations with AmphIBI scores ranging from 0 to 13. No sensitive amphibian species were encountered. Jefferson salamanders (*Ambystoma jeffersonianum*) were collected at one site and smallmouth salamanders (*Ambystoma texanum*) were present at four sites. The most abundant species was the leopard frog (*Rana pipiens*) (30.4%) followed by the spring peeper (*Pseudacris crucifer)* (27.2%) and green frog (*Rana clamitans)* (13.8%). Based on the Level 3 Vegetation IBI assessment 68% of urban wetlands were in poor (14%) or fair (54%) condition and 32% were in good (18%) or very good (14%) condition). The Level 2 and 3 assessments were in agreement regarding the poor/fair percentages but the Level 3 assessment concluded that fewer wetlands were in poor and good condition and more wetlands were in fair condition. We conclude that 1) average condition of urban wetlands is not "poor" but is best characterized as "fair" with 41% of wetlands in good or better condition, 2) reference-based assessment

protocols like ORAM and the Vegetation or Amphibian IBIs fairly assess urban wetland ecosystems, 3) that alternate (lower) ecological standards for judging the condition of urban wetlands are not needed and would be counterproductive, 4) Many urban wetlands have long-term viability as at least "fair" condition ecosystems and there should not be presumption that all urban wetland mitigation will be of poor condition,and 5) ecological services like flood storage/desynchronization should be assessed quantitatively with appropriate Level 3 protocols and not via Level 2 surrogates, or if Level 2 approaches are used they should be derived from Level 3 data sets. Although there are clearly urban wetlands that are so degraded, or so fragmented from the local hydrologic cycle, that they provide no, or nearly no ecological services this study shows thateven in highly urbanized watersheds, more than half of the remaining wetlands can be of sufficient condition, or providing sufficient services, to warrant at least "Category 2" levels of protection and mitigation ratios.

# INTRODUCTION

The State of Ohio has been developing wetland assessment methods since 1996 with the goal of incorporating statewide wetland monitoring into its existing rotating basin surface water monitoring program. Strategies for designing an effective monitoring program are described in what is known as the "three-tier framework" for wetland monitoring and assessment (U.S. EPA 2006). Wetland monitoring and assessment programs in the U.S. are designed to report on the ambient condition of wetland resources, evaluate restoration success, and report on the success of management activities. The "three-tier framework" is a strategy for designing effective monitoring programs. This approach breaks assessment procedures into a hierarchy of three levels that vary in the degree of effort and scale, ranging from broad, landscape assessments using readily available data (known as Level 1 methods), to rapid field methods (Level 2), to intensive biological and physico-chemical measures (Level 3) (Brooks 2004, Fennessy et al. 2004, 2007a). The objective of this project was to perform an ecological and functional assessment of urban wetlands using Level 2 and Level 3 assessment data. Level 3 data included 1) biological assessments of amphibians, macroinvertebrates and plants and 2) assessment of the flood storage function of urban wetlands by collecting detailed quantitative hydrologic data and three-dimensional geo-referenced basin maps of the wetlands. Results of the ecological assessment are reported here (Volume 1) and in Knapp (2007); functional assessment results are reported in Volume 2 of this report (Gamble et al. 2007).

The general effects of urbanization on aquatic resources, especially streams, are relatively well known. Urbanization can increase the frequency and intensity of floods, reduce stream baseflow during dry periods, and cause bank erosion and channel widening (Poff et al. 1997) and cause shifts in fish and invertebrate communities to tolerant, generalist, often low diversity assemblages. Wetlands can provide ecological services (functions and values) that can ameliorate these effects by capture and storing stormwater, desynchronizing peak flows, and storing or converting pollutants (Mitsch and Gosselink 2000). But, can also be degraded ecologically in the same manner as streams by stormwater, nutrient enrichment, sedimentation and altered hydrologic cycles.

Wetlands are well known for their "kidney-on-the-landscape" functions even though these ecological services are rarely assessed quantitatively and usually not in urban contexts. The problem of "kidney failure", by exceeding the capacity of a wetland to assimilate additional hydrologic, nutrient, or sediments, is usually not discussed and there seems to be an implicit assumption in the common understanding of wetlands that their capacity to assimilate is unlimited. The export of wetland functions from urban impact areas to rural mitigation sites is a well known problem to wetland regulators and is recently gaining attention (e.g. Ruhl and Salzman 2006). More germane to the assessment of the condition of urban wetlands is the attainable biological expectations of these systems in urban contexts. Several perennial questions are often raised when urban wetlands are discussed. Is it possible for a wetland to be in anything other than poor condition in urban contexts? Do assessment protocols which define excellent, good, fair, poor by comparison to reference ecosystems fairly assess wetlands in urban contexts? Should there be alternate (i.e. lower) standards for judging urban wetlands? Do wetlands in urban contexts have limited long-term viability (i.e are they inherently declined to degrade to the point they are of no value)? Should mitigation of urban wetland impacts focus on just replacing flood storage services and allow creation of an actual "wetland" to occur elsewhere in a (presumably) more sustainable context? Do urban wetlands provide significant ecological services to human society? The data collected in this study helps to provide a much needed context to evaluate these questions.

## REGULATORY BACKGROUND

### *Wetland Water Quality Standards*

The State of Ohio adopted Wetland Water Quality Standards and a Wetland Antidegradation Rule on May 1, 1998. The rules categorize wetlands based on their quality and functionality and impose differing levels of protection based on the wetland's category (OAC rules 3745-1-50 through 3745-1-54). The regulations specify three wetland categories: Category 1, Category 2, and Category 3 wetlands. These categories correspond to wetlands of low, medium and high quality and/or function. In addition, there is an implied fourth category described in the definition of Category 2 wetlands, i.e. wetlands that are degraded but restorable (modified Category 2). These potentially restorable wetlands are Category 2 wetlands and receive the same level of regulatory protection as other Category 2 wetlands.

### *Category 1 Wetlands*

Ohio Administrative Code Rule 3745-1-54(C)(1) defines Category 1 wetlands as wetlands which “...support minimal wildlife habitat, and minimal hydrological and recreational functions," and as wetlands which “...do not provide critical habitat for threatened or endangered species or contain rare, threatened or endangered species.” Category 1 wetlands are often hydrologically isolated, have low species diversity, no significant habitat or wildlife use, little or no upland buffers, limited potential to achieve beneficial wetland functions, and/or have a predominance of non-native species. Category 1 wetlands are defined as "limited quality waters" in OAC Rule 3745-1-05(A). They are considered to be a resource that has been so degraded or with such limited potential for restoration, or of such low functionality, that no social or economic justification and lower standards for avoidance, minimization, and mitigation are applied. Category 1 wetlands would include wetlands in "poor" ecological condition.

### *Degraded but Restorable (modified) Category 2 Wetlands*

Ohio Administrative Code Rule 3745-1-54(C) states that wetlands that are assigned to Category 2 constitute the broad middle category that “...support moderate wildlife habitat, or hydrological or recreational functions," but also include "...wetlands which are degraded but have a reasonable potential for reestablishing lost wetland functions" creating an implied fourth category of wetlands (modified Category 2 wetlands). Modified Category 2 wetlands include wetlands in "fair" ecological condition.

*Category 2 Wetlands*

Ohio Administrative Code Rule 3745-1-54(C)(2) defines Category 2 wetlands as wetlands which "...support moderate wildlife habitat, or hydrological or recreational functions," and as wetlands which are "...dominated by native species but generally without the presence of, or habitat for, rare, threatened or endangered species..." Category 2 wetlands constitute the broad middle category of "good" quality wetlands. In comparison to Ohio EPA's stream designations, they are equivalent to "warmwater habitat" streams, and thus can be considered a functioning, diverse, healthy water resource that has ecological integrity and human value. Some Category 2 wetlands are relatively lacking in human disturbance and can be considered to be naturally of moderate quality; others may have been Category 3 wetlands in the past, but have been disturbed "down to" Category 2 status. Category 2 wetlands would include wetlands in "good" ecological condition.

*Category 3 Wetlands*

Wetlands that are assigned to Category 3 have "...superior habitat, or superior hydrological or recreational functions." They are typified by high levels of diversity, a high proportion of native species, and/or high functional values. Category 3 wetlands include wetlands which contain or provide habitat for threatened or endangered species, are high quality mature forested wetlands, vernal pools, bogs, fens, or which are scarce regionally and/or statewide. Category 3 would include wetlands of "very good" or "excellent" condition.

*Wetland Tiered Aquatic Life Uses*

The State of Ohio has proposed draft rules which would revise OAC Rules 3745-1-50 to -54 and include an expansion of the OAC Rule 3745-1-53 with Wetland Tiered Aquatic Life Uses (WTALUs) (Tables 1, 2, and 3). The WTALUs generally correspond to the antidegradation categories with the exception that a wetland can be degraded but still exhibit a residual function or value at moderate or high levels such that it is Categorized as Category 2 or 3 but has a lower WTALU use designation. Narrative WTALU categories were first proposed in Mack (2001) and have been subsequently updated (Mack 2004b; Micacchion 2004; Mack and Micacchion 2006) and are summarized in Table 1. In addition to the tiered uses, special uses (values or ecological services) provided by wetlands can be assigned (Table 2). The WTALUs were developed by partitioning the 95th percentile of wetland IBI scores for that TALU category into sextiles and combining the sextiles into the 4 aquatic life use categories proposed as numeric biological criteria for Ohio wetlands: limited quality wetland habitat (LQWLH) (1st and 2nd sextiles), restorable wetland habitat (RWLH) (3rd and 4th sextiles), wetland habitat (5th sextile), and superior wetland habitat (SWLH) (6th sextile). Numeric TALUs (biological criteria) for Ohio wetlands were developed based on AmphIBI and VIBI scores, ecoregion, landscape position, and plant community (Table 3). In the context of this study, the WTALUs were used as true wetland condition categories for evaluating the results of the Level 1, 2, and 3 assessments.

## METHODS

*Assessment Approach*

Recent approaches to wetland assessment have advocated a multi-level approach which incorporates assessments based on landscape (remote sensing) data (level 1), on-site but "rapid" methods using checklists of observable stressors and other observable wetlands features (level 2), and intensive methods where quantitative floral, faunal, and/or biogeochemical data is collected (level 3) (USEPA 2006; Brooks 2004; Fennessy et al. 2004, 2007a). In this study we collected four types of data: 1) rapid assessment data obtained from a site visit and recorded on a background information form, a wetland determination form, the Penn State Stressor Checklist (Brooks 2004) and scores from the Ohio Rapid Assessment of Wetlands v. 5.0 (Mack 2001) (Appendix A); 3) quantitative ecological data on vegetation, amphibian, macroinvertebrate assemblages and soil and water chemistry data; and 4) hydrological and morphometric data which is reported in Volume 2 of this Report (Gamble et al. 2007). We assessed a "wetland" as defined by ORAM scoring boundary rules instead of a fixed area around a point.

*Study Region and Site Selection*

All of the wetland study sites were located in Franklin County, Ohio (Figure 1). Franklin County is located towards the eastern boundary of the Eastern Corn Belt Plains ecoregion (Woods et al. 1998), characterized by rolling till plains with local end moraines. Soils are rich, relatively well drained loams. Most of the original mesic forests have been converted to agriculture. Much of Franklin County is developed and includes the City of Columbus and its surrounding suburbs. However outlying areas of the county, particularly to the south and west are still predominately agricultural. The sample for this study was generally the boundary of the Interstate 270 outerbelt to exclude wetlands not located in urbanized locations. All wetlands mapped as palustrine emergent (PEM), palustrine forest (PFO), and palustrine scrub-shrub (PFO) by the National Wetland Inventory and significant pixel agglomerations of the Ohio Wetland Inventory that were not mapped by the NWI (predominately woods on hydric soils) were numbered (total = 649) and a simple random sample of 100 wetlands was obtained using the random sample feature of Minitab v. 12.0 (Appendix A). Areas mapped as PUBs were excluded. Recent (2006) aerial photography was inspected to determine whether a wetland could still be found near that location (e.g. the site was not developed or the wetland obviously destroyed). All sites in the first 100 points where a wetland was present and access could be obtained were assessed using the rapid (Level 2) assessment protocol (42 sites). The study goal was to assess at least 20 wetlands with intensive (Level 3) protocols. Ultimately, 22 sites divided into 26 assessment units were assessed with Level 3 methods.

*Sampling methods - Level 2 Rapid Assessment*

The ORAM assessment was performed at each wetland point in accordance with the *Ohio Rapid Assessment Method for Wetlands v. 5.0, User's Manual and Scoring Forms*, Ohio EPA Technical Report WET/2001-1. In addition to ORAM, the Penn State Stressor Checklist (also a Level 2 condition assessment) was completed at each site (Brooks 2004). The Checklist is made up of a set of indicators used to identify probable stressors, such as sedimentation, hydrologic modification, and habitat fragmentation. A Background Field Data form was also completed at each site.

*Sampling methods - Level 3 Assessment*

Vegetation. A plot-based vegetation sampling method was used to sample wetland plant communities (Peet et al., 1998). Sampling was performed in accordance with *Field Manual for Vegetation Index of Biotic Integrity v. 1.3* (Mack 2004c). At most sites, a "standard" 20 m x 50 m plot was established (0.1 ha). The location of the plot was qualitatively selected by the investigator based on site characteristics and rules for plot location (Mack 2004c). Presence and areal cover was recorded for herb and shrub stratums; stem density and basal area was recorded for all woody species >1m. Percent cover was estimated using cover classes of Peet et al. (1998) (solitary/few, 0-1%, 1-2.5%, 2.5-5%, 5-10%, 10-25%, 25-50%, 50-75%, 75-90%, 90-95%, 95-99%). All woody stems >1 m tall were counted and placed into diameter classes (0-1 cm, 1- 2.5 cm, 2.5-5 cm, 5-10 cm, 10-15 cm, 20-25 cm, 25-30 cm, 30-35 cm, 35-40 cm) except that trees with diameters >40 cm were individually measured. The midpoints of the cover and diameter classes were used in all analyses. Other data collected included standing biomass (g/m$^2$ from eight 0.1m$^2$ clip plots) and various physical variables (e.g. % open water, depth to saturated soils, amount of coarse woody debris, etc.). A soil pit was dug in the center of every plot and soil color, texture, and depth to saturation were recorded. A grab sample of soil and water was also collected and analyzed for standard inorganic parameters at Ohio EPA's laboratory.

Amphibians and Macroinvertebrates. Funnel traps were used in sampling both the macroinvertebrate and amphibians present in wetlands. Sample methods followed macroinvertebrate and amphibian IBI protocols in Micacchion (2004) and Knapp (2004). Funnel traps were constructed of aluminum window screen cylinders with fiberglass window screen funnels at each end. The funnel traps were similar in shape to commercially available minnow traps but with a smaller mesh-size. Ten funnel traps were placed evenly around the perimeter of the wetland and the trap location marked with flagging tape and numbered sequentially. Traps were set at the same location throughout the sample period. Of the Level 3 sites, 14 had sufficient water during spring 2006 to be trapped. Many wetlands in central Ohio appeared to still be recovering from a drought period the previous year. And we observed several sites which were unable to be trapped in spring 2006, having sufficient water in spring 2007. Additional amphibian sampling will be done in spring 2008 and reported in a supplemental volume or addendum to this report. Most of the 14 wetlands were sampled three times between March and July. Some sites did not have sufficient water present later by the 2$^{nd}$ or 3$^{rd}$ trapping run and were only trapped 1 or 2 times. Traps were unbaited and left in the wetland for twenty-four hours in order to ensure unbiased sampling for species with diurnal and nocturnal activity patterns. Upon retrieval, the traps were emptied by everting the funnel and shaking the contents into a white collection and sorting pan. Organisms that could be readily identified in the field (especially adult amphibians and larger and easily identified fish) were counted and released. The remaining organisms were transferred to wide-mouth one liter plastic bottles and preserved with 95% ethanol. Laboratory analysis of the funnel trap macroinvertebrate and fish samples followed standardized Ohio EPA procedures (Ohio EPA 1989). Invertebrate data is reported in Knapp (2007).

*Collection of hydrology/morphometric data*

Shallow ground water level monitoring wells were installed at each site (Ecotone or WM models, Remote Data Systems, Inc.). Twenty-two wells were installed in April and early May 2006 and operated until March 22, 2007. Extra wells were installed in August 2007 at the Ridenour Road, Sunbury Road and Watkins Road sites because survey work indicated that these sites appeared to have north and south areas that were hydrologically distinct. The wetland boundary was determined using the delineation procedures in the 1987 Federal Wetland Delineation Manual (Environmental Laboratory 1987). The perimeter of the wetland was flagged and mapped using Trimble GeoExplorer 3 GPS unit. The morphometric data were collected using transects radiating out from a rotating laser level (EAGL Model 1000 electronic rotating laser level). Manual triangulation was used to determine the position of the laser relative to the groundwater well. Elevations readings were taken using a laser detecting stadia rod. If one laser position did not adequately cover the wetland, the laser was moved to collect additional elevation readings, referencing the new laser location back to a known position. Hydrologic and morphometric data are reported in Volume 2 of this report (Gamble et al. 2007).

*Data analysis*

Minitab v. 12.0 was employed for the analyses of all data. Descriptive statistics, box and whisker plots, ANOVA, and regression analysis were used to evaluate the data.

## RESULTS AND DISCUSSION

*Status of urban wetlands in Franklin County*

The study sites selected for Level 3 assessment ranged in size from 0.04 to 3.6 ha (0.1 to 8.9 acres) with an average size of 0.77 ha (1.9 ac). Wetland perimeters ranged from 90 to 1281 m (296 to 4,206 ft), averaging 495 m (1,624 ft). The average depressional wetland was half as small as a riverine wetland, averaging 0.45 ha (1.1 ac) versus 1.0 ha (2.5ac), respectively, while the average depressional perimeter was 349 m (1144 ft) compared to the average riverine perimeter 617 m (2023 ft) (differences were not significant for area or perimeter). Details of morphometric results are reported in Volume 2 of this report (Gamble et al. 2007).

The 100 points evaluated were ultimately determined to include 104 assessment units. Of the 104 wetlands, Level 2 and Level 3 assessments were able to be performed at 40.4% of the sites (Figure 2). However a large percentage of the sites mapped as wetlands ca1980s by the National Wetland Inventory (NWI) or Ohio Wetland Inventory (OWI) (42.3%) were determined to have been filled or converted to non-wetland land uses (Figure 2). Of the remaining sites, 12.5% were determined to not be wetlands due to mapping errors by the NWI or OWI maps and the status of 4.8% of the sites was not able to be determined (Figure 2). We considered this kind of mapping error to be a Type 1 error (mapping a wetland where one did not really exist). The Type 1 error rate observed in this study was nearly identical to that measured in a probabilistic assessment of wetland condition in the Cuyahoga watershed of northeast Ohio (Fennessy et al. 2007b). Although we could not rigorously evaluate the Type 2 error rate of the NWI/OWI sample frames used in study (not mapping a wetland when one really existed), we would note that we added nearly 150 significant pixel agglomerations of OWI mapped wetlands that were not mapped by the NWI as wetlands. This suggests NWI may be under-mapping the wetland resource by as much as one-third.

Of the sites determined to be wetlands, depressional (47%) and riverine (41%)

hydrogeomorphic classes accounted for nearly all of the wetlands evaluated (Figure 3A), with small percentages of slope, fringing, and impoundment wetland classes accounting for the remainder (Figure 3A). Because they were located in strongly riverine landscape positions, the slope (The Quarry Seep, Ridenour Rd Meadow), fringing (The Quarry Fringe), and impoundment (Ridenour Rd Oxbow) wetlands were included in the "riverine" HGM classes for the analyses below. Over two-thirds of urban wetlands were forested (69%) with the remainder dominated by emergent vegetation (31%) (Figure 3B). No good examples of shrub dominated wetlands were found in this study. Similar percentages of emergent versus forest dominated wetlands were found for depressional and riverine wetlands (Figures 4A and 4B).

*Level 2 Assessment of Condition of Urban Wetlands*

Nearly 60% of the urban wetlands assessed were in poor (26%) or fair (33%) condition, but over one-third were in good (31%) to excellent (10%) condition (Figure 5A). There were significant differences in average condition between depressional and riverine wetlands ($df = 39$, $t = -2.49$, $p = 0.017$) and observable differences in percentages of wetlands by condition class and HGM class (Figures 5B and 5C). On average, urban depressional wetlands appeared to be in poorer condition than urban riverine wetlands (Figures 5B and 5C).

Total ORAM score was significantly correlated with percent of ORAM disturbance metric scores (Figure 6). ORAM scores were also significantly correlated with number of stressors (low correlation) and the Weighted Stressor Score (medium correlation) derived from the PA Stressor Checklist (Figures 6 and 7, respectively). Average PA stressor counts were not significantly different by wetland condition class (Table 4; Figure 9), although significant differences by condition class of average Weighted Stressor Scores were observed (Table 4; Figure 10). The Weighted Stressor Score (WSS) is a modification to the PA Stressor Checklist, where the stressors were coded as present in low, medium or high amounts and weighted with 1, 3, or 5, respectively. The weighted stressors are then summed into an overall score (WSS) with a practical maximum of around 50 points (See Fennessy et al. (2007b) for additional discussion).

The kinds of stressors observed in urban wetlands was evaluted. Graphical differences in box and whisker plots for hydrologic (ORAM Metric 3e) and habitat (ORAM Metric 4c) disturbances were present (Figures 11A, 11B) but significant differences between some condition categories were only observed when Metric 3e (hydrologic) and 4c (habitat) disturbances were summed (Table 5; Figure 11C). Percentages of hydrologic and habitat stressors are summarized in Tables 7 and 8. Percentages of stressors declined from Category 1 (>30%) to Category 3 (<10%) with Category 3 wetlands having low percentages of hydrologic (8%) and habitat (7%) disturbances. The most common hydrologic disturbances were ditching, stormwater, filling, roads/RR beds, and other (Table 7); the most common habitat disturbances were mowing, clearcutting, sedimentation, toxic pollutants, shrub removal and nutrient enrichment (Table 8). Depression and riverine wetlands had similar percentages of hydrologic and habitat disturbances but forested wetlands had substantial higher numbers of disturbances than emergent wetlands for hydrologic (67% to 33%, respectively) and habitat (62% to 38%, respectively) (Tables 7 and 8), although these differences were not significant for hydrologic (df = 23, t = 0.29, p = 0.78) disturbances and marginally significant for habitat disturbances (df = 30, t = 2.09, p = 0.046) when average numbers of disturbances per site were compared.

The average subscores for hydrologic, sedimentation, and vegetation alteration stressors in the WSS were compared by condition category. There were significant differences in average scores by condition category for the hydrologic and vegetation alteration stressors and graphical differences for the sedimentation stressor (Table 6; Figures 12A, B, C), with category 1 wetlands having significantly higher stressor scores than Category 2 or 3. There were no significant difference in average number of stressors or WSS between depressional and riverine wetlands (Figures 13A and B), although differences were observed between depressions and riverine wetlands when stressor subscores were evaluated (Figures 14A, B, C): depressions had significantly higher vegetation alteration scores (Figure 14C); average sedimentation score was higher for riverine wetlands but this difference was not significant (Figure 14B).

*Level 3 Assessment of Condition of Urban Wetlands - Amphibians*

Amphibian results are summarized in Table 9. Of the 14 sites assessed only 7 were forested depressional wetlands appropriate for assessment using the AmphIBI. All of the wetland's amphibian communities represented poor quality associations with AmphIBI scores ranging from 0 to 13 (Table 9). Wetlands that scored highest on the AmphIBI had the greatest amount of buffer and less high intensity surrounding land uses. Three sites were determined to be Restorable Wetland Habitat and the remainder Limited Quality Wetland Habitat with regard to the condition of the their amphibian populutions. Additional amphibian sites will be assessed in Spring 2008 to increase the sample size of appropriate AmphIBI sites to make further conclusions regarding urban wetland condition.

Nine species of amphibians were collected from the fourteen wetlands (10 if both *Bufo americanus* and *B. fowleri* tadpoles were present; their tadpoles cannot be keyed out separately). At two wetlands, no amphibians were collected. One of these sites was a depressional marsh that was inundated long enough to support breeding of some species but was totally surrounded by an old landfill site and other intensive land uses. The other site where no amphibians were encountered, while a forested swamp depression, was only inundated for a very short period, allowing only the first sampling pass to be conducted. This site is probably not suitable habitat, from a hydrologic standpoint, for any amphibian breeding in most years.

No sensitive species (coefficient of conservation of 6 or higher) (Micacchion et al. 2000) were encountered at any of the urban study sites. Six frog, one or two toad and two salamander species were sampled. Jefferson salamanders, *Ambystoma jeffersonianum* were monitored at one site and smallmouth salamanders, *Ambystoma texanum* were present at four sites (Table 10). At two of the sites smallmouth salamanders were the only amphibian species present. The most abundant species was the leopard frog, *Rana pipiens* (30.4%) followed by the spring peeper, *Pseudacris crucifer* (27.2%) and the green frog, *Rana clamitans melanota* (13.8%) (Table 10). However, leopard frogs only occurred at two sites, while spring peepers were present at four sites and green frogs at five sites, the most of any species. Smallmouth salamanders, toad tadpoles, *Bufo sp.* and bullfrogs, *Rana catesbeiana* were also present at four sites.

The common characteristic that most seriously limited amphibian utilization of the urban wetlands we studied were the surrounding intensive land uses. In most instances the amount of intact upland habitat needed to provide for the non-breeding requirements of pond-breeding salamanders (Semlitsch 1998) and other amphibians was not present due to the level of development and other disturbances in the adjoining landscape. Spring peepers, toads and green frogs are all species that tolerate a fair amount of disturbance in the habitats surrounding their aquatic breeding sites and have relatively small home ranges. Therefore, it is not surprising that these three were the species most commonly encountered.

The one site where Jefferson salamanders, the most sensitive species sampled, were monitored had extensive buffers on half of its perimeter that were connected to a large forested tract that included parts of a Columbus City Park. While some of the pool directly adjoined a residential development, there was enough of a nexus to the forested upland habitat to provide for the presence of the Jefferson salamanders. This type of connection was rare in the urban setting and many of the study wetlands were the only remnant of green space in an otherwise completely developed landscape.

Another site where smallmouth salamanders were present had previously been part of a much larger forested upland/ wetland complex. Recently the other part of the wetland was filled and now the remaining wetland is almost completely surrounded by development. Only a very slender sliver of forested upland buffer has been left around the pool. Otherwise, the remaining wetland and its narrow buffer is completely surrounded by roads, paved parking lots and buildings. As other suitable upland habitat was outside the radius of their mitigration distances, this indicates that smallmouth salamanders can rely on a very narrow band of upland for their non-breeding habitat requirements.

Semlitsch and Bodie (2003) found that, in general, amphibians need a radius of somewhere between 159 m and 290 m of suitable upland forest habitat around breeding wetlands to maintain viable populations. These types of habitats are uncommon in the urban setting. Urban land conversion leads to the local extirpation of those amphibian species such as red-spotted newts, *Notophthalmus viridescens*, spotted salamanders, *Ambystoma maculatum*, and wood frogs, *Rana sylvatica* that are dependent on large areas of forested upland habitat as well as breeding wetlands to exist (Porej et al. 2005), leaving only those amphibian species which can tolerate high levels of disturbance and require only small amounts of upland habitat outside their breeding pools.

*Level 3 Assessment of Condition of Urban Wetlands - Vegetation*

Vegetation IBI score was significantly correlated with ORAM score and the WSS (Figures 15 and 17) but not with simple counts of stressors (Figure 16). Sixty-eight percent of urban wetlands were in poor (14%) or fair (54%) condition and 32% were in good (18%) or very good (14%) condition) based on the results of Level 3 vegetation sampling (Table 11; Figure 18. The Level 2 and 3 assessments were in agreement regarding the poor/fair percentages (Figure5A) but the Level 3 assessment concluded that fewer wetlands were in poor

(LQWLH/Category 1) and good (WLH/Category 2) condition and more wetlands were in fair (RWLH/modified Category 2) condition (Table 12; Figures 5A and 18).

The State of Ohio has only completed one other probabilistic wetland assessment (Fennessy et al. 2007b). In order to put the results from the Urban Wetland Study into perspective, we compared the average Level 2 and 3 assessment values from the Cuyahoga and Urban wetland assessments to average values from Ohio EPA's reference wetland data set for antidegradation and WTALU categories (Table 11; Figures 19, 20). Average ORAM score from the Urban Wetland Study watershed was nearly identical to average ORAM score for modified Category 2 wetlands (Figure 19). Average scores from the Cuyahoga and Urban wetland assessments were significantly different (Table 11); urban wetland ORAM scores were not significantly different from the modified Category 2 wetland scores (Table 11). Comparing VIBI scores, the 25th and 75th percentile of wetlands in the Urban Wetland Study overlapped the RWLH habitat box and whiskers (Figure 20); average VIBI scores were not significantly different from average RWLH scores but were significantly different from average scores from Category 1, 2, 3, and Cuyahoga Study wetlands (Table 11). Compared to the results from the Cuyahoga study, where the wetland resource is in good condition on average, the overall "report card" for urban wetlands in Franklin County, Ohio is "fair." In contrast, comparing AmphIBI scores from the Urban Study to average scores from Ohio EA's reference data set, showed that amphibian habitat in the 14 urban wetlands sampled was poor (Figure 21), although the Amphibian data set was very small and will be supplemented with additional sites in 2008.

*Comparison of Results from Level 2 and 3 Assessments*

Comparing results from the Level 2 Assessments (ORAM, WSS) and the Level 3 (VIBI Assessment provides interesting information regarding the uses and advantages of combining these approaches. The stressor-based approach estimate much high percentages (41%) of poor quality wetlands than ORAM (26%) or the VIBI (14%) (Table 12). This is not surprising given the high numbers of stressors that can be counted at urban wetlands. But, this may point to a limitation in Level 2 assessments that use simple enumeration or enumeration with weighting factors (the WSS) in that they are susceptible to under-assessment of wetlands in urban contexts. The biggest distinction between ORAM and the VIBI was in the "fair" category. The Level 3 VIBI Assessment had lower percentages in "poor" and "good" and higher percentages of "fair" condition wetlands than ORAM (Table 12). Percentages of under- and over-categorization were evaluated in Table 13. The WSS had similar patterns of agreement to the ORAM and VIBI with 20-30% of sites assessed as one category above or below the ORAM and VIBI categories. Categorization agreement was very high between ORAM and the VIBI with 71.4% of the determinations in agreement and only 10.7% under-categorization (Table 13).

*Attainable Biological Expectations, Long-term Viability, and Services of Urban Wetlands*

Returning to the questions posed at the beginning of this report, we can address some of the problems posed for the assessment of urban wetlands.

1. Is it possible for a wetland to be in anything other than poor condition in urban contexts? The answer, based on this study, is clearly yes. Although average condition is best characterized as "fair", 17 of the 42 wetlands we assessed (41%) were Category 2 or 3 wetlands based on our Level 2 assessment and 32% were Wetland Habitat or Superior Wetland Habitat based on our Level 3 assessment (although our limited data set suggests that condition as defined by amphibian community quality may be degraded further than results from the plant community assessment indicate).

2. Do assessment protocols which define excellent, good, fair, poor by comparison to reference ecosystems fairly assess wetlands in urban contexts? Reference-based assessment protocols like ORAM and the Vegetation or Amphibian IBIs can definitely assess urban wetland ecosystems and obtain results which would not be unexpected (these systems are an average moderately or severly degraded). Whether these protocols are "fair" is a more nuanced question implying there are ecological services ("functions" or "values") that urban wetlands provide regardless of their ecological "condition". Our answer, based on these results, is that "yes," referenced-based assessment protocols do fairly assess urban wetlands.

The ORAM protocol (which has some conservative biases built into because of its use in regulatory categorization), and also awards some points for ecological services despite degraded condtion, agreed with the classification based on the Vegetation IBI-based Wetland Tiered Aquatic Life Uses more than 70% of the time (Table 11), and under- and over-categorized wetlands only + - 10%. From a regulatory perspective, the distinction between ecological "condition" and ecological "services" should be evaluated separately when moderately to severaly ecologically degraded wetlands are being considered (for intact wetlands, the highly defensible assumption is that all ecosystem functions and ecological services that that type and kind of wetland can provide are present at "intact", i.e. high, levels). The key consideration for wetlands that are moderately to severely degraded is whether they continue to provide at least one or more "residual" ecological services such that they should be provided regulatory protections or mitigation ratios equivalent to good to high condition wetlands. In Ohio, this situation is addressed in our rapid assessment protocol by the award of some points based on features that have potential to increase ecological services but which are often condition-neutral.[1] It is also addressed narratively. Both ORAM v. 5.0 and the Vegetation IBI by require the Rater to answer questions whether residual moderate or superior ecological services are being provided by the wetland despite moderate to severe degradation (See final question in ORAM Categorization Worksheet and Questions on VIBI Background Form). In its regulatory program, the State of Ohio addresses this by distinguishing between services and condition. For example, it has been consistent practice to assign Tiered Aquatic Life

1 ORAM v. 5.0 has point assessments for size (Metric 1), water source (Metric 3a), connectivity (Metric 3b), water depth (Metric 3c), hydrologic duration (Metric 3d), horizontal heterogeneity (Metric 6b) that, other things being equal, will ensure the categorization of a degraded wetland as at least "Category 2" despite substantial ecological degradation. The last question in the ORAM Score Categorization Worksheet also states that if a wetland has a residual moderate or superior flood, habitat or recreational function despite moderate to severe disturbances, it should be categorized as a Category 2 or 3 regardless of the condition-based assessment results from the Quantitative Rating.

Uses (TALUs) to streams based on their ecological condition but also to assign "uses" related to public water supply, recreation etc. It has always been the case that streams can be degraded in their ecological condition but have other services they provide that are protected and maintained (Ohio Administrative Code Chapter 3745-1). A similar system has been proposed for wetlands where under Ohio's Wetland Antidegradation Rule (OAC Rule 3745-1-54) a wetland can receive the highest level of protection (Category 3) if it is still performing a superior hydrologic or other service even if it is very degraded ecologically. A draft Wetland TALU rule has been proposed which would assign a wetland TALU based on its ecological condition (http://www.epa.state.oh.us/dsw/rules/draft_401wetland_feb06.html). Under this rule (draft 3745-1-53), a wetland could be assigned a lower TALU because it is degraded ecologically, but would still be regulated as Category 3 because it has a residual, superior ecological service. Conversely, a wetland assigned the Superior Wetland Habitat TALU would always be a Category 3 wetland. Put another way, every SWLH wetland is Category 3 under the antidegradation policy, but a Category 3 may or may not be SWLH, depending on its ecological condition.

Finally, the question of fairly assessing urban wetlands frequently becomes a discussion of whether a "functional assessment" has advantages over the condition-based approaches used in this study. For example, many "HGM functional assessment" methods have been published for various wetland types (Lin 2006; Aisnlie et al. 2004; Klimas et al. 2004; Noble et al. 2004; Uranowski et al. 2003; Hauer et al. 2002; Hauer et al. (2002); Rheinhardt et al. 2002; Shafer et al. 2002; Smith and Klimas 2002; Wilder and Roberts 2002).[2] However, a close examination of the type of data used to derive the functional assessments reveals that for the critical hydrologic and nutrient process functions, which presumably set these methods apart from an IBI, the data sources are Level 1 (landscape data) and Level 2-type data. In contrast , the approach taken in this study (Volume 2) was to collected detailed Level 3 hydrologic data and derive our "functional" assessment of urban wetlands separately, keeping our assessment of ecological condition and ecological services separate and not merged into a non-transparent composite index.

3. Should there be alternate (i.e. lower) standards for judging the condition of urban wetlands? We conclude the answer should be "no." Condition-based wetland assessment protocols, just like their stream counterparts, fairly assess the ecological condition of urban wetlands. And it is not unexpected that this condition is, on average, "fair" vis-a-vis systems without the disturbances and buffer encroachments typical of most urban wetlands. Setting lower ecological condition set points will not improve the actual condition these systems or provide them any additional regulatory protections. Again, as discussed above, for residual ecological services, especially flood storage and nutrient/sediment retention or conversion, supplementary evaluation may be needed, but this evaluation is separate and

2 Although the foundational documents for HGM Functional Assessment approaches recognize the "ecological integriy" is the integrating, ultimate function (Smith et. al 1995), in practice most functional assessment approaches have eschewed this fundamental understanding. Moreover, none of these published "functional" assessments used Level 3 quantitative data to derive their functional modeles, other than quantitative plant community data.

complementary to the assessment of the condition of these wetlands.

4. Do wetlands in urban contexts have limited long-term viability (i.e are they inherently declined to degrade to that point they are of no value)? To the extent that we found 44% of the wetlands mapped ca1980s no longer existed, there is clearly very high development pressure on urban wetland ecosystems. However, our data suggests that on average, urban wetlands will tend to degrade to a "fair" condition that is bracketed by substantial numbers of "poor" and "good" condition wetlands. We observed a similar pattern in the assessment of wetlands in the Cuyahoga watershed (Fennessy et al. 2007b) where equivalent percentages of poor condition wetlands were observed across the watershed regardless of the landscape (urban, rural, etc.) but the percentages of high condition wetlands declined to very low amounts having not been disturbed "down" to fair or good condition. This "dumbing down" of the wetland resource is clearly observable in the data collected, but urban wetlands appear to have a long-term viability as fair or good condition wetlands.

5. Should mitigation of urban wetland impacts focus on just replacing flood storage services and allow the creation of an actual "wetland" to occur elsewhere in a (presumably) more sustainable context? To the extent that "fair" condition wetlands are the average condition in urban contexts, the answer would be "no." The presumption should be that fair to good condition wetlands can be created in urban contexts when determining performance standards for urban wetland mitigation. However, there will be urban wetland mitigation that is designed to primarily address flood storage, flood desynchronization, or nutrient retention/convervsion services that may only be able to achieve what, ecologically, is "poor" condition, despite the provision of moderate or even high services (functions and values)

CONCLUSIONS

Ultimately, the question is "Do urban wetlands provide significant ecological services to human society?" When considered in their aggregate, the answer is clearly "yes." When considered from the perspective of each individual wetland , the answer can be "yes", "no" or "maybe" depending on the wetland, its landscape position, the wetlands around it, and the watershed. To the extent that the Section 401 and 404 programs consider this question on a wetland-by-wetland basis, they usually only provide protections when the individual wetland is providing significant services, even though the ecologically meaningful answer is what the population of wetlands are providing to their watersheds. The question of flood storage/desynchornization is addressed in detail in Volume 2 of this report, but even apparently fragmented and disconnected urban wetlands, when considered as a population, can store measurable percentages of the daily flow of medium and large streams and potentially significant percentages of small streams (Gamble et al. 2007). At some point, this question reaches the ecological limits of the current legal framework for wetland regulation in Ohio and the United States, with its pragmatic, wetland-by-wetland, focus (both Ohio Section 401 and federal 404 regulations provide for the consideration of cumulative, secondary, and indirect impacts, but the current regulations make the application of these considerations very difficult in practice). There are also clearly individual wetlands that are so degraded, or so fragmented from the local hydrologic cycle, that they provide no, or nearly no ecological services, and are also very degraded ecologically. Under the State of Ohio's wetland categorization system, these would be wetlands that have limited ecologic or hydrologic functionality (Category 1 wetlands). Estimates of this population of wetlands range from 5-10% in the upper to lower Cuyahoga watershed (Fennessy et al. 2007b), over a relatively intact watershed[3], at least in its middle and upper reaches, to 14-26% in this study, a clearly urbanized study population. The clear implication is that, even in highly urbanized watersheds, more than half of the remaining wetlands are in sufficient condition, or providing sufficient services, to warrant at least "Category 2" levels of protection and mitigation ratios.

3 Because of the probabilistic approach taken in the Cuyahogo Wetland study, urban wetlands, given their lower numbers, were under-represented. A comprehensive assessment of urban wetland condition would have required an intensification of sampling of wetlands in Cuyahoga and perhaps Summit counties.

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Table 1. General Wetland Aquatic Life Use Designations.

| code | designation | definition |
|---|---|---|
| SWLH | Superior Wetland Habitat | Wetlands that are capable of supporting and maintaining a high quality community with species composition, diversity, and functional organization comparable to the vegetation IBI score of at least 83% (five-sixths) of the 95$^{th}$ percentile for the appropriate wetland type and region as specified in Table 11. |
| WLH | Wetland Habitat | Wetlands that are capable of supporting and maintaining a balanced, integrated, adaptive community having a species composition, diversity, and functional organization comparable to the vegetation IBI score of at least 66% (two-thirds) of the 95$^{th}$ percentile for the appropriate wetland type and region as specified in Table 11. |
| RWLH | Restorable Wetland Habitat | Wetlands which are degraded but have a reasonable potential for regaining the capability of supporting and maintaining a balanced, integrated, adaptive community of vascular plants having a species composition, diversity, and functional organization comparable to the vegetation IBI score of at least 33% (one-third) of the 95$^{th}$ percentile distribution for the appropriate wetland type and region as specified in Table 11. |
| LQWLH | Limited Quality Wetland Habitat | Wetlands which are seriously degraded and which do not have a reasonable potential for regaining the capability of supporting and maintaining a balanced, integrated, adaptive community having a species composition, diversity, and functional organization comparable to the vegetation IBI score of less 33% (one-third) of the 95$^{th}$ percentile for the appropriate wetland type and region as specified in Table 11. |

Table 2. Special wetland use designations.

| subscript | special uses | description |
|---|---|---|
| A | recreation | wetlands with known recreational uses including hunting, fishing, birdwatching, etc. that are publicly available |
| B | education | wetlands with known educational uses, e.g. nature centers, schools, etc. |
| C | fish reproduction habitat | wetlands that provide important reproductive habitat for fish |
| D | bird habitat | wetlands that provide important breeding and nonbreeding habitat for birds |
| E | T or E habitat | wetlands that provide habitat for federal or state endangered or threatened species |
| F | flood storage | wetlands located in landscape positions such that they have flood retention functions |
| G | water quality improvement | wetlands located in landscape positions such that they can perform water quality improvement functions for streams, lakes, or other wetlands |

Table 3. Wetland Tiered Aquatic Life Uses (WTALUs) for specific plant communities and landscape positions. LQWLH = limited quality wetland habitat, RWLH = restorable wetland habitat, WLH = wetland habitat, SWLH = superior wetland habitat.

| HGM class | HGM subclass | plant community | ecoregions | LQWLH (Cat1) | RWLH (mod Cat2) | WLH (Cat2) | SWLH (Cat3) |
|---|---|---|---|---|---|---|---|
| Depression | all | Swamp forest, Marsh, Shrub swamp | EOLP<br>all other regions | 0 - 30<br>0 - 24 | 31 - 60<br>25 - 50 | 61 - 75<br>51 - 62 | 76 - 100<br>63 - 100 |
| | all | Wet Meadow (incl. prairies and sedge/grass dominated communities that are not slopes) | all regions | 0 - 29 | 30 - 59 | 60 - 75 | 76 - 100 |
| Impound-ment | all | Swamp forest, Marsh, Shrub Swamp | EOLP<br>all other regions | 0 - 26<br>0 - 24 | 27 - 52<br>25 - 47 | 53 - 66<br>48 - 63 | 67 - 100<br>64 - 100 |
| | | Wet Meadow (incl. prairies and sedge/grass dominated communities that are not slopes) | all regions | 0 - 29 | 30 - 59 | 60 - 75 | 76 - 100 |
| Riverine | Headwater | Swamp forest, Marsh, Shrub swamp | EOLP<br>all other regions | 0 - 27<br>0 - 23 | 28 - 56<br>24 - 47 | 57 - 69<br>47 - 59 | 70 - 100<br>60 - 100 |
| | Mainstem | Swamp forest, Marsh, Shrub swamp | EOLP<br>all other regions | 0 - 29<br>0 - 20 | 30 - 56<br>21 - 41 | 57 - 73<br>42 - 52 | 74 - 100<br>53 - 100 |
| | Headwater or Mainstem | Wet Meadow (incl. prairies and sedge/grass dominated communities that are not slopes) | all regions | 0 - 29 | 30 - 59 | 60 - 75 | 76 - 100 |
| Slope | all | Wet meadow (fen), tall shrub fen, forest seep | all regions | 0 - 29 | 30 - 59 | 60 - 75 | 76 - 100 |
| Coastal | various | Swamp forest, Marsh, Shrub swamp | all regions | 0 - 24 | 25 - 49 | 50 - 61 | 62 - 100 |
| Bog | weakly ombrotrophic | Tamarack-hardwood bog, Tall shrub bog | all regions | 0 - 32 | 33 - 65 | 66 - 82 | 83 - 100 |
| | moderately to strongly ombrotrophic | Tamarack forest<br>Leatherleaf bog<br>Sphagnum bog | all regions | 0 - 23 | 24 - 47 | 48 - 59 | 60 - 100 |

Table 4. Mean (standard deviation) of number of stressors from the PA Stressor Checklist and Weighted Stressor Score by wetland condition category. Means without shared letters significantly different ($p < 0.05$) after Tukey's multiple comparison test.

| Condition category | Number of Stressors | Weighted Stressor Score |
|---|---|---|
| Category 1 | 8.2 (2.2) | 36.0(12.6)a |
| mod Category 2 | 5.7(3.1) | 19.5(12.6)b |
| Category 2 | 5.2(3.3) | 14.5(11.9)b |
| Category 3 | 4.4(2.3) | 7.2(2.6)b |
| df | 41 | 41 |
| F | 3.1 | 10.3 |
| p value | 0.036 | 0.000 |

Table 5. Mean (standard deviation) of number of hydrologic (Metric 3e), Habitat (Metric 4c) or combined stressors by wetland condition category. Means without shared letters significantly different ($p < 0.05$) after Tukey's multiple comparison test.

| | Metric 3e | Metric 4c | Metric 3e + 4c |
|---|---|---|---|
| Category 1 | 2.8 (1.2) | 4.8(1.5) | 7.6(1.9)a |
| mod Category 2 | 2.4(1.4) | 4.1(2.4) | 6.5(2.7)ab |
| Category 2 | 1.6(1.5) | 3.0(1.5) | 4.4(2.3)b |
| Category 3 | 1.4(0.9) | 2.6(1.7) | 4.0(2.3)b |
| df | 41 | 41 | 41 |
| F statistic | 2.1 | 3.0 | 5.2 |
| p value | 0.112 | 0.043 | 0.004 |

Table 6. Mean (standard deviation) of Hydrologic Score Sedimentation Score, and Vegetation Alteration (VA) Score by wetland condition category from the Weighted Stressor Score. Means without shared letters significantly different ($p < 0.05$) after Tukey's multiple comparison test.

| | Hydro Score | Sed Score | VA Alter Score |
|---|---|---|---|
| Category 1 | 11.8 (5.5)a | 6.6(2.8) | 13.0(7.9)a |
| mod Category 2 | 6.0(6.3)b | 3.4(5.1) | 7.3(7.5)ab |
| Category 2 | 4.1(3.2)b | 4.7(4.7) | 1.5(1.9)b |
| Category 3 | 1.4(1.1)b | 1.2(1.6) | 2.8(1.8)b |
| df | 41 | 41 | 41 |
| F statistic | 7.9 | 2.4 | 8.4 |
| p value | 0.000 | 0.085 | 0.000 |

Table 7. Percentage of Metric 3e (Hydrologic alteration) stressors by condition category, HGM class and plant community

| | N | % of total | ditch | tile | dike | weir | storm wtr | pt source | filling | road/ RR bed | dredge | other |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Category 1 | 30 | 32% | 5% | 3% | 0% | 0% | 3% | 0% | 10% | 3% | 0% | 8% |
| mod Category 2 | 35 | 38% | 6% | 0% | 0% | 0% | 6% | 0% | 11% | 4% | 0% | 10% |
| Category 2 | 21 | 23% | 2% | 0% | 1% | 1% | 5% | 0% | 8% | 1% | 0% | 4% |
| Cateogry 3 | 7 | 8% | 1% | 0% | 0% | 0% | 1% | 0% | 3% | 0% | 2% | 0% |
| | | | | | | | | | | | | |
| depression | 47 | 51% | 9% | 3% | 0% | 0% | 4% | 0% | 16% | 6% | 0% | 12% |
| riverine | 46 | 49% | 6% | 0% | 1% | 1% | 12% | 0% | 15% | 2% | 2% | 10% |
| | | | | | | | | | | | | |
| emergent | 31 | 33% | 6% | 2% | 0% | 0% | 6% | 0% | 9% | 3% | 0% | 6% |
| forest | 62 | 67% | 9% | 1% | 1% | 1% | 10% | 0% | 23% | 5% | 2% | 15% |

Table 8. Percentage of Metric 4c (Habitat Alteration) stressors by condition category, county, TMDL region, HGM class, and plant community.

| | N | % of total | mow | graze | clear cut | sel cut | woody removal | sedimen-tation | toxic poll. | shrub removal | aq bed/emerg removal | farming | nut enrich | dredge | other |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Category 1 | 54 | 34% | 3% | 1% | 5% | 1% | 3% | 4% | 2% | 6% | 1% | 3% | 4% | 0% | 3% |
| mod Category 2 | 55 | 35% | 3% | 1% | 5% | 1% | 2% | 4% | 4% | 4% | 2% | 1% | 4% | 1% | 4% |
| Category 2 | 39 | 25% | 1% | 0% | 3% | 0% | 1% | 4% | 3% | 1% | 1% | 2% | 4% | 1% | 4% |
| Category 3 | 11 | 7% | 1% | 0% | 0% | 0% | 1% | 2% | 1% | 1% | 0% | 0% | 1% | 0% | 0% |
| depression | 86 | 54% | 5% | 1% | 9% | 1% | 4% | 4% | 3% | 9% | 3% | 3% | 4% | 1% | 6% |
| riverine | 73 | 46% | 3% | 1% | 4% | 1% | 3% | 10% | 6% | 3% | 0% | 3% | 8% | 1% | 5% |
| emergent | 60 | 38% | 4% | 1% | 4% | 1% | 3% | 6% | 3% | 5% | 1% | 3% | 4% | 0% | 3% |
| forest | 99 | 62% | 4% | 1% | 9% | 1% | 4% | 9% | 6% | 8% | 2% | 3% | 8% | 2% | 9% |

Table 9. Results of Level 3 Amphibian Assessment. Sites coded as "na" in Amphibian WTALU column are non-forested and/or non-depressional sites not appropriate for evaluation with the Amphibian WTALU categories.

| site no. | site name | AQAI | %tolerant | %sensitve | no. of sal. spp. | presence spotted sal./wood frog | AmphIBI score | Amphibian WTALU category | ORAM antideg category | Vegetation WTALU category |
|---|---|---|---|---|---|---|---|---|---|---|
| 44 | Airport Plaza | 3.00 | 1.0000 | 0.0 | 0 | no | 3 | LQWLH | mod Cat2 | RWLH |
| 204A | Alum Creek Dr | 2.07 | 1.0000 | 0.0 | 0 | no | 0 | na | mod Cat2 | RWLH |
| 82 | ATV | 2.00 | 1.0000 | 0.0 | 0 | no | 0 | na | Cat2 | SWLH |
| 308 | Easton | 0.00 | 0.0000 | 0.0 | 1 | no | 0 | LQWLH | Cat2 | RWLH |
| 286 | Hill's | 3.50 | 0.5000 | 0.0 | 1 | no | 10 | RWLH | Cat2 | RWLH |
| 147/150 | ISG147/150 | 2.61 | 0.8977 | 0.0 | 1 | no | 0 | LQWLH | Cat2 | WLH |
| 464B | The Quarry Fringe | 2.00 | 1.0000 | 0.0 | 0 | no | 0 | na | Cat3 | SWLH |
| 19O | Ridenour Rd Oxbow | 1.46 | 1.0000 | 0.0 | 0 | no | 0 | na | Cat2 | WLH |
| 274 | Someset Park | 4.00 | 0.0000 | 0.0 | 1 | no | 13 | RWLH | mod Cat2 | RWLH |
| 242A | Sunbury Rd | 3.00 | 0.7544 | 0.0 | 0 | no | 6 | na | Cat2 | SWLH |
| 201 | Three Creeks | 3.00 | 1.0000 | 0.0 | 0 | no | 3 | na | Cat2 | WLH |
| 268 | Towne Centre | 3.86 | 0.4286 | 0.0 | 0 | no | 10 | RWLH | Cat1 | RWLH |
| 141B | Watkins Rd B | 0.00 | 0.0000 | 0.0 | 0 | no | 0 | LQWLH | mod Cat2 | RWLH |
| 409 | Wilson Rd | 0.00 | 0.0000 | 0.0 | 0 | no | 0 | na | Cat1 | LQWLH |

Table 10.  Species and relative abundances of amphibians collected at urban wetland study sites.

| no. | site name | Jefferson salamander | Small-mouth salamander | Toads | Gray tree frog | spring peeper | chorus frog | Bullfrog | Green frog | Leopard frog | No amphibs |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 44 | Airport Plaza | | | | | | 1.000 | | | | |
| 204A | Alum Creek Dr | | | 0.008 | | | | 0.004 | 0.053 | 0.936 | |
| 82 | ATV | | | | | | | 1.000 | | | |
| 308 | Easton | | 1.000 | | | | | | | | |
| 286 | Hill's | 0.500 | | | | 0.250 | | 0.250 | | | |
| 147/150 | ISG147/150 | | 0.106 | | | 0.509 | 0.384 | | | | |
| 464B | The Quarry Fringe | | | | | | | 1.000 | | | |
| 19O | Ridenour Rd Oxbow | | | 0.579 | | 0.070 | | 0.018 | 0.035 | 0.298 | |
| 274 | Someset Park | | 1.000 | | | | | | | | |
| 242A | Sunbury Rd | | | 0.032 | 0.246 | 0.425 | | | 0.298 | | |
| 201 | Three Creeks | | | | | | | | 1.000 | | |
| 268 | Towne Centre | | 0.571 | | | | | | 0.429 | | |
| 141B | Watkins Rd B | | | | | | | | | | 1.00 |
| 409 | Wilson Rd | | | | | | | | | | 1.00 |
| | Relative abundance all sites | 0.002 | 0.049 | 0.051 | 0.081 | 0.272 | 0.098 | 0.006 | 0.138 | 0.304 | 1.00 |
| | No. of sites spp. occurred in | 1 | 4 | 3 | 1 | 4 | 2 | 4 | 5 | 2 | 2 |

Table 11. Mean (standard deviation) of 1) ORAM scores (N =246) for Ohio EPA's reference wetland data set (Category 1, mod 2, 2, and 3) and Cuyahoga and Urban Wetland study sites, and 2) VIBI scores (LQWLH, RWLH, WLH, SWLH), mitigation bank sites, individual mitigation sites, and Cuyahoga and Urban Wetland Study sites. Means without shared letters significantly different ($p < 0.05$) after Tukey's multiple comparison test.

| Antidegradation Categories | ORAM score | Wetland Tiered Aquatic Life Uses | VIBI score |
|---|---|---|---|
| Category 1 | 26.0(6.1)a | Limited Quality Wetland Habitat (LQWLH) | 13.8(7.5)a |
| modified Category 2 | 39.3(2.4)b | Restorable Wetland Habitat (RWLH) | 41.8(9.1)b |
| Category 2 | 55.8(5.2)c | Wetland Habitat (WLH) | 61.3(8.6)c |
| Category 3 | 74.8(6.5)d | Superior Wetland Habitat (SWLH) | 78.4(11.1)d |
| bank sites | ---- | bank sites | 38.2(16.8)b |
| mitigation sites | ---- | mitigation sites | 30.0(14.1)b |
| Cuyahoga study sites | 62.4(12.0)e | Cuyahoga study sites | 64.4(21.6)c |
| urban wetland study | 44.0(12.6)b | urban wetland study | 36.3(14.6)b |
| df | 246 | df | 296 |
| F statistic | 233.6 | F statistic | 126.4 |
| p value | 0.000 | p value | 0.000 |

Table 12. Percentage of wetlands by condition category for the ORAM (n = 42), the Weighted Stressor Score (WSS) (n = 42), and the VIBI (n = 26). WSS condition categories derived by quadrsecting 95$^{th}$ percentile of WSS scores for urban wetlands.

| | ORAM | WSS | VIBI |
|---|---|---|---|
| Poor | 26% | 41% | 14% |
| Fair | 33% | 17% | 54% |
| Good | 31% | 21% | 18% |
| Excellent | 10% | 21% | 14% |

Table 13. Comparison of wetland condition class as determined by ORAM (antidegradation category), Weighted Stressor Score (quartiles of 95th percentile of scores), and Vegetation IBI (Wetland Tiered Aquatic Life Uses).

| no. | site name | HGM | plant community | OR AM | WSS | VIBI | antidegra-dation category | WSS category (37.0) | WTALU | WSS to ORAM | ORAM to VIBI | WSS to VIBI |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 019M | Ridenour Rd. | slope | fen | 71 | 10 | 80 | Category 3 | good | SWLH | under by 1 | same | under by 1 |
| 019O | Ridenour Rd. | impound | swamp forest | 47 | 37 | 53 | Category 2 | poor | WLH | under by 2 | same | under by 2 |
| 44 | Airport Plaza | depression | swamp forest | 35 | 30 | 39 | mod Cat 2 | poor | RWLH | under by 1 | same | under by 1 |
| 76 | Big Walnut | mainstem | swamp forest | 43 | 12 | 26 | mod Cat 2 | good | RWLH | over by 1 | same | over by 1 |
| 82 | ATV | mainstem | swamp forest | 63 | 8 | 58 | Category 2 | excellent | SWLH | over by 1 | under by 1 | same |
| 142A | Watkins Rd | depression | swamp forest | 35 | 32 | 26 | mod Cat 2 | poor | RWLH | under by 1 | same | under by 1 |
| 142B | Watkins Rd | depression | swamp forest | 35 | 32 | 34 | mod Cat 2 | poor | RWLH | under by 1 | same | under by 1 |
| 147/150 | ISG | depression | swamp forest | 54 | 9 | 60 | Category 2 | excellent | WLH | over by 1 | same | over by 1 |
| 201 | Three Creeks | mainstem | swamp forest | 59 | 17 | 43 | Category 2 | good | WLH | same | same | same |
| 204A | Alum Creek A | mainstem | swamp forest | 41 | 37 | 27 | mod Cat 2 | poor | RWLH | under by 1 | same | under by 1 |
| 204B | Alum Creek B | mainstem | wet meadow | 46 | 11 | 43 | Category 2 | good | WLH | same | same | same |
| 242A | Sunbury Rd | mainstem | marsh | 60 | 9 | 53 | Category 2 | excellent | SWLH | over by 1 | under by 1 | same |
| 242B | Sunbury Rd | mainstem | wet meadow | 60 | 9 | 49 | Category 2 | excellent | WLH | over by 1 | same | over by 1 |
| 242C | Sunbury Rd | mainstem | marsh | 31 | 40 | 32 | mod Cat 2 | poor | RWLH | under by 1 | same | under by 1 |
| 268 | Towne Centre | depression | swamp forest | 30 | 17 | 29 | Category 1 | good | RWLH | over by 2 | under by 1 | over by 1 |
| 274 | Somerset | depression | swamp forest | 40 | 21 | 43 | mod Cat 2 | fair | RWLH | same | same | same |
| 281 | Bridgeview | headwater | swamp forest | 36 | 18 | 27 | mod Cat 2 | good | RWLH | over by 1 | same | over by 1 |
| 286 | Hills | depression | swamp forest | 64 | 13 | 50 | Category 2 | good | RWLH | same | over by 1 | over by 1 |
| 308 | Easton | depression | swamp forest | 47 | 24 | 25 | Category 2 | fair | RWLH | under by 1 | over by 1 | same |
| 351 | Worthing HS | mainstem | swamp forest | 43 | 18 | 29 | mod Ca 2 | good | RWLH | over by 1 | same | over by 1 |
| 352 | Worthing Park | mainstem | swamp forest | 39 | 29 | 19 | mod Ca 2 | poor | LQWLH | under by 2 | over by 1 | same |
| 354 | Antrim Park | mainstem | swamp forest | 46 | 28 | 20 | Category 2 | fair | LQWLH | under by 1 | over by 2 | over by 1 |
| 358 | Graceland | mainstem | swamp forest | 36 | 23 | 23 | mod Cat 2 | fair | RWLH | same | same | same |
| 409 | Wilson Rd | depression | marsh | 29 | 21 | 23 | Category 1 | fair | LQWLH | over by 1 | same | over by 1 |
| 464A | Quarry Seep | slope | forest seep | 69 | 8 | 47 | Category 3 | excellent | RWLH | same | over by 2 | over by 2 |
| 464B | Quarry Fringe | fringing | swamp forest | 74 | 8 | 67 | Category 3 | excellent | SWLH | same | same | same |
| 492 | Bolton Field | depression | swamp forest | 21 | 36 | 10 | Category 1 | poor | LQWLH | same | same | same |
| 529 | Cherry Bottom | mainstem | swamp forest | 35 | 31 | 24 | mod Cat 2 | poor | RWLH | under by 1 | same | over by 1 |
| | | | | | | | | | under by 2 | 7.1% | 0.0% | 3.6% |
| | | | | | | | | | under by 1 | 32.1% | 10.7% | 21.4% |
| | | | | | | | | | same cat. | 28.6% | 71.4% | 35.7% |
| | | | | | | | | | over by 1 | 28.6% | 10.7% | 35.7% |

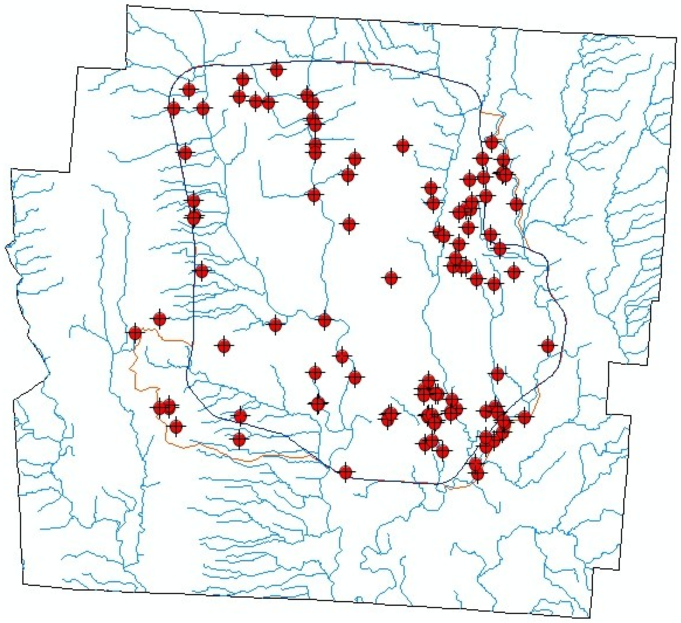

Figure 1. Map of random points for urban wetland study.

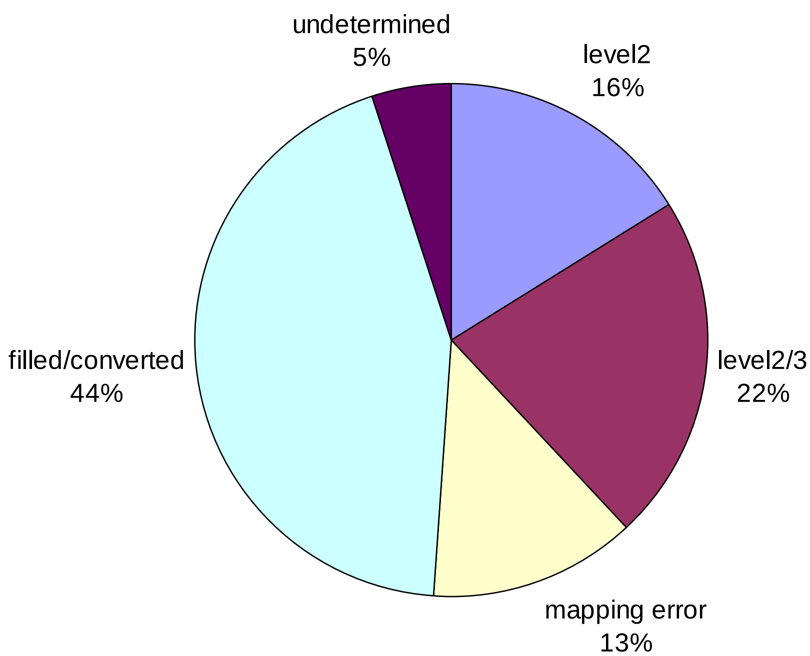


Figure 2. Fate of first 100 random points in urban wetland study. Filled/converted = mapped wetland filled or converted, undetermined = fate of point unable to be determiend, mapping error = wetland mapped but field verification determined no wetland exists, level2 = ORAM assessment performed, level 2/3 = ORAM, IBI and functional assessments performed.

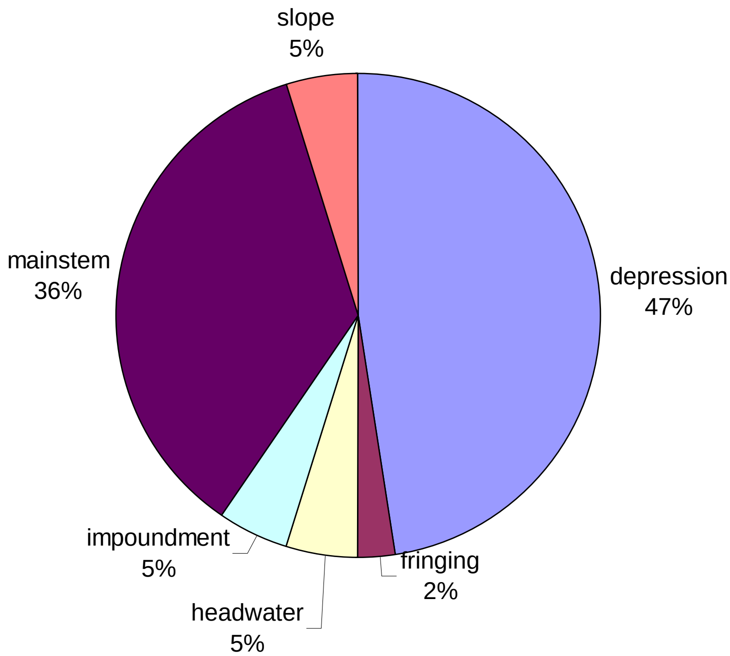


Figure 3A. Percentage of urban wetland sites in Franklin County, Ohio by HGM class.

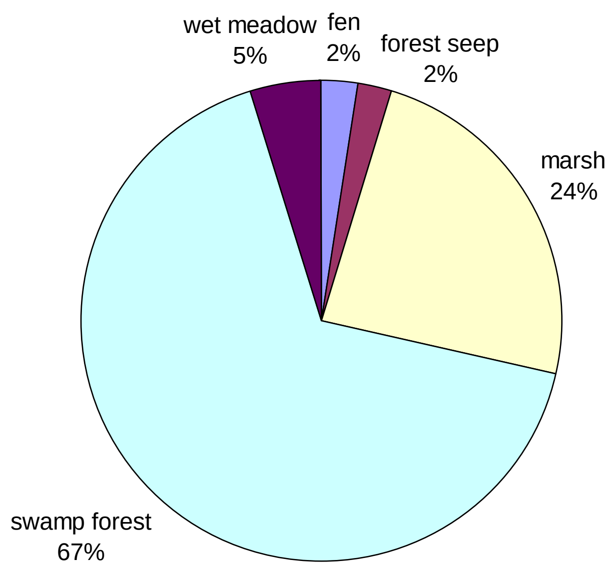


Figure 3B. Percentage of urban wetland sites in Franklin County, Ohio by dominant plant community class.

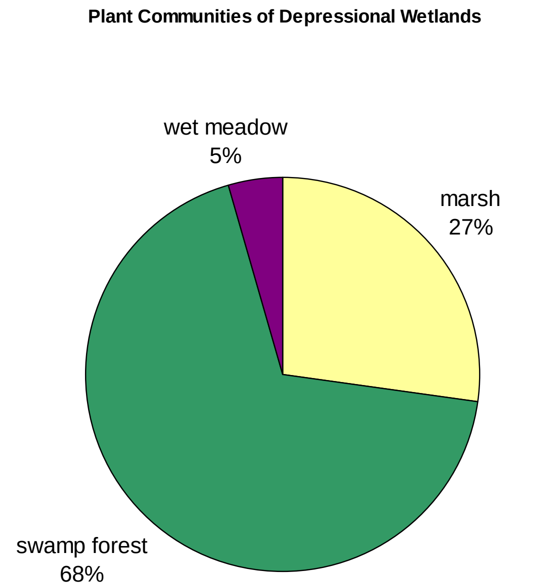


Figure 4A. Plant communities of depressional wetland sites in Franklin County, Ohio.

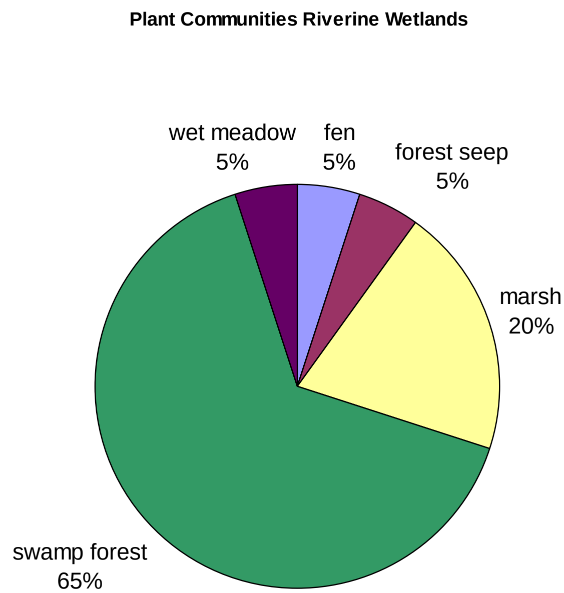


Figure 4B. Plant communities of riverine wetland sites in Franklin County, Ohio.

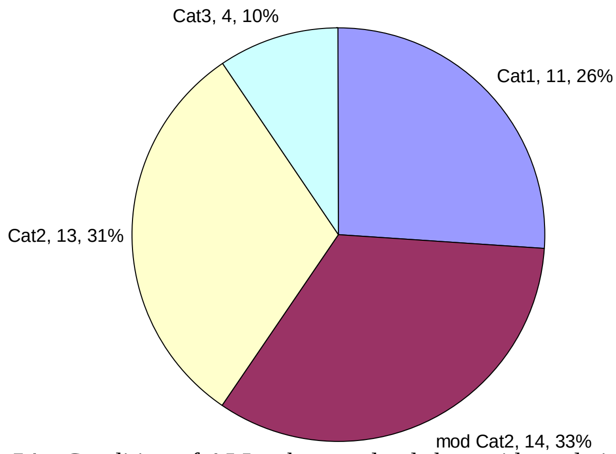


Figure 5A.  Condition of ALL urban wetlands by antidegradation category

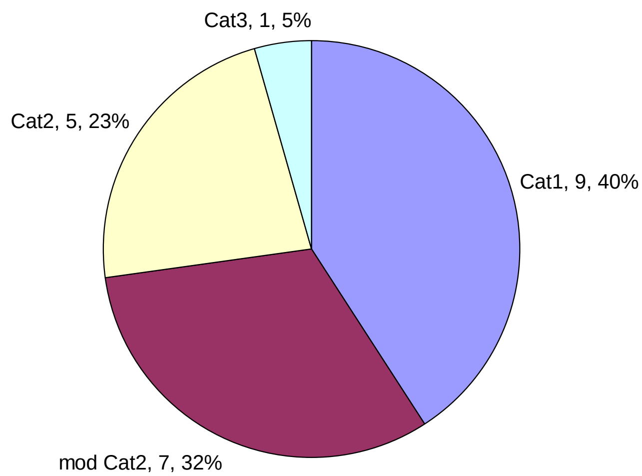


Figure 5B.  Condition of DEPRESSIONAL urban wetlands by antidegradation category

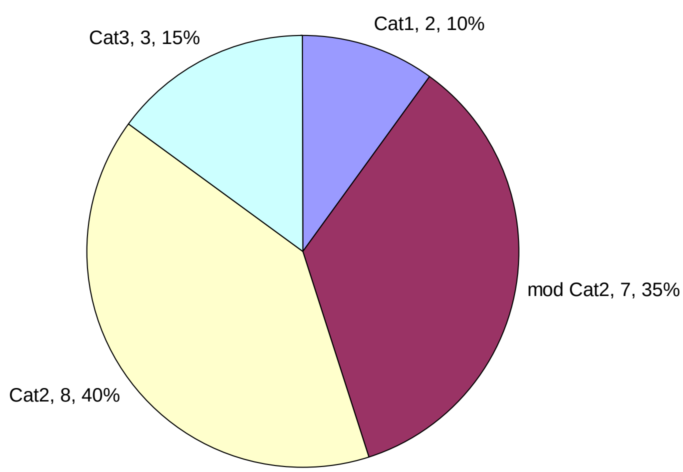


Figure 5C.  Condition of RIVERINE urban wetlands by antidegradation category

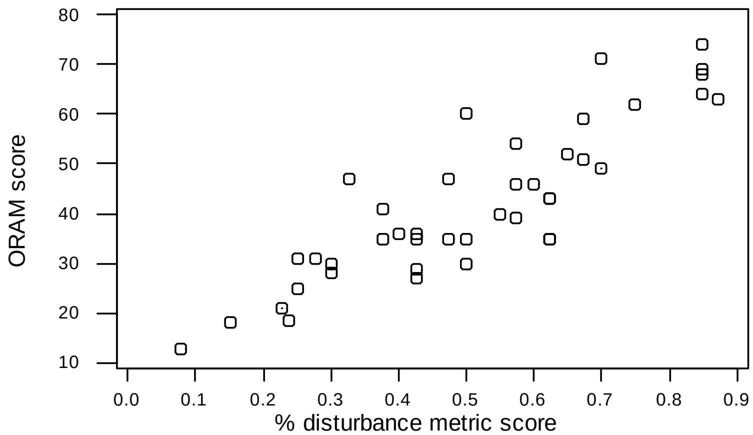


Figure 6. Regression of ORAM Score versus percentage of score from "disturbance" metrics (2a, 2b, 3e, 4a, 4c, 6c) (df = 41, F = 125.4, $R^2$ = 76.2%, p = 0.000).

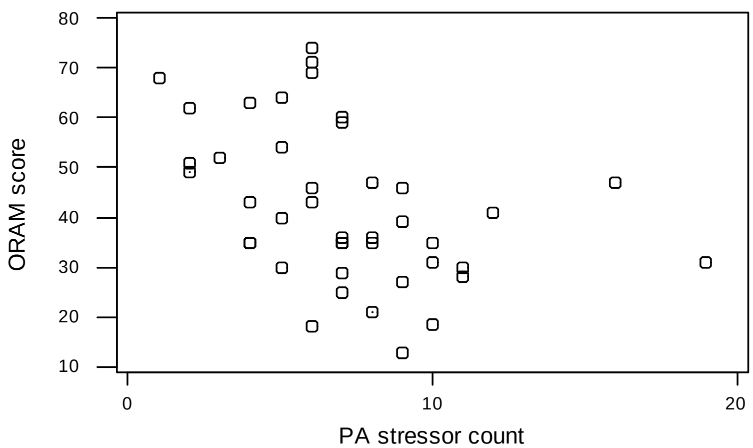


Figure 6. Scatterplot of ORAM score and number of stressors from the PA stressor checklist (df = 41, F = 8.6, $R^2$ = 17.6%, p = 0.006).

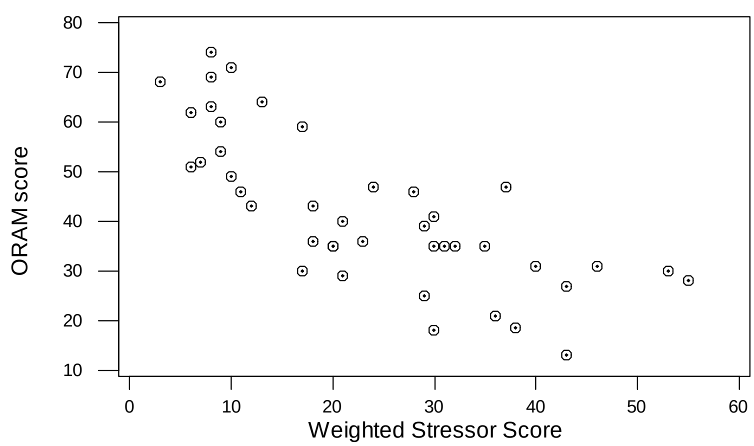


Figure 8. Scatterplot of ORAM score and Weighted Stressor Score derived from the PA Stressor Checklist (df = 41, F = 55.1, $R^2$ = 58.0%, p = 0.000).

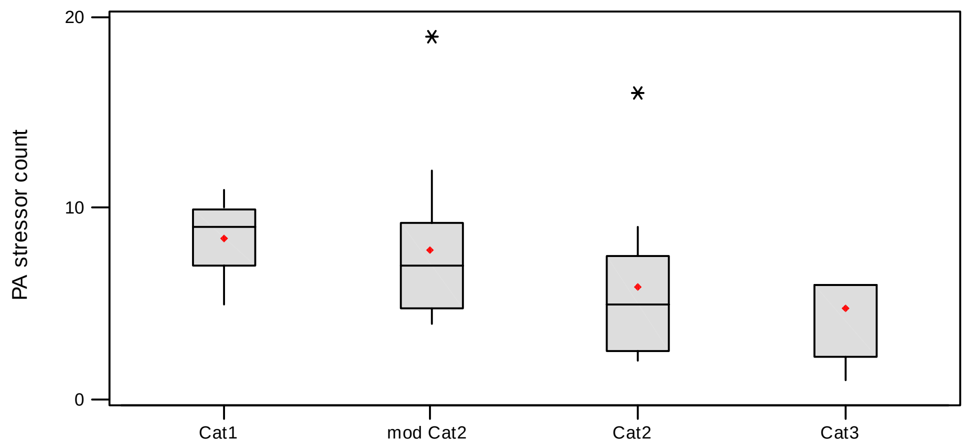


Figure 9. Box and whisker plots of stressor counts from PA Stressor Checklist by wetland antidegradation category (df = 41, F = 2.0, p = 0.127).

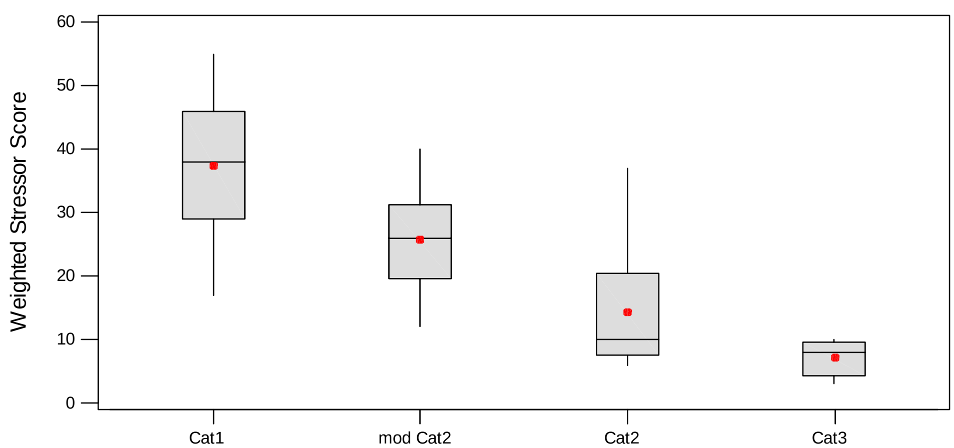


Figure 10. Box and whisker plots of Weighted Stressor Score derived from the PA Stressor Checklist by wetland antidegradation category (df = 41, F = 15.9, p = 0.000). All means significantly different except Cat2 versus Cat3 after Tukey's multiple comparison test (p < 0.05).

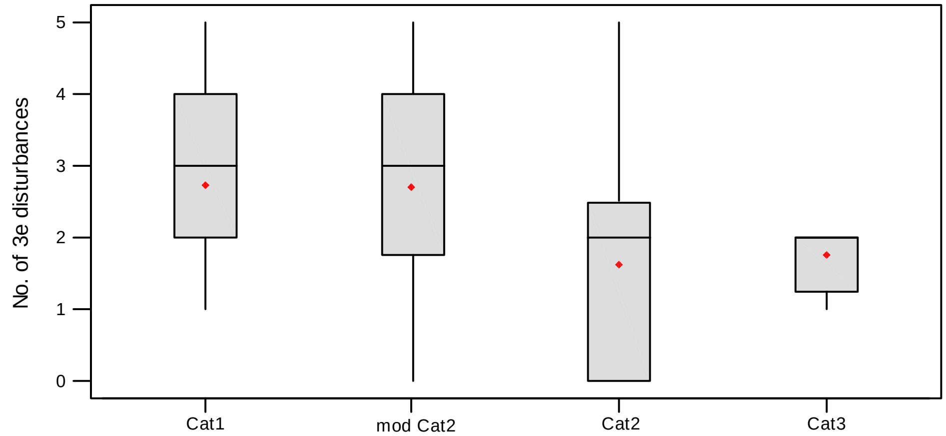


Figure 11A. Box and whisker plots of number of Metric 3e disturbances by wetland antidegradation category (df = 41, 41, F = 1.88, p = 0.149).

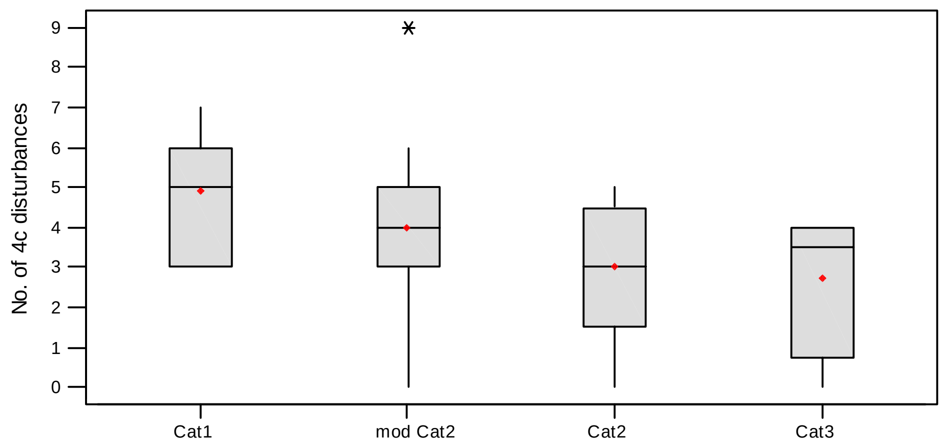


Figure 11B. Box and whisker plot of number of Metric 4c disturbances by wetland antidegradation category (df = 41, F = 2.70, p = 0.059).

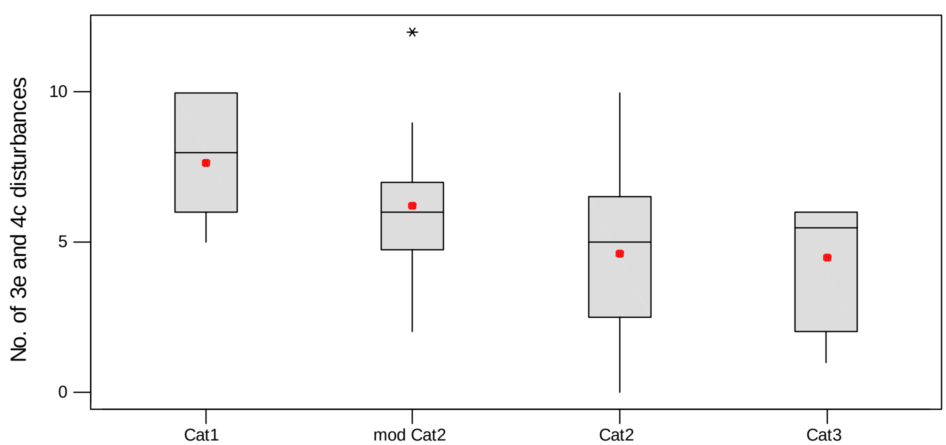


Figure 11C. Box and whisker plot of number of Metric 3e + 4c disturbances by wetland antidegradation category (df = 41, F = 3.62, p = 0.021). Only Cat1 and Cat2 means significantly different after Tukey's multiple comparison test (p < 0.05).

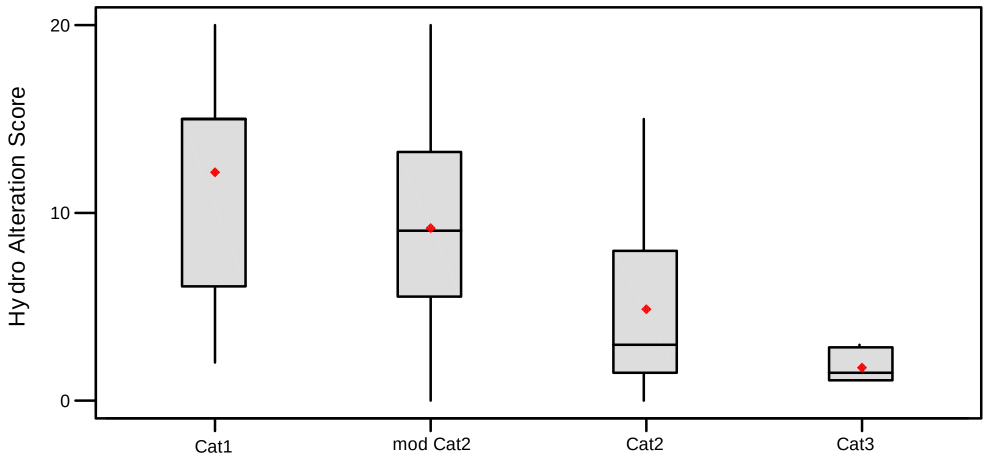


Figure 12A. Box and whisker plots of Weighted Stressor Score from Hydrologic Modification Question of PA Stressor Checklist by wetland antidegradation category (df = 41, F = 5.99, p = 0.002). Cat 1 significantly different from Cat2 and Cat3 ($p < 0.05$)

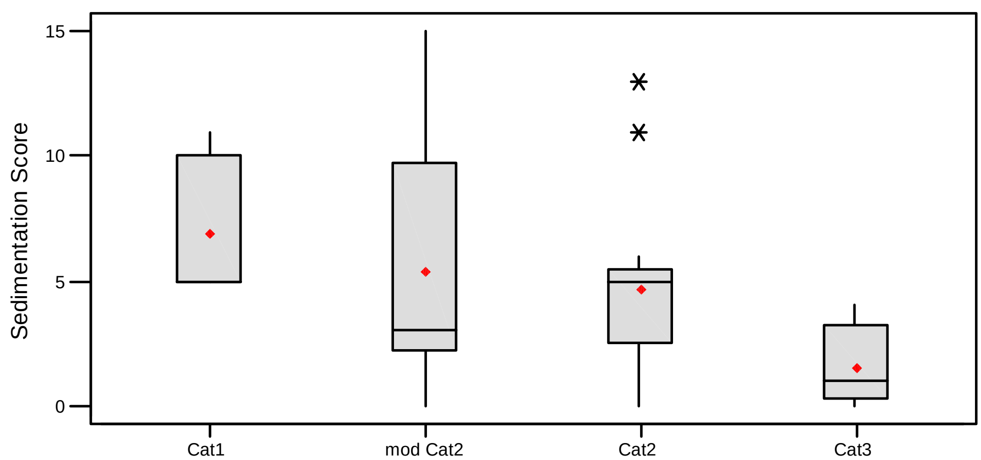


Figure 12B. Box and whisker plot of Weighted Stressor Score from Sedimentation Question of PA Stressor Checklist by wetland antidegradation category (df = 41, F = 1.95, p = 0.139).

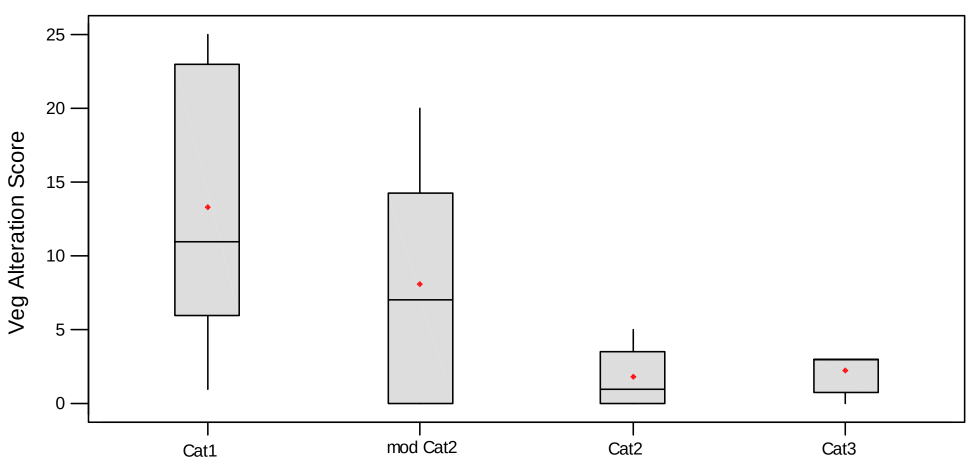


Figure 12C. Box and whisker plot of Weighted Stressor Score from Vegetation Alteration Question of PA Stressor Checklist by wetland antidegradation category (df = 41, F = 8.16, p = 0.000). Cat1 significantly different from Cat2 and Cat3; Cat2 significantly different from mod Cat2 ($p < 0.05$).

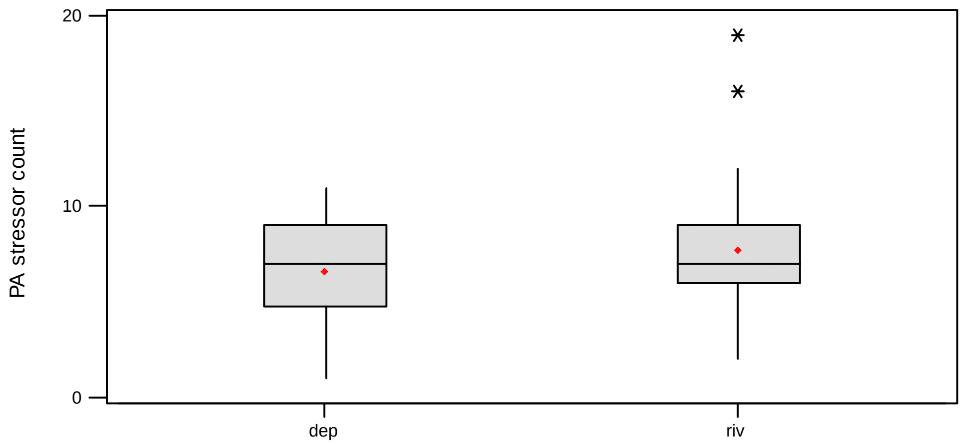


Figure 13A. Box and whisker plots of stressor counts from PA Stressor Checklist by wetland HGM class (df = 33, t = -1.04, p = 0.31).

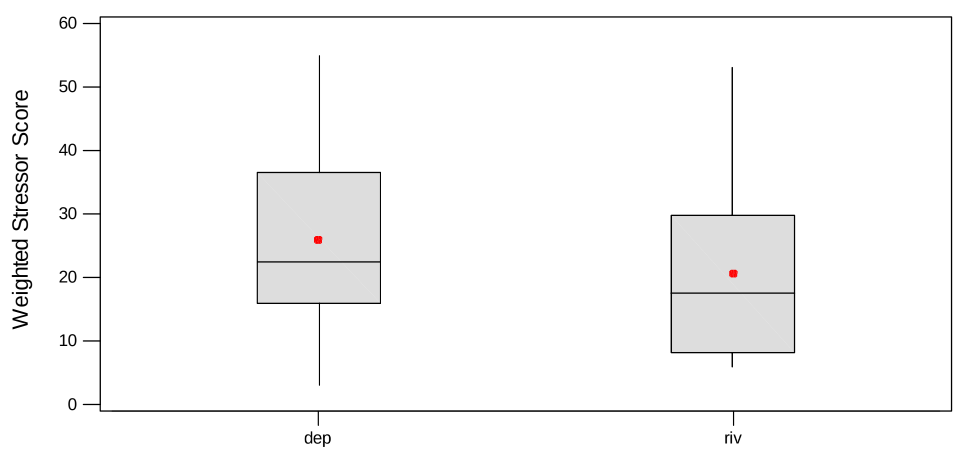


Figure 13B. Box and whisker plots of Weighted Stressor Score Derived from the PA Stressor Checklist by HGM class (df = 39, t = 1.23, p = 0.23).

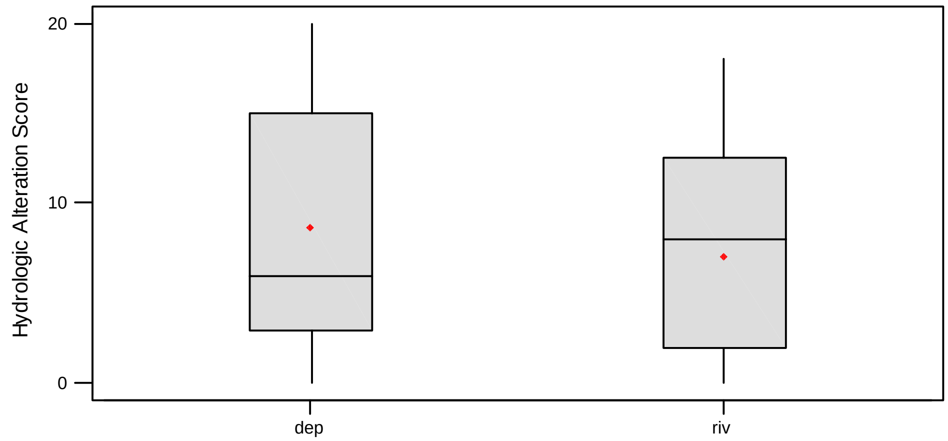


Figure 14A. Box and whisker plots of Weighted Stressor Score from Hydrologic Modification Question of PA Stressor Checklist by HGM class (df = 39, t = 0.86, p = 0.39.

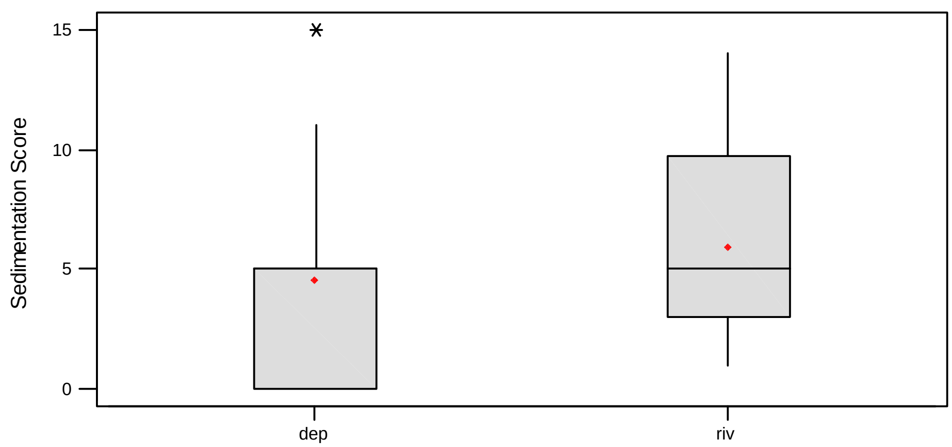


Figure 14B. Box and whisker plot of Weighted Stressor Score from Sedimentation Question of PA Stressor Checklist by HGM class (df = 39, t = -1.08, p = 0.29).

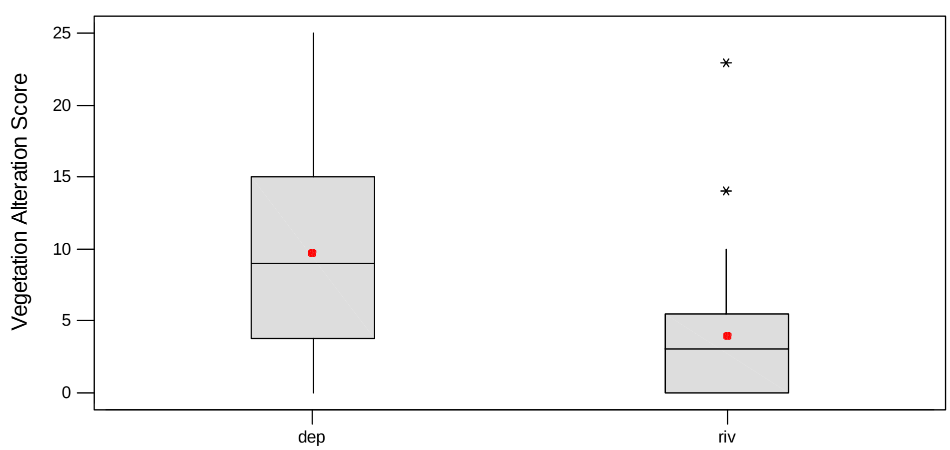


Figure 14C. Box and whisker plot of Weighted Stressor Score from Vegetation Alteration Question of PA Stressor Checklist by HGM class (df = 38, t = 2.69, p = 0.011).

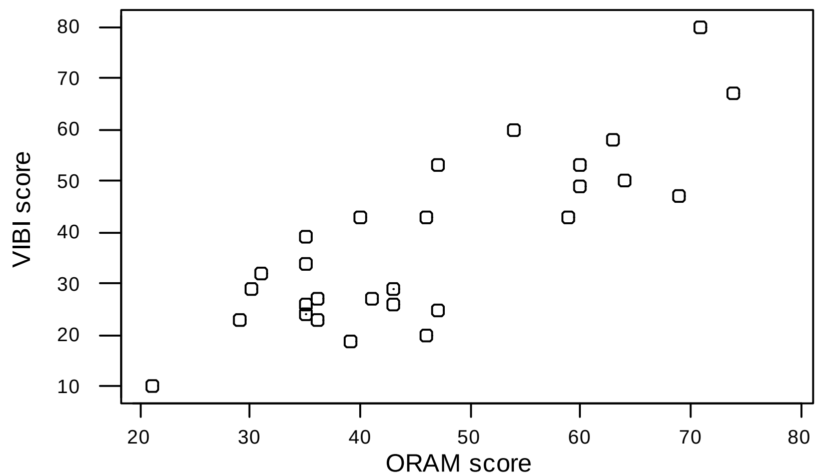


Figure 15. Vegetation IBI score versus ORAM score (df = 27, F = 56.6, $R^2$ = 68.5%, p = 0.000).

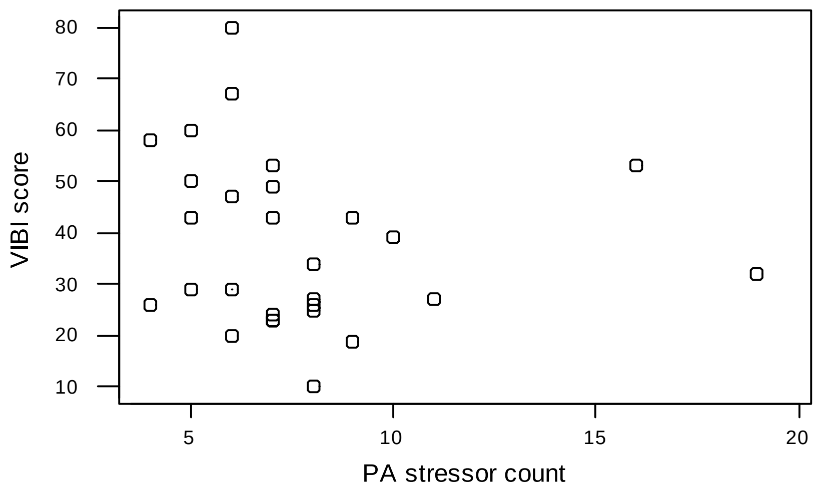


Figure 16. Scatterplot of VIBI score and number of stressors from the PA stressor checklist (df = 27, F = 0.53, $R^2$ = 2.0%, p = 0.472).

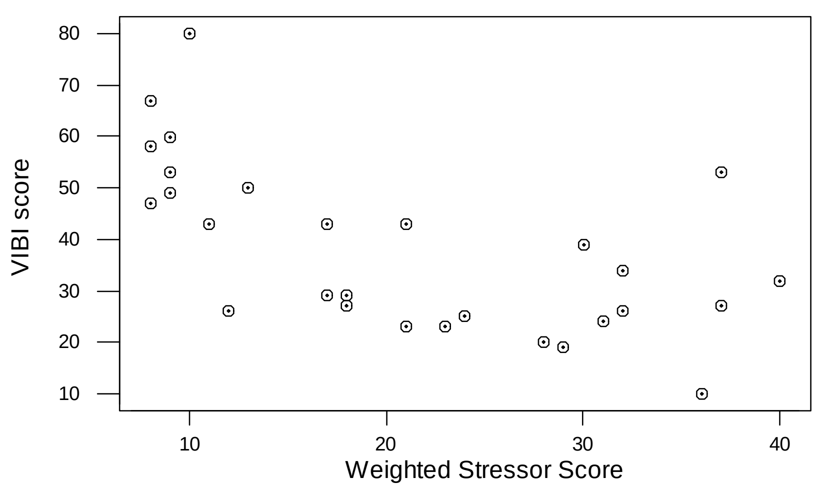


Figure 17. Scatterplot of VIBI score and Weighted Stressor Score derived from the PA Stressor Checklist (df = 27, F = 15.5, $R^2$ = 37.3%, p = 0.001).

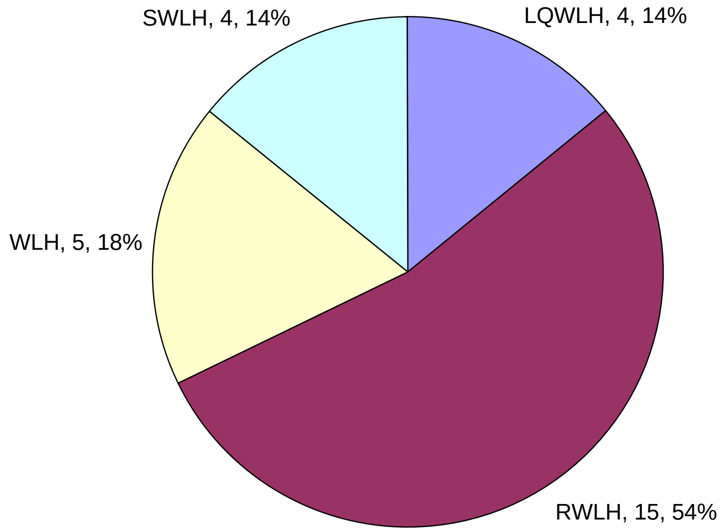


Figure 18. Wetland condition based on Vegetation IBI scores and Wetland Tiered Aquatic Life Use classes.

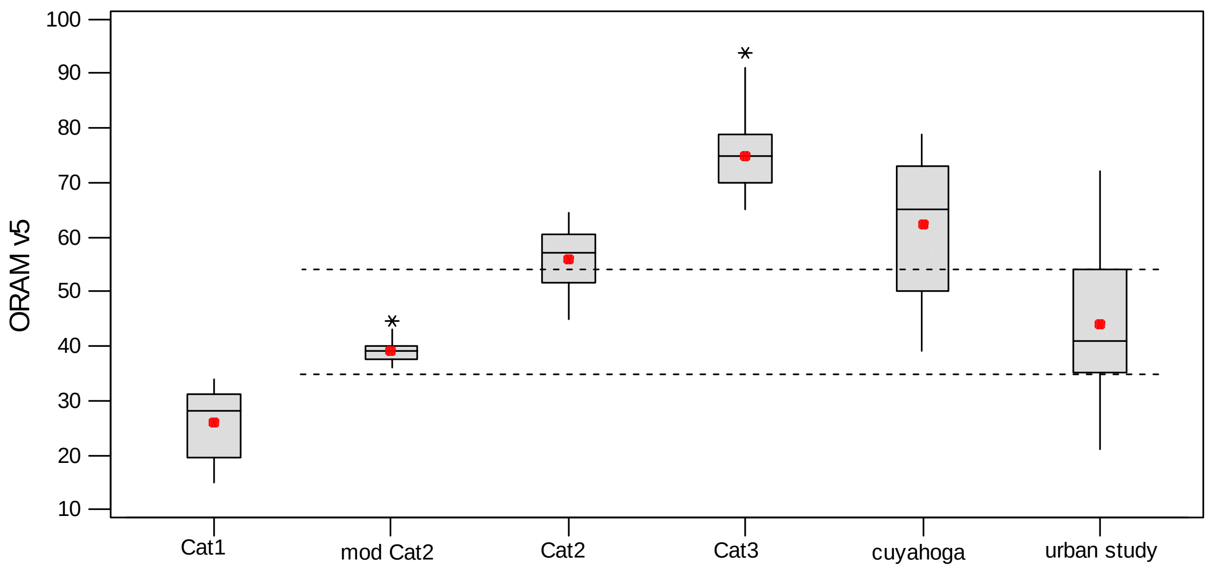


Figure 19. Wetland condition based on ORAM scores and wetland antidegradation condition categories for wetlands in Ohio EPA's reference wetland data set, Cuyahoga Study (Level 3 sites only), and Urban Wetland Study (df = 246, F = 233.6, p = 0.000). Mean of wetlands in urban study and modified Category 2 reference wetlands not significantly different ($p < 0.05$).

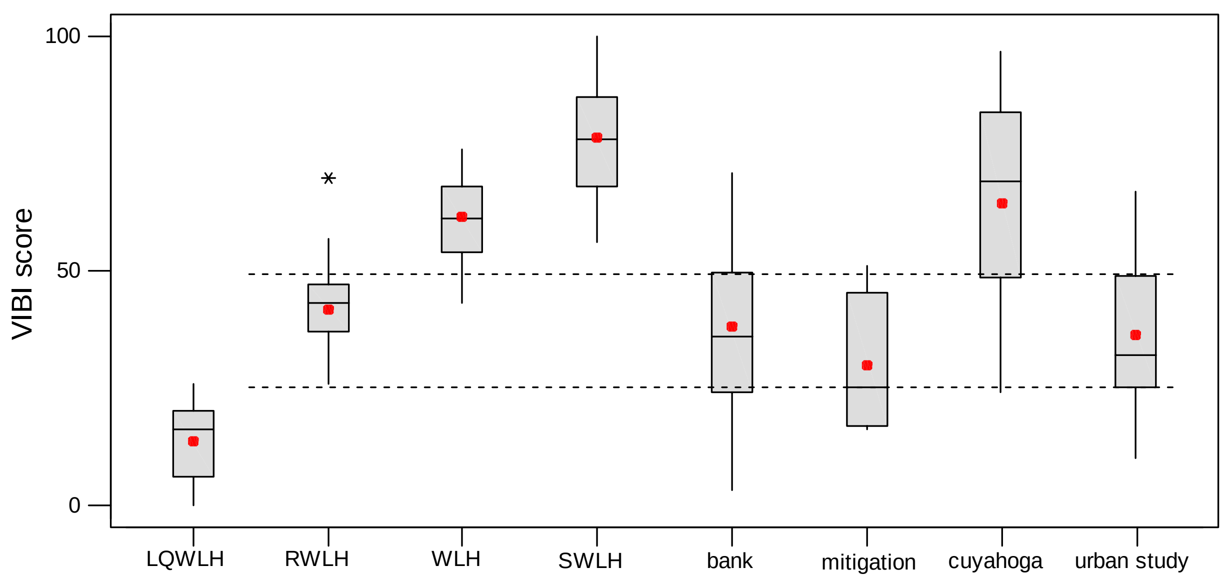


Figure 20. Wetland condition based on VIBI scores and WTALU categories for wetlands in Ohio EPA's reference wetland data set, individual and mitigation bank sites, Cuyahoga Study (Level 3 sites only), and Urban Wetland Study (df = 246, F = 233.6, p = 0.000). Mean of wetlands in urban study and modified Category 2 reference wetlands not significantly different ($p < 0.05$). (df = 296, F = 126.4, p = 0.000). Mean of wetlands in urban study and Restorable Wetland Habitat reference wetlands not significantly different ($p < 0.05$).

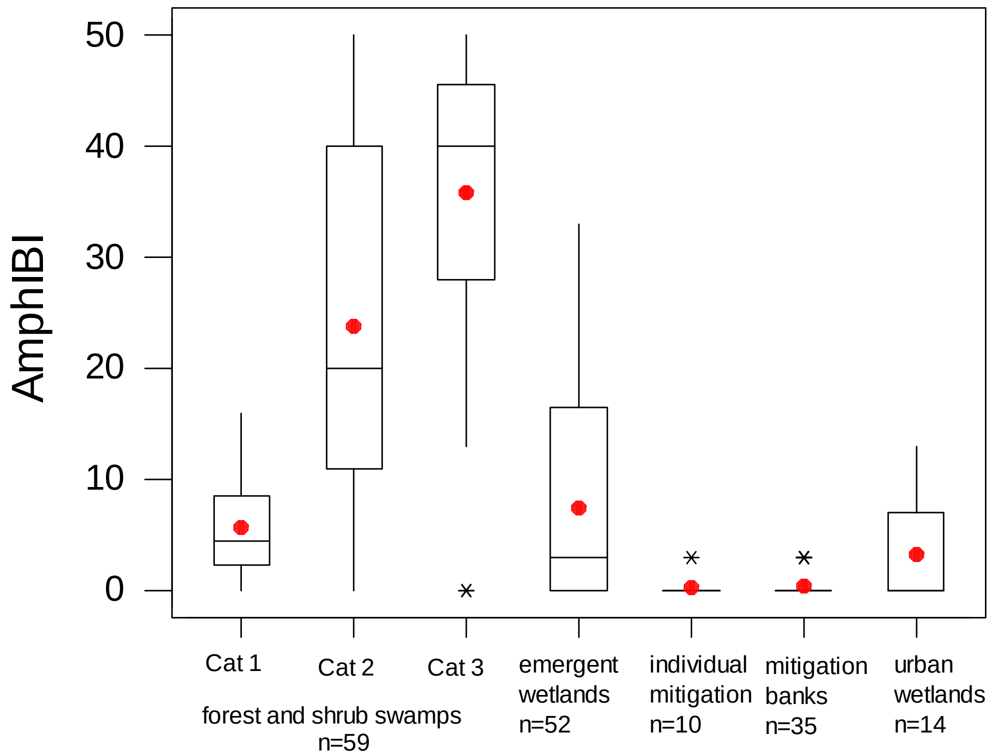


Figure 21. Wetland condition based on Amphbian IBI scores and Wetland Tiered Aquatic Life Use classes (df = 159, F = 50.44, p = 0.000). Urban wetlands significantly different from Category 2 and 3 wetlands, not signficantly different from Category 1, Emergent reference wetlands, individual mitigations and mitigation banks (p <0.05) after Tukey's multiple comparison test.