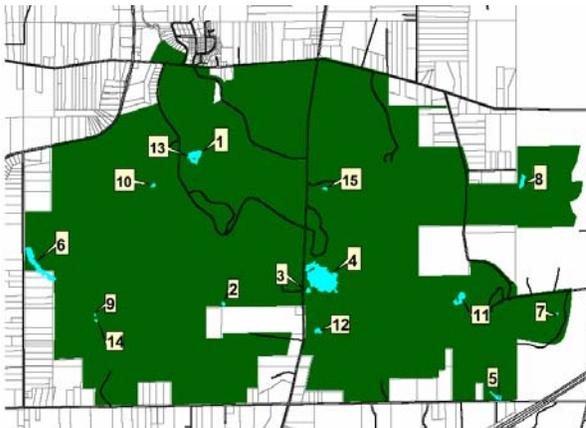


THE STATE OF WETLANDS IN CLEVELAND METROPARKS: Implications for urban wetland conservation and restoration

Cleveland Metroparks Technical Report 2009/NR-07



Fred Rzepka, David W. Whitehead, William J. Ryan
Board of Park Commissioners

Vern J. Hartenburg
Executive Director

Cleveland Metroparks
4101 Fulton Parkway, Cleveland, Ohio 44114

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Images cover page. Top of page: Swamp in Brecksville Reservation and map of wetlands surveyed Park District-wide in 2006. Middle of page: Impounded marsh in North Chagrin Reservation. Bottom of page: map of wetlands surveyed in Hinckley Reservation and wet meadow in Mill Stream Run Reservation.

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THE STATE OF WETLANDS IN CLEVELAND METROPARKS: Implications for Urban Wetland Conservation and Restoration

Michael Durkalec, Claire Weldon, John J. Mack, and Joseph Bishop

ABSTRACT

Cleveland Metroparks is a 90 year old park district with over 21,000 acres of land in five counties surrounding greater Cleveland, Ohio. Wetlands were assessed with a probabilistic study design in 2005 and 2006 and used the Landscape Development Index (LDI) and the Ohio Rapid Assessment Method for Wetlands v. 5.0 (ORAM) as assessment tools. The results confirmed conclusions of prior studies in Ohio that ORAM is a useful tool for assessing wetland condition that is unbiased by hydrogeomorphic class or dominant vegetation. Similarly, the LDI was useful at evaluating wetlands at the population level but was a poor predictor of individual wetland condition. Across Cleveland Metroparks land holdings, 15.9% of wetland were in poor condition, 23.0% were in fair condition, 46.7% were in good condition, and 14.4% were in very good condition. Similar proportions of poor, fair, good and very good wetlands were obtained using the LDI at 2000 and 4000 meter buffer distances. Shape of park (long v. square) and size (big v. small) was a significant factor in explaining proportions of high quality wetlands with big square parks > big long parks > small square > small long, in terms of numbers and acreage of high quality wetlands. Land use trends showed that if land use intensity was high with 100 m of the wetland, no very good quality and only a few good quality wetlands were observed. But, when land use intensity was very high within 4000 m of the wetland, but low closer to the wetland, many good and some very good wetlands were persisting. With 30% of wetlands in poor to fair condition (10% of wetland acreage in park), substantial restoration potential exists within the generally urbanized region of the park system. Data collected here confirms that large blocks of land (>400 ha) have higher proportions of high quality wetlands, but that even within developed landscapes, a significant wetland resource can persist in smaller urban wildlands.

MANAGEMENT RECOMMENDATIONS

1. Approximately 30% of wetlands in the Cleveland Metroparks are in poor to fair condition. On average, these wetlands tended to be small and represent only 10% of the wetland acreage in the park. This represents a significant percentage of park's wetland resource and justifies park-wide wetland rehabilitation program. Small wetlands are also the type of wetland that can be habitat for many of conservative amphibian species (ambystomid salamanders, wood frogs). Rehabilitation of these small wetlands could significantly improve overall population health for small wetland-"vernal pool" species (cf. [Semlitsch and Bodie 2001](#)).
2. Given the amount of fragmentation in the landscape surrounding the park, the Cleveland Metroparks should avoid causing additional fragmentation itself by the construction of roads, trails or other recreational facilities in high quality wetlands or in big- or long-blocks of parkland, or portions thereof, that are presently lacking such potentially fragmenting features.
3. This study confirms decisions made to acquire smaller parks in the urban core like Ohio & Erie Canal and West Creek. Future park acquisitions should certainly focus on preserving big- and long-blocks of land (e.g. expansions in the Rising Valley area of the Upper East Branch of the Rocky River) wherever possible. However, the park should also pursue smaller acquisitions of urban wildland within Cleveland and its suburbs since functioning and often good to high quality remnant habitats can persist in this context even if located in small- or long-blocks.
4. This study represents a snap shot of wetland condition in Cleveland Metroparks as of 2005-2006. However, based on this assessment, we are not able to determine if the condition of our wetland resource is stable, decreasing or increasing. Being able to say something about this is critical given the cumulative effects of changes in urbanization, invasive plants, deer browse, climate change and other factors. In order to begin to track trends in resource condition, implementation of a Long-term Terrestrial and Aquatic Resource Monitoring and Assessment Program is necessary.
5. Although the design used in this study obtained a random sample of wetlands in Cleveland Metroparks, it has some limitations over other sample frames of the wetland population in the park. The current design entailed navigating to a randomly selected point with the park system. If a wetland was not present at the point, the design required the field crew to find the nearest wetland and sample it. In effect, every point yields a sampleable wetland. Using this data, no data is collected for determining losses in wetlands over time. Future inventories should consider using a sample frame capable of tracking wetland loss or conversion.

INTRODUCTION

Overview and Justification

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 (US 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). Rapid methods are well-suited for assessing the ecological condition of a large number of wetlands in a relatively short time frame.

The overall project objective was to assess the ecological health of wetlands in Cleveland Metroparks using existing Ohio wetland assessment tools and determine trends in quality between reservations and position within the landscape (and, if so, corresponding causal factors). Obtaining this baseline information is critical to informed decision making regarding the management of wetland resources of the Park District in the following ways: 1) to help guide mitigation efforts in determining the status of wetland quality and identify those in need of preservation versus restoration or enhancement; 2) inventory a representative sample of wetlands to aid in watershed/regional level management efforts; and 3) to assist in guiding the direction of future wetland research in the Park District, and 4) to monitor trends in wetland condition over

time. This study represents a baseline assessment of wetland condition in the Cleveland Metroparks that will be followed by a reassessment of wetland condition every 4 to 6 years (Mack 2008).

This baseline study also implements, recommendations found in *Application of Elements of State Water Monitoring and Assessment Programs* (the "Elements" document) (US EPA 2006) and the latest *Surface and Ground Water Monitoring Assessment Strategy 2005-2009* (Monitoring Strategy) prepared by Ohio EPA (INSERT CITATION). The most recent Monitoring Strategy document states (p. 30), that:

"The final step [in Wetland Monitoring objectives] will be to perform a fully integrated assessment of both wetlands and flowing waters (streams, rivers) in a watershed. This will involve the inclusion of ambient wetland assessments as part of Ohio EPA's routine intensive biological and water quality surveys, or "biosurveys," on a systematic basis statewide. Such an integrated survey would be an interdisciplinary monitoring effort coordinated on a watershed scale. Such efforts may involve a relatively simple setting focusing on a small watershed or a much more complex effort including entire large river drainage basins and multiple and overlapping stressors. Wetlands would be included in the routine, annual, biosurveys Ohio EPA already conducts in 20-25 U.S. Geological Survey 11-digit HUB-based Watershed Assessment Units (WAUs) and 2-3 Large River Assessment Units (LRAUs)."

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 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 poor, good and excellent quality. There is also an implied fourth category (fair) 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.

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 "excellent" condition.

Landscape setting of Cleveland Metroparks Watersheds

Cleveland Metroparks Park District land holdings encompass approximately 22,000 acres predominantly in Cuyahoga County (Figure 1). The park has landholdings in the Rocky River Watershed (East and West Branches of the Rocky River, Abram Creek, Baldwin Creek), the Chagrin River watershed, the Cuyahoga River watershed (Big Creek, Burk Branch, Chippewa

Creek, Mill Creek, Tinkers Creek, West Creek, and several other small Lake Erie watersheds (Cahoon Creek, Euclid Creek, French Creek, Porter Creek).

Cleveland Metroparks watersheds are all located in the Erie-Ontario Drift and Lake Plains (EOLP) ecoregion (Woods et al. 1998) which is part of the glaciated Allegheny Plateau. The EOLP ecoregion is a glacial plain that lies between the unglaciated Allegheny Plateau region to the south and the relatively flat, more fertile, Eastern Corn Belt Plain ecoregion to the west. It is characterized by glacial formations that can have significant local relief and has a mosaic of cropland, pasture, woodland and urban areas. Soils are mainly derived from glacial till and lacustrine deposits from former pro-glacial lakes.

The park system was established in 1917 and is presently comprised of 16 reservations plus the Cleveland Metroparks Zoo (Figure 1). The park's early developers envisioned a system of parks and trails that encircled Cleveland (an emerald necklace) that would provide a green oasis from the pollution and congestion of the city. The system followed the major river valleys to the east and west of Cleveland (Rocky River, Chagrin River) with a series of linking parkways across southern Cuyahoga County. The core of of the system (the 7 largest reservations) were largely acquired by 1980. Since then, the park system has added mostly reservations within the urban core of Cleveland (e.g. West Creek, Ohio & Erie Canal, Garfield Park, Brookside) by taking over existing parks from the City of Cleveland or acquiring remnant urban wildlands.

At the time of acquisition of much of the park, the surrounding land use was predominately rural but after World War II, the second and third tier suburbs of Greater Cleveland have landlocked many of the parks with suburban development. At the present, only Hinckley Reservation and areas east of North and South Chagrin Reservations retain a rural character.

Location, size, surrounding land use, shape, perimeter:area ratio, and average ORAM

score are summarized in Table 1. Reservations range in size from 24 ha (59 ac) (Washington) to 1400 ha (3494 ac) (Brecksville). Average reservation size is 527 ha (1302 ac). Average size of the seven largest reservations is 1029 ha (2543 ac); average size of the nine smallest, mostly urban reservations is 126 ha (312 ac) (Table 1). Reservations are located in the Chagrin River (2), Cuyahoga River (8), Rocky River (5) watersheds or are within small Lake Erie tributaries (3). Parts of Big Creek reservation drain to the Rocky River and to the Cuyahoga River.

METHODS

Site selection and Study Design

Wetland assessment was initiated in May 2005 using a targeted study design. The rationale at the beginning of the study was that location of wetlands in the park was relatively well known and this would be the most efficient approach to a park-wide wetland assessment. A total of 84 wetlands were assessed in 2005. In 2006, the study design was reevaluated and a probabilistic site selection procedure was adopted to assure a Park District-wide representative sample. An ArcView random point generating extension was utilized to obtain a geospatially balanced random sample. Using this system, the point generated would fall within a wetland (and in this case, it would be assessed), or it would fall within a non-wetland area. If this occurred, the field crew navigated to the nearest wetland from the point using local topography and hydrology. This method worked very well in finding a wetland within a relatively short distance of the point. A total of 196 wetlands were sampled in 2006.

Although sites sampled in 2005 were not selected using a strict random approach, they were relatively evenly distributed across the park system. A comparison of mean and standard deviation of ORAM scores and probability plots of 2005 sites (mean = 49.27, sd = 14.25), 2006 (mean 49.12, sd = 13.72) sites and all sites (mean = 49.16, sd = 13.89), yielded virtually identical results, so data analysis included all sites assessed in both years (n = 280).

Because natural resource staff in the park system have been voluntarily creating or restoring wetlands in the parks for decades and in recent years for Section 401/404 wetland mitigation requirements, mitigation wetlands were included in the sample. Only 25-36 sites were identified as potential “created” wetlands. In some instances, it was very difficult to determine whether the sites developed naturally or were the result of past construction activities in the park. In addition, most of these sites were not actively managed in terms of water control structures. For these reasons, all of these sites

were included in the data analysis, even though the Ohio Rapid Assessment Method (ORAM) v. 5.0 User’s Manual cautions using the method to assess “mitigation” wetlands.

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) (US EPA 2006; Brooks 2004; Fennessy et al. 2004; Fennessy et al. 2007a). We collected two types of data in this study: 1) GIS data (land use information and other information obtained from existing geographic information system data layers); and 2) rapid assessment data obtained from a site visit. Future wetland assessment efforts at Cleveland Metroparks will include intensive level 3 data collection of vegetation assemblages, as well as other ecological information.

Sampling methods - Level 2 Rapid Assessment

An 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 (Mack 2001).

Wetlands were located on the ground using Cleveland Metroparks mapping resources and GPS device and orienteering to the random point (as outlined in detail earlier in the Methods section). The scoring boundary (assessment unit) was defined by rules outlined in the ORAM v. 5.0 User's Manual (Mack 2001). Wetland perimeters were mapped with a Trimble Geoplotter survey grade GPS unit. An electronic data dictionary was generated to include other points of interest, including: hydrologic inlets/outlets and colonies of invasive plants.

Land Use

Land-use surrounding the wetland sites was characterized using the Ohio Digital land-use survey database. Land-use was classified into the following categories (Frohn 2005): 1) forest (a combination of evergreen and deciduous forest cover); 2) pasture (areas of grasses, legumes, or grass-legume mixtures planted for livestock grazing or the production of seed or hay crops); 3) crop (areas used for the production of crops such as corn, soybeans, and wheat); 4) residential (includes both heavily built up urban centers (high intensity residential) and areas with a mixture of constructed materials and vegetation (low intensity residential) and included apartment complexes, row houses, and single-family housing units); 5) commercial (includes infrastructure (e.g. roads, railroads, etc.) and all highways and all developed areas not classified as residential); 6) wetland (a combination of wooded wetland and herbaceous wetland cover); 7) open water; and 8) bare /mined lands.

Land-use was characterized at distances of 100 m, 250 m, 500 m, 1000 m, 2000 m and 4000 m from the scoring boundary of each site (Houlahan and Findlay 2004). The percent land use for each buffer distance was calculated starting at the wetland perimeter, so the actual area of each land-use type varies with the size of the wetland (Brooks et al. 2004; Rheinhardt et al. 2006). State-wide land cover data for Ohio, available from Frohn (2005), were used to calculate land cover characteristics. The composition of each land cover class as well as a series of landscape metrics were calculated using a specifically programmed ArcView 3.3 (ESRI 2002) project that automates the processing of multiple polygons (Bishop and Lehning 2007). The program incorporates the landscape metrics included with the ArcView extension software Patch Analyst (Rempel 2007) with several more standard geographic information system (GIS) functions that provide for buffering designated distances away from selected polygons. For this study, the polygons are the digitized wetlands boundaries that were sampled. The program was

used to calculate all metrics from within each wetland boundary as well as all specified buffer distances listed above.

Land-use proportions were converted to a Landscape Development Intensity (LDI) index which integrates the impacts of human land use on a given site (Brown and Vivas 2005). The LDI scores were calculated based on assignment of land-use coefficients (Table 2). Coefficients were calculated as the normalized natural log of energy per area per time, a measurement used to quantify human activity (Brown and Vivas 2005). In terms of the LDI index, energy is energy corrected for different qualities and includes all non-renewable energies, such as electricity and water. The LDI_{total} is calculated as a weighted average, such that:

$$LDI_{total} = \sum \%LU_i * LDI_i$$

where, LDI_{total} = the LDI score, $\%LU_i$ = percent of total area in that land use i , and LDI_i = landscape development intensity coefficient for land use i (Brown and Vivas 2005). What is unique to this calculation is that it integrates all land-uses into one score rather than looking at each land-use separately. By using this method (level 1 assessment) in combination with the level 2 assessments, we could evaluate the response of wetland ecosystems as the human impact on surrounding land-use increases.

The LDI index was calculated for each of the six buffer distances by analyzing the different land-uses from the wetland boundary edge. We classified LDI scores to correspond to four wetland condition categories by quadrisectioning the 95th percentile of LDI scores for each buffer distance. The LDI coefficients used in the analysis were developed for the land uses and climatic conditions of southern Minnesota (Brandt-Williams and Campbell 2006) (Table 2). The LDI score coefficients can range from 0 to 465. We felt this was a reasonable approach given Minnesota's relatively close proximity to Ohio within the Great Lakes region, as well as due to the successful use of this set of coefficients in the Cuyahoga River watershed wetland study

(Fennessy et al. 2007b).

Fragmentation

Perimeter to area ratio of Cleveland Metroparks reservations was utilized as a simple, but effective, indicator of landscape level fragmentation. This metric has been used successfully for this purpose in other studies (e.g. Liu and Cameron 2001; Helzer and Jelinski 1999). Long, thin parkway corridors were analyzed separately from the main parts of reservations they were connected to and part of. Preliminary data analysis showed that these parkway corridors skewed the P:A ratios of the larger reservations and that wetlands assessed within these corridors were more similar to long-thin reservations (see below).

Data processing and analysis

GPS Pathfinder Office (v.2.51 and 2.80) and DNR Garmin (Minnesota DNR freeware program) were utilized for raw GIS data processing, and ArcView 3.2 was used for data analysis and presentation.

Minitab v. 15.0 was employed for the analyses of ORAM and LDI scores. One-way analysis of variance was used to detect differences in continuous variables such as ORAM and LDI scores between HGM classes, wetland condition categories, and wetland size categories. This program was also used to generate figures and tables for summarizing data and analysis results.

RESULTS

ORAM (Level 2) Assessment Results

Field crews visited 280 wetlands in this survey, primarily between late May and mid-August during 2005 and 2006, although a number of sites were assessed as late as the third week of September. A single field crew (of two to three members) each season spent a total of 78 combined field days, averaging 4.0 sites per day.

Of the 280 wetlands assessed, the majority were depressional (62.9%). The remaining sites constituted a combination of riverine (16.9%), natural (beaver) and man-made impoundments (10.4%), slope wetlands (8.6%) and fringing wetlands (1.1%) (Figure 2). ORAM scores ranged from a low of 13.0 to a high of 87.5, which represents most of the range of possible ORAM scores (Figure 3). ORAM has an effective range of 6 to 90 with a scores occasionally of <6 or >90 for a few sites that receive point subtractions or additions under Metric 5. The size of the assessment areas sampled (as determined by the ORAM scoring boundary rules) varied widely, ranged from 0.008 ha to 19.7 ha. The size distribution of all wetlands sampled showed that the largest proportion of wetlands, regardless of HGM class fell in the 0.12 to <1.2 ha (0.33 to 3.0 ac) size category (Figure 4).

For the wetlands sampled in Cleveland Metroparks, ORAM scores were normally distributed within their range of 13.0-87.5 with a mean score of 49.2 (± 13.9 SD, $n = 280$) (Figure 5). Wetland condition was evaluated by comparing ORAM scores to the State of Ohio's wetland antidegradation categories: Category 1 (poor), modified Category 2 (fair), Category 2 (good), and Category 3 (excellent). Across the entire Park District, 15.9% of individual wetlands were in poor condition, 23.0% in fair condition, 46.7% in good condition, and 14.4% in excellent condition (Figure 6). On an areal basis, 2.5% of the wetland area assessed was Category 1, 9.0% was modified Category 2, 45.2% was Category 2, and 43.3% was Category 3 (Table 3; Figure 7). Wetland condition by percentage and acreage of

wetlands was also evaluated by Cleveland Metroparks reservation (Figures 8 and 9). The percentage of individual wetlands in each reservation in any antidegradation category was highly variable, but Brookside Reservation had the highest percentage of individual Category 1 wetlands (85.7%) and Hinckley Reservation had the highest percentage of individual Category 3 wetlands (40.0%) (Figures 8 and 9).

Overall wetland condition varied across the Park District by watershed location and surrounding land use, with the best condition in terms of individual wetlands occurring in the upper parts of the East Branch Rocky River watershed in Hinckley Reservation, although significant high quality wetland resources also still remain in the middle Cuyahoga and upper Chagrin river watersheds of Cleveland Metroparks (Figures 8 and 9). As a general characterization by number, approximately two-thirds of the wetland resources in Cleveland Metroparks are in good or better condition and approximately one-third are in poor to fair condition. By area, nearly 90% of wetlands are in good or better condition, with the remaining 10% of wetland acreage in the park of poor to fair quality.

These patterns in the number of wetlands and wetland area by condition class are also reflective of the size of wetlands and landscape fragmentation. Median size of wetlands in the four condition categories was significantly different: Category 1 = 0.16 ha (0.39 ac), modified Category 2 = 0.40 ha (1.0 ac), Category 2 = 0.98 ha (2.41 ac), Category 3 = 3.14 ha (7.75 ac) (Tables 3 and 4; Figure 10).

Wetland condition was also evaluated by stratifying wetlands by HGM and plant community classes. There were no significant (or in most instances not even observable) differences in average ORAM scores by condition category for HGM class or plant community (Tables 5a and 5b). These results are an important verification of a fundamental approach adopted in ORAM: a single set of metrics calibrated to allow all wetland types to score well or poorly in a similar manner, a finding

which is also corroborated by the Cuyahoga River watershed (Fennessy et al. 2007b).

Landscape Development Index (LDI) Assessment Results

Mean LDI scores for all points assessed ranged from 58.8 (100 m) to 229.5 (4000 m) surrounding Cleveland Metroparks, with lower scores reflective of a lower intensity of land use. Overall, watershed-wide land use intensity could thus be characterized as varying from low to very high (Table 6). Wetlands in Hinckley Reservation had significantly lower LDI score range across most buffer distances than wetlands in the rest of Cleveland Metroparks, although these differences were increasingly pronounced when land use data from the 1000 m, 2000 m, and 4000 m buffers were used (Table 6).

Overall, LDI scores increased as land use data from larger areas were used to calculate the score (Tables 6 and 7; Figure 11). The score distributions for LDI scores at 100 m and 250 m, and to some extent 500 m, are strongly left-skewed, reflecting the predominance of sites with low intensity land uses in the first few hundred meters from the wetland (Figure 12) (a not surprising result given that all the wetlands were located in parks). For example, within the 100 m buffer, Cuyahoga county wetlands had an average LDI (52.0) score similar to Medina county wetlands (62.6), but had a significantly higher score (241.2 versus 91.88) at the 4000 m distance. Medina county wetlands, (Hinckley Reservation) were surrounded by rural lands, and showed comparatively little variation in LDI scores across the various buffer distances as opposed to the Cuyahoga county wetlands, many of which are surrounded by urban land uses and exhibited great increases in LDIs as buffer zones increased (Table 7).

Score distributions become more normal when land use data at 1000, 2000, or 4000 meters was used (Figure 12). The increase in average LDI scores by buffer class continued to be observed when sites were stratified by condition categories (Table 8). Mean Category 2 wetland LDI scores increase from 37 to 219, and mean

Category 3 wetland scores increased from 22 to 177 over the different buffer distances (Table 8) (Category 1 and modified Category 2 scores also increased in the same manner). From a practical perspective, results from a level 1 LDI assessment are strongly scale-dependent. The results, not surprisingly, also suggest that the land use is less developed at shorter buffer distances (apparent up to 500 meters) surrounding land holdings in the Park District (Tables 6 and 7). Overall, wetlands in this study were generally well buffered locally (as might be expected with their location in a park), but were often embedded in a highly developed landscape. Hinckley Reservation in rural Medina County and Brecksville Reservation, adjoining the 32,000 acre Cuyahoga Valley National Park being notable exceptions.

It was further observed that the LDI could be used for predicting trends in wetland condition classes between the four land use intensity categories at all buffer distances. The condition class of wetlands decreased (lower quality) as land use intensity category increased, and vice versa as land use intensity category decreased. This trend was noted at all buffer distances, but was especially apparent when Category 3 (highest quality category) wetlands and Category 1 (lowest quality) wetlands were compared against LDI intensity categories (Figure 13).

On the other hand, the predictive power of the level 1 LDI assessment at the individual site level for all wetlands was low ($R^2 = 8.6-12.2\%$) for all buffer distances (Figure 14). However, at the population level, the LDI assessment could distinguish between three or four significantly different condition categories at every buffer distance (Table 9; Figure 15). P-values were significant at all buffer distances (Table 9).

LDI scores were also evaluated by the four most common HGM classes (depression, riverine, slope, impoundment). LDI scores increased significantly as the distance from the wetland boundary increased for all HGM classes (Figure 16) in the same manner observed for the

entire data set (Table 10). Mean LDI scores increased such that the 4000 m buffer had a mean LDI score nearly four times the value for the 100 m buffer. Similarly, variability in scores within HGM classes decreased as the buffer distance increased (as measured by reduced standard deviations at the largest buffer distances), i.e., the landscape at this scale is more homogeneous.

The intensity of land-use as measured by LDI scores also exhibited variation between HGM classes, although not to a significant level. Overall, slope wetlands had the highest mean LDI scores at shorter buffer distances (100-500m) and depressional wetlands had the highest mean LDI scores at wider buffer distances (1000-4000m). This may be explained by the fact that many of Cleveland Metroparks land holdings are located in stream corridors, and the corridor rims (and adjacent slopes) are often very near the park boundaries, with non-park lands (and more intensive land uses) immediately outside. Across all buffer distances, impounded wetlands showed the overall lowest consistent LDI values (Figure 16). This is likely due to the predominance of open water in their immediate vicinity. Open water is given a 0.0 weighting factor even if it is created as part of a managed reservoir.

In order to equate LDI score to potential wetland condition, LDI scores were grouped into condition categories based on the intensity of surrounding land use. Condition categories were determined by quadrisectioning the 95th percentile for each buffer distance. The overall report card of wetland condition based on the Level 1 assessment again varied depending on the scale at which the landscape around the wetland was evaluated (Figure 17). From 100 m to 500 m, 80-90% of the wetland resource in Cleveland Metroparks would be expected to be in good to excellent condition (Table 10). At the 1000 m and 2000 m buffer distances one-half to two thirds of the resource is predicted to be in good to excellent condition. At the 4000 m distance, about one third of the resource is predicted to be in good to excellent condition, one third in fair to good condition, and one third in poor to fair

condition (Table 10).

Reservation Size and Perimeter to Area Ratio Analysis Results

In an effort to determine landscape level trends in wetland health, fragmentation of Cleveland Metroparks reservations were assessed and compared to level 2 assessment scores grouped by condition category. Initial categorization of land holdings was based on size (large $\geq 1,000$ acres and small $< 1,000$ acres) and “blockiness” as apparent by spatial observation on a map.

To facilitate analysis, reservations were further broken up into four categories based on size and general shape, as follows: big-block, big-long, small-block, and small-long. The idea being that wetland resources of smaller and/or longer reservations would have more pronounced exposure (based on small size and/or greater perimeter) to land holdings outside the Park District and “non-park” land uses and their potential stressors.

Allocation of Cleveland Metroparks reservations into these four categories were as follows. “Big-block” reservations included Bedford, Brecksville, Hinckley, North Chagrin and South Chagrin. “Big-long” reservations included Mill Stream Run and Rocky River. “Small-block” reservations included Bradley Woods, Brookside, Garfield Park, Huntington, and West Creek. “Small-long” reservations included Big Creek, Euclid Creek, and Ohio and Erie Canal (Table 1; Figure 1).

The trend observed was that the big reservations had, proportionately, approximately 100-500% more Category 3 (highest quality) wetlands than the small reservations (Figure 18). Conversely, big reservations had proportionally half the number of Category 1 (poor quality) wetlands than small reservations. Between the big reservations, big-block reservations had twice as many Category 3 wetlands than long-block reservations. No strong trend was noted between small-block versus small-long reservations.

In an effort to further corroborate this observation using a more objective metric,

perimeter:area ratio of each reservation was calculated. Perimeter:area ratio has been used successfully as a general measure of habitat fragmentation by previous researchers (Liu and Cameron 2001; Helzer and Jelinski 1999). Also worth noting is that several reservations with otherwise “blocky” sections had very thin parkway corridors between them (e.g., Brecksville, Big Creek, and South Chagrin), which were analyzed separately from the main part of the reservation).

Perimeter:area ratios (P:A) for each reservation were then plotted against mean ORAM wetland scores for each reservation. This revealed a trend in which P:A value clearly exhibited a relationship with mean ORAM score in a predictable manner ($R^2 = 0.48$, Figure 19). The inverse nature of this relationship reveals that higher P:A value (higher fragmentation) is linked to lower mean ORAM scores, while lower P:A value is linked to higher mean wetland quality scores. However it is important to note that good to excellent condition wetlands did exist in very fragmented or developed landscapes (most of the small-block, small-long reservations), presumably because they were well-buffered locally (Figure 19). But the overall trend in the data was that big is better and big-blocks are better than long-blocks (Figures 18 and 19).

Causes and sources of wetland degradation

There are lists of the stressors provided in ORAM Metrics 3e (hydrologic alteration) and 4c (Habitat alteration). Category 2 and 3 wetlands had significantly lower numbers of hydrologic stressors than Category 1 and modified Category 2 wetlands and Category 3 wetlands had significantly lower numbers of habitat stressors than all other condition categories (Table 12). The most important hydrologic stressors related to condition category were ditching, tiling, dikes, stormwater input, filling, and roads (Table 12). Some watershed oriented differences in percentages were observed. In the Rocky and Chagrin river watersheds, there were greater percentages of

hydrologic and habitat stressors in the downstream versus the upstream basin reaches (Tables 12 and 13). Specifically, ditching, tiling, diking, stormwater input, filling, roads, sedimentation, mowing, and nutrient enrichment were the most prevalent stressors noted and, in most cases, were more prevalent in the downstream versus upstream segments of these two watersheds.

Habitat and hydrologic stressors by HGM class and plant community were approximately equivalent except for impoundments which (not unexpectedly) had much higher percentages of nearly all stressor categories versus other HGM types (Tables 12 and 13). This was no doubt due to the fact that 87% of these impoundment were of human versus beaver origin (Figure 3), and exhibited elevated levels of the associated human land use and development that often accompany such impoundments.

DISCUSSION

This study represents only the third¹ time in Ohio that a probabilistic regional wetland assessment has been completed (Mack and Micacchion 2006; Fennessy et al. 2007) and one of relatively few such studies nationally (e.g. Genet and Olsen 2008, Wardrop et al. 2007, Whigham et al. 2007). In many ways, this study can be considered an intensification of the Cuyahoga River wetland assessment performed by the Ohio Environmental Protection Agency in 2005 (Fennessy et al. 2007). Although Cuyahoga County wetlands were included in that study, they were relatively under-represented relative to the more abundant wetland resource in Geauga, Portage and Summit Counties (only 12 Cuyahoga County sites were sampled in the Cuyahoga survey). To the extent that wetlands located in the park system represent a large portion of the remaining wetland resource in the Cuyahoga County, this study also is the first county-wide evaluation of wetland condition for Cuyahoga County. This study also represents a new evaluation of the LDI and ORAM as assessment tools in an independent study with different investigators and data sets.

Results from this study corroborated several conclusions in the Cuyahoga wetland assessment and in other respects found very similar patterns of wetland condition. First, percentages of Category 1, 2 and 3 wetlands by number and acreage were very similar between the two studies (Table 15), indicating that despite a generally more developed landscape, condition of the wetland resource is more similar to the larger, multi-county Cuyahoga River watershed than different. Similarly, this study also found that a main effect of increasing disturbance and land use intensity was to reduce or completely lose the highest quality wetlands, while

proportions of poor to fair condition sites remained relatively constant (Figures 8 and 9).

Second, this study confirmed a major methodological conclusion of the Cuyahoga survey: ORAM continued to perform very well in its role of as Level 2 assessment tool. Other recently developed rapid assessment approaches have taken a multi-score sheet approach for dominant hydrogeomorphic (HGM) classes or other wetland types. For example, the California Rapid Assessment Method (CRAM) has unique questions and score sheets associated with each major HGM type (Collins et al. 2006). The ORAM specifically took a "single-score sheet" approach with precisely calibrated point totals such that all wetland types can score well or poorly on the same set of questions. This data set provided a second evaluation of this approach and the design of ORAM v. 5.0. No significant, or in most instances even observable, differences were observed when average ORAM scores by condition category for HGM class or plant community were compared (Tables 5a and 5b). Average scores for HGM class and plant community types were nearly identical to those obtained in the Cuyahoga survey.

Finally, this study also found the LDI to be a useful tool for integrating land use data into a single score. But as in the Cuyahoga survey, although LDI is a useful tool for drawing conclusions about a population of wetlands, it was a poor predictor of any particular wetland's condition.

Condition of Wetlands in Cleveland Metroparks

Approximately approximately one-third of wetlands (based on number) in the park system are in poor to fair condition and two-thirds are in good or better condition (Figure 6). By area, nearly 90% of wetlands are in good or better condition, with about 10% in poor to fair condition (Figure 7). Wetlands in good or better condition were not evenly distributed throughout the park district. The results from this study were compared to the results obtained by the State of Ohio's other probabilistic wetland assessments:

1 The Cuyahoga Valley National Park has initiated a probabilistic wetland assessment that is on-going. <http://science.nature.nps.gov/im/units/htln/wetlands.cfm>

one in the Cuyahoga River watershed (Fennessey et al. 2007b) and the other for urban wetlands in Franklin County, Ohio (Mack and Micacchion 2007; Gamble et al. 2007). Compared to the results from these other studies the overall "report card" for the wetlands of Cleveland Metroparks is generally a good one. Average ORAM scores for wetlands in Cleveland Metroparks were equivalent to "good" condition when compared to the state of Ohio's reference wetland data set and are better, on average, than those obtained in the Franklin County urban wetland study. This may be due to the fact that non-park wetlands (the majority of sites in the Franklin County survey) may be subject to more stressors than wetlands located entirely within a park system. Average condition in Cleveland Metroparks wetlands was somewhat lower than that observed in the Cuyahoga wetland survey, presumably because of the numerous high quality sites in rural Geauga and Portage counties assessed in the Ohio EPA Cuyahoga Watershed survey (Figure 20).

LDI as an Assessment Tool

Land use has been shown in previous studies to have an effect on wetland biologic communities, especially in the case of amphibians, with more urban or otherwise high intensity land uses within close proximity to a wetland having a negative affect (Porej et al. 2006; Houlihan and Findlay 2003; Knutson et al. 1999). Additionally, land use has also been shown to negatively affect other wetland associated taxa; including birds, mammals, and plants (Findlay and Houlihan 1997). Links have also been noted between land use and immediate water quality, primarily nutrient enrichment and sedimentation, wetland habitats (Houlihan and Findlay 2004; Crosbie and Chow-Fraser 1999). Similar results have been shown for streams and wetlands. In a study of stream health, Patty et al. (1997) showed that riparian grass buffers 6-18 m wide along a stream were efficient at removing nearly 100% of all water contaminants, leading to higher functioning streams. Wetlands surrounded by low intensity land-use in the 1 km radius area surrounding a site have been found to

be more ecologically intact than wetlands with higher intensity land-use (Brooks 2004). Assessing seven separate watersheds in Pennsylvania, Brooks (2004) evaluated wetland condition based on a continuum of human-disturbance and compared it to the land-use in the immediate 1 km area. They found that as land-use shifted from forest and wetland areas to agricultural and urban uses, wetland disturbance scores increased.

The LDI provides an integrated score summarizing land use intensity. It has been previously evaluated two times in Ohio (Mack 2006; Fennessey et al. 2007). Because Fennessey et al. (2007) found no difference in the use of coefficients from Florida and Minnesota, we only used coefficients from Minnesota (Brandt-Williams and Campbell 2006) in calculating the LDI. As in the other Ohio studies, the LDI was not good at assessing the condition of any particular wetland. But, at the population and watershed level, the LDI did provide a similar report card of wetland condition as the Level assessment.

The LDI was able to distinguish between 3 condition classes at 250, 500, 1000, 2000 and 4000 meter buffer distances and two classes at the 100 m buffer (Table 8). Percentages of wetlands in each condition class were most similar to results from the ORAM assessment of those same wetlands at the 2000 and 4000 meter buffers (Table 8). These results were different from the Cuyahoga survey (Fennessey et al. 2007) which found the best discrimination in the 100 m to 250 m range. The Cuyahoga survey interpreted the lack of discrimination at larger buffer distances as due to a "homogenization" of land uses above 500 m (i.e., every becomes medium). This trend was not observed here and may be due to the fact most of the wetlands in this study were located in heterogeneous urban landscapes rather than rural landscapes characteristic of much of Geauga and Portage Counties. But, the more straightforward explanation is that wetlands in this study were surrounded by parkland at shorter buffer distances and only at larger distances did land use

provide information useful in predicting condition.

Implications for Urban Wetland Preservation and Restoration

There is a considerable literature on the effects of fragmentation, patch size and park size on diversity and the long-term viability of species, communities or ecosystems (Barrera et al. 2007; Heergaard et al. 2007; Davis 2004; Meffe et al. 2002; Voller 1998). In wetlands, Knutson et al. (1999) (frogs) and Wettstein and Schmid (1999) (invertebrates) found diversity was negatively with fragmentation (see also Smiley and Allred 2008; McIntosh et al. 2006; Wettstein and Schmid 1999) communities which favors larger wetlands habitats. In general, bigger areas contiguous to other large areas or corridors are considered to be more sustainable and/or able to support higher diversity. Results on average condition of wetlands from this study confirms this general proposition. Average condition of wetlands in big-block parks was significantly other park configurations. In turn, average condition in big-long parks was significantly different than small-block and small-long wetlands (Figure 18). While "bigger is better" is a not unexpected result, the fact that the shape of the bigness (blocky versus long) is important is not as well appreciated. We found that perimeter to area ratio was a simple, effective measure of park size and configuration (Liu and Cameron 2001; Helzer and Jelinski 1999) that was significantly correlated with average condition (Figure 19). The converse of the literature and conclusions discussed above is that species diversity, habitats, ecosystems in urban contexts are *not* sustainable and fated to decline to low levels of condition and/or function. This is a common understanding with regards to urban wetlands when impacts to urban wetlands are discussed within the context of 401/404 permit programs (Mack, personal communication). The prior study of urban wetlands in Franklin County, Ohio (Mack and Micacchion 2007; Gamble et al. 2007) found that good to high condition and/or function wetlands can persist in urban landscapes.

Results from this study strongly confirm this conclusion. Even in very highly developed landscapes, Category 2 and 3 wetlands can persist if they are locally buffered within 100 to 250 meters (Figure 15). And, even in relatively small urban parks, good to high condition wetlands can persist (Figure 18) for long periods of time (decades or centuries). Most of the recent additions to Cleveland Metroparks have been in densely developed urban contexts where the Metroparks has taken over parkland previously owned for many decades by the City of Cleveland (Brookside, Garfield Park, Euclid Creek), private industry (Ohio & Erie Canal) or other cities or universities (Big Creek, West Creek), and most of these parks are small (less than 500 acres).

Overall, results of this study found that average wetland condition in big-block parks was better than big-long parks which in turn was greater than small-block/small-long parks in terms of numbers and acreage of high quality wetlands. If land use intensity was high or very high with 250 meters of the wetland, very few high quality and only a few good quality wetlands persisted in this landscape. *But, when land use intensity was very high within 2000-4000 m of the wetland, but low closer to the wetland, many good and some high quality wetlands could persist.* Data collected here confirms that large blocks of land (>400 ha) have higher proportions of high quality wetlands, *but also confirm that a significant wetland resource can persist in smaller urban wildlands.*

Conclusions and Recommendations

Several conclusions and recommendations can be drawn from this study.

1. Approximately 30% of wetlands in the Cleveland Metroparks are in poor to fair condition. On average, these wetlands tended to be small and represent only 10% of the wetland acreage in the park. This represents a significant percentage of park's wetland resource and justifies park-wide wetland rehabilitation program. Small wetlands are also the type of

wetland that can be habitat for many of conservative amphibian species (ambystomid salamanders, wood frogs). Rehabilitation of these small wetlands could significantly improve overall population health for small wetland-"vernal pool" species (cf. [Semlitsch and Bodie 2001](#)).

2. Given the amount of fragmentation in the landscape surrounding the park, the Cleveland Metroparks should avoid causing additional fragmentation itself by the construction of roads, trails or other recreational facilities in high quality wetlands or in big- or long-blocks of parkland, or portions thereof, that are presently lacking such potentially fragmenting features.

3. This study confirms decisions made to acquire smaller parks in the urban core like Ohio & Erie Canal and West Creek. Future park acquisitions should certainly focus on preserving big- and long-blocks of land (e.g. expansions in the Rising Valley area of the Upper East Branch of the Rocky River) wherever possible. However, the park should also pursue smaller acquisitions of urban wildland within Cleveland and its suburbs since functioning and often good to high quality remnant habitats can persist in this context even if located in small- or long-blocks.

4. This study represents a snap shot of wetland condition in Cleveland Metroparks as of 2005-2006. However, based on this assessment, we are not able to determine if the condition of our wetland resource is stable, decreasing or increasing. Being able to say something about this is critical given the cumulative effects of changes in urbanization, invasive plants, deer browse, climate change and other factors. In order to begin to track trends in resource condition, Cleveland Metroparks will be implementing a Long-term Terrestrial and Aquatic Resource Monitoring and Assessment Program ([Mack 2008](#)).

5. Although the design used in this study obtained a random sample of wetlands in

Cleveland Metroparks, it has some limitations over other sample frames of the wetland population in the park. The current design entailed navigating to a randomly selected point with the park system. If a wetland was not present at the point, the design required the field crew to find the nearest wetland and sample it. In effect, every point yields a sampleable wetland. Using this data, no data is collected for determining losses in wetlands over time. In contrast, using a sample frame based on map of wetlands present in a given year (e.g. the National Wetland Inventory or NWI maps), would allow estimates of wetland losses to also be made. If the field crew navigated to a mapped wetland and it was no longer present to human or climatic factors, estimates of wetland loss can be obtained. For example, in [Mack and Micacchion \(2007\)](#), NWI maps of wetlands circa 1980 were used. This allowed that study to conclude that nearly 60% of mapped wetlands had been converted or destroyed since 1980.

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Table 1. Summary of reservation characteristics in Cleveland Metroparks.

Reservation	Size (ac)	County	Watershed (Subwatershed)	Surrounding Land	Size/Shape	P:A Ratio	Average ORAM
Bedford	2,206	Cuyahoga	Cuyahoga River (Tinkers Creek)	urban/suburban	big block	0.0014	51
Big Creek	781	Cuyahoga	Cuyahoga River (Big Creek), Rocky River (Abram Creek, Baldiwin Creek)	urban/suburban	small long	0.0038 (north) 0.0036 (Lake-to-Lake)	45
Bradley Woods	795	Cuyahoga, Lorain	Lake Erie (Cahoon Creek)	suburban	small block	0.0015	49
Brecksville	3,494	Cuyahoga	Cuyahoga River (Chippewa Creek)	suburban	big block	.0014 (main) 0.0065 (parkway)	51
Brookside	145	Cuyahoga	Cuyahoga River (Big Creek)	urban	small block	0.0035	26
Euclid Creek	345	Cuyahoga	Euclid Creek	urban	small long	0.0025	51
Garfield Park	213	Cuyahoga	Cuyahoga River (Mill Creek)	urban	small block	0.0033	51
Hinckley	2,682	Medina, Summit	Rocky River (East Branch)	rural	big block	0.0007	59
Huntington	103	Cuyahoga	Lake Erie (Porter Creek)	suburban	small block	0.0020	40
Mill Stream Run	3,189	Cuyahoga	Rocky River (East Branch)	suburban	big long	0.0013	48
North Chagrin	2,140	Cuyahoga, Lake	Chagrin River	suburban	big block	0.0011	55
Ohio & Erie Canal	312	Cuyahoga	Cuyahoga River	urban	small long	0.0048	40
Rocky River	2,572	Cuyahoga	Rocky River (Mainstem, East and West Branches)	urban/suburban	big long	0.0015	52
South Chagrin	1,521	Cuyahoga	Chagrin River (Mainstem, Aurora Branch)	suburban	big block	0.0024 (north) 0.0040 (parkway) 0.0012 (main)	53
Washington	59	Cuyahoga	Cuyahoga River	urban	small block	0.0028	29
West Creek	278	Cuyahoga	Cuyahoga River (West Creek)	urban	small block	0.0063	44

Table 2. List of land use categories and associated LDI Minnesota coefficients.

Land Use	Description	Coefficient
deciduous forest	areas dominated by trees where 75% or more of the tree species shed foliage simultaneously during season change	0.00
evergreen forest	areas characterized by trees where 75% or more of the tree species maintain their leaves all year, canopy is never without green foliage	0.00
woody wetland	areas characterized by wetlands dominated by woody vegetation	0.00
herbaceous wetland	areas characterized by wetlands dominated by herbaceous vegetation	0.00
open water	areas of open water, generally with 25% or greater cover of water	0.00
pasture	areas of grasses, legumes, or grass-legume mixtures planted for livestock grazing or the production of seed or hay crops	1.08
crop	areas used for the production of crops (corn, soybeans, vegetables, tobacco, cotton)	3.247
urban/recreational grasses	vegetation planted in developed settings for recreation, erosion control, or aesthetic purposes	3.566
residential	includes both heavily built up urban centers (high intensity residential) and areas with a mixture of constructed materials and vegetation (low intensity residential)	4.04
commercial/bare ground	includes infrastructure and all highways and all developed areas not classified as residential and bare ground lacking any vegetative cover	4.65

Table 3. Mean, median and total area of wetlands assessed by by condition category for all of Cleveland Metroparks. Means without shared letters significantly different ($p < 0.05$) ($df = 278$, $F = 14.72$, $p < 0.001$)

Condition Category	mean (st dev) (acres)	median (acres)	total (acres)	% of total acres	N
Cat 1	0.4(0.5)a	0.2	17.7	2.5%	46
mod Cat 2	1.0(1.4)a	0.5	62.7	9.0%	63
Cat 2	2.4(5.1)a	0.6	315.6	45.2%	131
Cat 3	7.8(11.9)b	3.0	302.3	43.3%	39

Table 4. Mean, median and total acres of wetlands assessed by watershed region and condition category.

Region	Condition Category	mean (st dev) (acres)	median (acres)	total (acres)	% total acres	N
Mid-Lower Rocky	Cat 1	0.4(0.5)	0.1	3.0	13%	8
	mod 2	1.2(1.9)	0.4	18.7	23%	15
	Cat 2	3.2(5.9)	0.7	109.8	53%	34
	Cat 3	7.8(7.9)	4.9	54.7	11%	7
Upper Rocky	Cat 1	0.2(0.0)	0.2	0.2	7%	1
	mod 2	0.4(0.0)	0.4	0.4	7%	1
	Cat 2	0.5(0.3)	0.4	3.3	46%	7
	Cat 3	2.5(4.0)	0.6	14.8	40%	6
Lower Cuyahoga	Cat 1	0.4(0.4)	0.2	8.1	33%	21
	mod 2	1.2(1.5)	0.7	25.8	33%	21
	Cat 2	1.3(1.7)	0.7	26.1	31%	20
	Cat 3	0.4(0.4)	0.4	0.8	3%	2
Middle Cuyahoga	Cat 1	0.7(0.9)	0.5	5.1	13%	7
	mod 2	0.8(0.8)	0.5	10.0	23%	12
	Cat 2	4.9(8.7)	0.3	121.4	47%	25
	Cat 3	9.4(15.4)	4.5	84.3	17%	9
Mid-Lower Chagrin	Cat 1	0.1(0.0)	0.1	0.1	3%	1
	mod 2	0.1(0.0)	0.1	0.3	9%	3
	Cat 2	1.5(1.5)	1.1	35.2	70%	23
	Cat 3	12.9(11.9)	7.6	77.1	18%	6
Upper Chagrin	Cat 1	0.1(0.0)	0.1	0.2	17%	4
	mod 2	1.4(2.2)	0.3	5.6	17%	4
	Cat 2	0.9(0.8)	0.5	6.8	33%	8
	Cat 3	3.1(5.3)	1.4	24.7	33%	8

Table 5a. Average (standard deviation) ORAM scores by four HGM classes for four wetland condition categories.

	ANOVA results	depression	riverine	impoundment	slope
All sites	df=276, F=3.61, p=0.014	47.5(5.0)	54.6(13.4)	48.3(13.3)	50.7(14.7)
Category 1	df=45, F=1.49, p=0.231	28.1(5.1)	31.6(1.6)	28.4(3.1)	23.8(10.8)
Modified 2	df=62, F=0.64, p=0.591	40.2(3.1)	40.0(3.6)	41.7(1.8)	41.5(3.0)
Category 2	df=128, F=2.35, p=0.076	53.5(5.5)	56.7(4.9)	55.7(4.4)	53.9(6.7)
Category 3	df=38, F=0.27, p=0.848	71.4(5.8)	70.0(5.4)	72.5(2.1)	69.9(4.5)

Table 5b. Average (standard deviation) ORAM scores by five plant community classes for four wetland condition categories.

	ANOVA results	forest seep	marsh	shrub swamp	swamp forest	wet meadow
All sites	df=276, F=5.54, p=0.000	52.7(10.8)	45.9(14.9)	52.6(14.4)	52.9(12.6)	43.2(12.9)
Category 1	df=45, F=0.98, p=0.430	33.8(1.1)	27.5(5.9)	29.5(0.0)	30.8(1.9)	28.2(3.6)
Modified 2	df=62, F=0.14, p=0.968	40.1(3.2)	40.1(3.2)	40.3(2.9)	40.5(3.1)	41.1(3.5)
Category 2	df=128, F=2.33, p=0.060	53.7(5.3)	56.2(5.1)	52.0(6.2)	53.2(5.2)	55.1(6.2)
Category 3	df=38, F=1.22, p=0.318	69.8(4.5)	69.1(3.4)	74.1(7.1)	71.1(5.7)	---

Table 6. Descriptive statistics for LDI scores (Minnesota coefficients) at different buffer distances.

	100 m	250 m	500 m	1000m	2000m	4000 m
mean	58.8	77.7	98.1	138.8	183.0	229.5
st dev	109.7	106.2	106.5	107.7	109.1	98.4
minimum	0.0	0.0	0.0	0.0	22.8	63.2
1st quartile	0.0	0.0	16.0	42.2	73.4	137.0
median	0.0	32.7	61.4	113.7	175.7	251.5
3rd quartile	75.8	123.5	155.0	224.0	280.4	312.9
maximum	185.5	308.1	356.5	438.0	422.0	385.0
N	270.0	270.0	270.0	270.0	270.0	270.0

Table 7. Average (standard deviation) LDI scores by reservation for different buffer distances.

	100 m	250 m	500 m	1000 m	2000 m	4000 m
Bedford	4(11)	26(43)	64(59)	115(56)	171(45)	240(36)
Big Creek	95(95)	129(102)	184(104)	234(96)	284(74)	314(41)
Bradley Woods	43(78)	60(84)	85(74)	160(45)	247(16)	313(6)
Brecksville	26(73)	25(51)	32(49)	48(47)	55(37)	91(26)
Brookside	239(138)	272(54)	310(16)	341(27)	359(4)	380(2)
Euclid Creek	82(118)	71(89)	112(99)	206(69)	275(36)	336(6)
Garfield Park	121(139)	148(109)	166(81)	277(27)	347(5)	359(4)
Hinckley	52(76)	61(60)	54(33)	56(33)	65(21)	92(8)
Huntington	404(0)	401(5)	359(50)	301(41)	227(17)	210(9)
Mill Stream Run	53(95)	67(86)	79(89)	121(73)	178(51)	239(26)
North Chagrin	17(57)	17(38)	22(31)	35(35)	76(36)	143(15)
Ohio & Erie Canal	129(130)	177(111)	210(98)	268(56)	327(12)	349(19)
Rocky River	24(34)	68(59)	129(73)	195(68)	255(56)	317(33)
South Chagrin	31(93)	33(79)	28(49)	37(52)	67(62)	114(57)
Washington Park	407(2)	423(0)	432(0)	437(1)	422(1)	385(0)
West Creek	27(43)	76(67)	119(72)	207(44)	294(7)	312(9)

Table 8. Average (standard deviation) LDI scores by antidegradation categories for different buffer distances. Antidegradation categories defined by ORAM scores as follows: Category 1 = 0-34.9, Modified Category 2 = 35.0-44.9, Category 2 = 45.0-64.9, Category 3 = 65.0-100. Means without shared letters significantly different ($p < 0.05$).

	100 m	250 m	500 m	1000 m	2000 m	4000 m
Category 1	147(157)a	159(145)a	172(144)a	199(131)a	237(121)a	270(104)a
Modified Cat 2	69(117)b	93(113)b	116(107)b	161(100)ab	208(96)ab	156(82)ab
Category 2	37(82)b	55(82)bc	80(87)bc	125(98)bc	172(103)bc	219(95)bc
Category 3	22(47)b	37(55)c	54(64)c	82(82)c	120(97)c	177(100)c
F statistic	14.34	14.72	12.48	10.67	10.52	8.72
p value	0.000	0.000	0.000	0.000	0.000	0.000

Table 9. Average (standard deviation) LDI scores for different buffer distances by the 4 major HGM classes.

	100 m	250 m	500 m	1000 m	2000 m	4000 m
depression	56.2(109.0)	78.2(108.1)	101.8(110.6)	145.8(108.7)	190.8(105.8)	233.7(95.0)
impoundment	41.3(63.2)	54.8(59.6)	74.5(77.5)	108.7(93.5)	162.5(113.7)	223.7(95.0)
slope	86.5(132.9)	90.3(123.0)	106.1(112.3)	136.4(115.7)	168.4(124.5)	213.4(115.7)
riverine	69.7(120.1)	83.1(112.5)	100.2(104.8)	132.7(107.4)	175.2(110.6)	226.0(103.3)
F statistic	0.93	0.59	0.57	1.03	0.84	0.37
p value	0.426	0.623	0.638	0.381	0.471	0.777

Table 10. Percentage of wetlands in each condition class that were surrounded by low, medium, or high intensity land uses by increasing buffer distances around the wetland.

	Low Excellent Condition Category 3	Medium Good Condition Category 2	High Fair Condition mod Category 2	Very High Poor Condition Category 1
100 m	80.7	8.5	2.6	8.1
250 m	60.7	21.5	9.6	8.1
500 m	60.7	21.5	9.6	8.1
1000 m	45.9	23.0	22.2	8.9
2000 m	30.4	25.2	27.0	17.4
4000 m	16.3	20.7	32.6	30.4

Table 11. Average (standard deviation) number of hydrologic (Metric 3e), habitat (Metric 4c), or combined stressors by wetland condition category.

	Metric 3e	Metric 4c	Metric 3e+4c
Category 1	1.8(2.4)	1.2(1.4)	3.0(3.0)
Modified 2	1.0(1.0)	0.7(1.0)	1.6(1.6)
Category 2	0.8(1.2)	0.5(1.0)	1.3(1.6)
Category 3	0.8(1.1)	0.5(1.1)	1.2(1.8)
df	277	278	277
F statistic	5.48	5.72	9.23
p value	0.001	0.001	0.000

Table 12. Percentage of Metric 3e (hydrologic alteration) stressors by condition category, watershed region, HGM class, and plant community.

Condition Category	N	ditching	tiling	dikes	weirs	stormwater input	point source	filling	roads	dredging	other
Category 1	46	15.2%	17.4%	17.4%	8.7%	19.6%	6.5%	21.7%	50.0%	6.5%	13.0%
modified 2	63	11.1%	12.7%	3.2%	1.6%	9.5%	0.0%	7.9%	39.7%	0.0%	9.5%
Category 2	131	9.9%	13.7%	6.1%	0.8%	13.0%	0.8%	1.5%	33.6%	0.8%	3.8%
Category 3	38	5.1%	10.3%	10.3%	0.0%	17.9%	0.0%	5.1%	35.9%	0.0%	0.0%
Region											
Mid-Lower Rocky	64	15.6%	20.3%	17.2%	7.8%	21.9%	6.3%	7.8%	48.4%	3.2%	14.3%
Upper Rocky	15	6.7%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	33.3%	0.0%	0.0%
Lower Cuyahoga	64	0.0%	3.1%	6.3%	1.6%	4.7%	0.0%	10.9%	35.9%	1.6%	7.8%
Middle Cuyahoga	53	17.0%	11.3%	1.9%	0.0%	22.6%	0.0%	7.5%	32.1%	0.0%	1.9%
Mid-Lower Chagrin	33	12.1%	33.3%	12.1%	0.0%	18.2%	0.0%	3.0%	39.4%	3.0%	3.0%
Upper Chagrin	25	4.0%	8.0%	8.0%	0.0%	8.0%	0.0%	0.0%	40.0%	0.0%	4.0%
HGM Class											
depression	175	5.7%	8.0%	3.4%	0.0%	6.9%	0.0%	4.6%	41.1%	0.6%	6.3%
riverine	49	10.0%	18.0%	14.0%	0.0%	20.0%	2.0%	8.0%	34.0%	0.0%	2.0%
impoundment	29	37.9%	41.4%	31.0%	20.7%	48.3%	10.3%	17.2%	34.5%	10.3%	17.2%
slope	24	8.3%	12.5%	0.0%	0.0%	12.5%	0.0%	8.3%	29.2%	0.0%	0.0%
Plant Community											
forest seep	39	5.1%	7.7%	0.0%	0.0%	15.4%	0.0%	5.1%	33.3%	0.0%	2.6%
marsh	103	15.5%	21.4%	19.4%	5.8%	20.4%	3.9%	8.7%	36.9%	3.9%	11.7%
shrub swamp	26	7.7%	19.2%	0.0%	0.0%	15.4%	0.0%	0.0%	53.8%	0.0%	0.0%
swamp forest	77	7.7%	9.0%	2.6%	0.0%	7.7%	0.0%	6.4%	37.2%	0.0%	3.9%
wet meadow	32	6.3%	3.1%	0.0%	0.0%	6.3%	0.0%	9.4%	37.5%	0.0%	3.1%

Table 13. Percentage of Metric 4c (habitat alteration) stressors by condition category, watershed region, HGM class, and plant community.

Condition Category	N	mowing	grazing	clear cutting	select cutting	woody debris removal	sedimentation	toxic pollut.	shrub removal	aq bed removal	farming	nutrient enrichment	dredging
Category 1	46	39.1%	2.2%	0.0%	8.7%	13.0%	19.6%	13.0%	0.0%	4.3%	2.2%	21.7%	0.0%
modified 2	63	27.0%	0.0%	1.6%	4.8%	1.6%	11.1%	6.3%	0.0%	0.0%	4.8%	11.1%	0.0%
Category 2	131	13.7%	0.8%	1.5%	9.9%	3.1%	9.2%	3.1%	0.0%	0.8%	2.3%	3.8%	0.0%
Category 3	39	10.3%	0.0%	0.0%	5.1%	2.6%	23.1%	2.6%	0.0%	5.1%	0.0%	5.1%	0.0%
Region													
Mid-Lower Rocky	64	23.4%	1.6%	0.0%	7.8%	1.6%	32.8%	9.4%	0.0%	4.7%	1.6%	15.6%	0.0%
Upper Rocky	15	6.7%	6.7%	0.0%	0.0%	0.0%	6.7%	6.7%	0.0%	0.0%	6.7%	6.7%	0.0%
Lower Cuyahoga	64	21.9%	0.0%	0.0%	4.7%	4.7%	1.6%	7.8%	0.0%	0.0%	1.6%	7.8%	0.0%
Middle Cuyahoga	53	15.1%	0.0%	5.7%	11.3%	7.5%	5.7%	0.0%	0.0%	0.0%	0.0%	1.9%	0.0%
Mid-Lower Chagrin	33	18.2%	0.0%	0.0%	15.2%	6.1%	15.2%	3.0%	0.0%	6.1%	0.0%	9.1%	0.0%
Upper Chagrin	25	32.0%	0.0%	0.0%	8.0%	4.0%	20.0%	0.0%	0.0%	0.0%	4.0%	12.0%	0.0%
HGM Class													
depression	175	20.0%	0.0%	0.6%	6.9%	4.6%	13.7%	8.0%	0.0%	0.0%	4.0%	9.7%	0.0%
riverine	50	14.0%	0.0%	2.0%	6.0%	2.0%	12.0%	2.0%	0.0%	2.0%	0.0%	2.0%	0.0%
impoundment	29	34.5%	3.4%	0.0%	13.8%	10.3%	24.1%	0.0%	0.0%	13.8%	0.0%	17.2%	0.0%
slope	24	16.7%	4.2%	4.2%	8.3%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	4.2%	0.0%
Plant Community													
forest seep	39	12.8%	2.6%	2.6%	5.1%	2.6%	5.1%	0.0%	0.0%	0.0%	0.0%	2.6%	0.0%
marsh	103	27.2%	1.0%	1.0%	8.7%	7.8%	14.6%	4.9%	0.0%	4.9%	1.0%	11.7%	0.0%
shrub swamp	26	30.8%	0.0%	0.0%	7.7%	3.8%	7.7%	0.0%	0.0%	0.0%	0.0%	3.8%	0.0%
swamp forest	78	9.0%	0.0%	0.0%	7.7%	1.3%	19.2%	10.3%	0.0%	0.0%	5.1%	10.3%	0.0%
wet meadow	32	25.0%	0.0%	3.1%	6.3%	3.1%	9.4%	6.3%	0.0%	0.0%	6.3%	6.3%	0.0%

Table 14. Average LDI score (standard deviation) for different buffer distances and average ORAM score (standard deviation) in Hinckley Reservation (Medina County) vs. all other reservations (in Cuyahoga County).

	All Other Reservations	Hinckley Reservation
100 m	62.6(113.1)	52.0(76.4)
250 m	81.57(109.6)	60.6(59.5)
500 m	105.4(109.4)	54.1(32.9)
1000 m	147.9(108.6)	56.1(33.0)
2000 m	193.9(108.6)	64.7(21.2)
4000 m	241.2(95.4)	91.9(7.7)
ORAM Score	48.4(13.8)	59.4(13.9)

Table 15. Comparison of results of Cleveland Metroparks and Cuyahoga wetland survey (Fennessy et al. 2007).

	Percentage of Wetlands		Acreage of Wetlands	
	Cuyahoga Survey	CM Survey	Cuyahoga Survey	CM Survey
Category 1	9.1%	16.5%	3.0%	2.5%
Modified Category 2	13.2%	22.6%	6.1%	9.0%
Category 2	51.0%	47.0%	35.2%	45.2%
Category 3	26.7%	14.0%	55.7%	43.3%

Table 16. Average (standard deviation) LDI scores by antidegradation categories for different buffer distances. Antidegradation categories defined by ORAM scores as follows: Category 1 = 0-34.9, Modified Category 2 = 35.0-44.9, Category 2 = 45.0-64.9, Category 3 = 65.0-100. Means without shared letters significantly different ($p < 0.05$).

	ORAM	100 m	250 m	500 m	1000 m	2000 m	4000 m
poor	16.4	7.9	7.9	7.9	8.5	29.3	15.7
fair	22.5	2.5	9.3	9.3	21.4	24.3	20.0
good	46.7	8.2	20.7	20.7	22.1	26.1	31.4
excellent	13.9	77.9	58.8	58.6	44.3	16.8	29.3

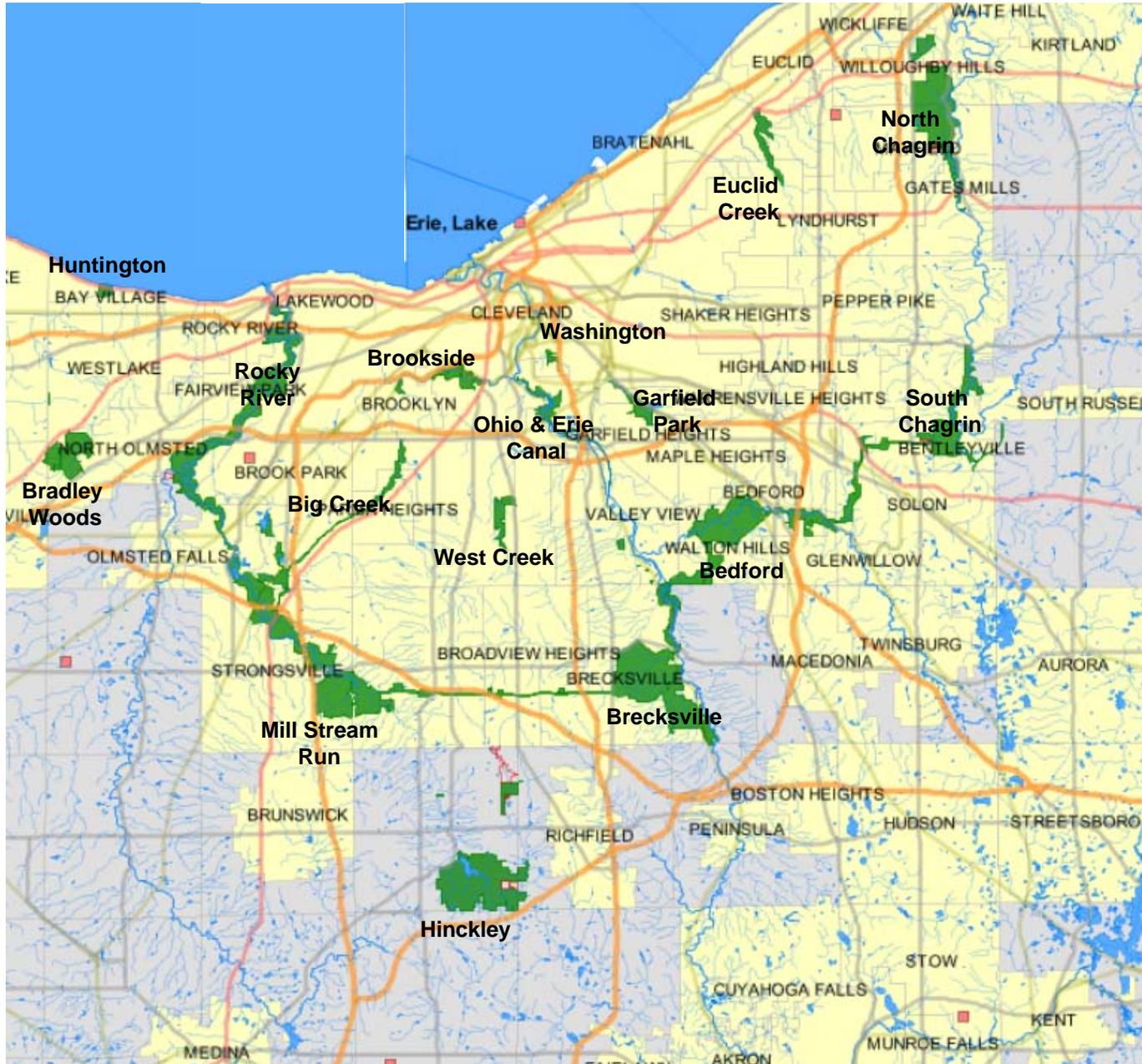


Figure 1. Cleveland Metroparks Reservations.

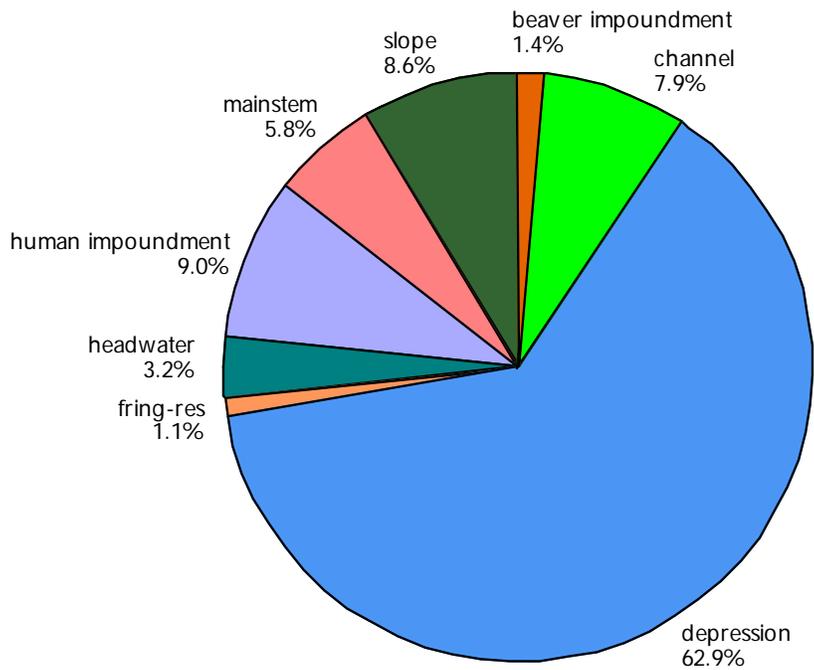


Figure 2. The distribution of wetlands over the eight HGM classes.

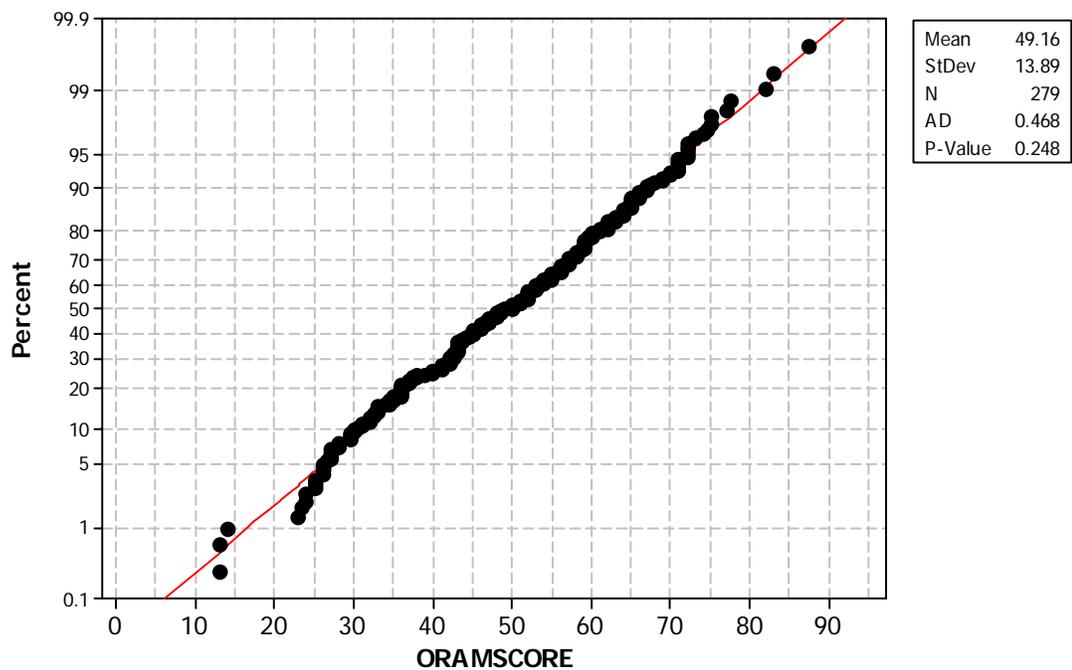


Figure 3. Probability plot and Anderson-Darling Normality Test.

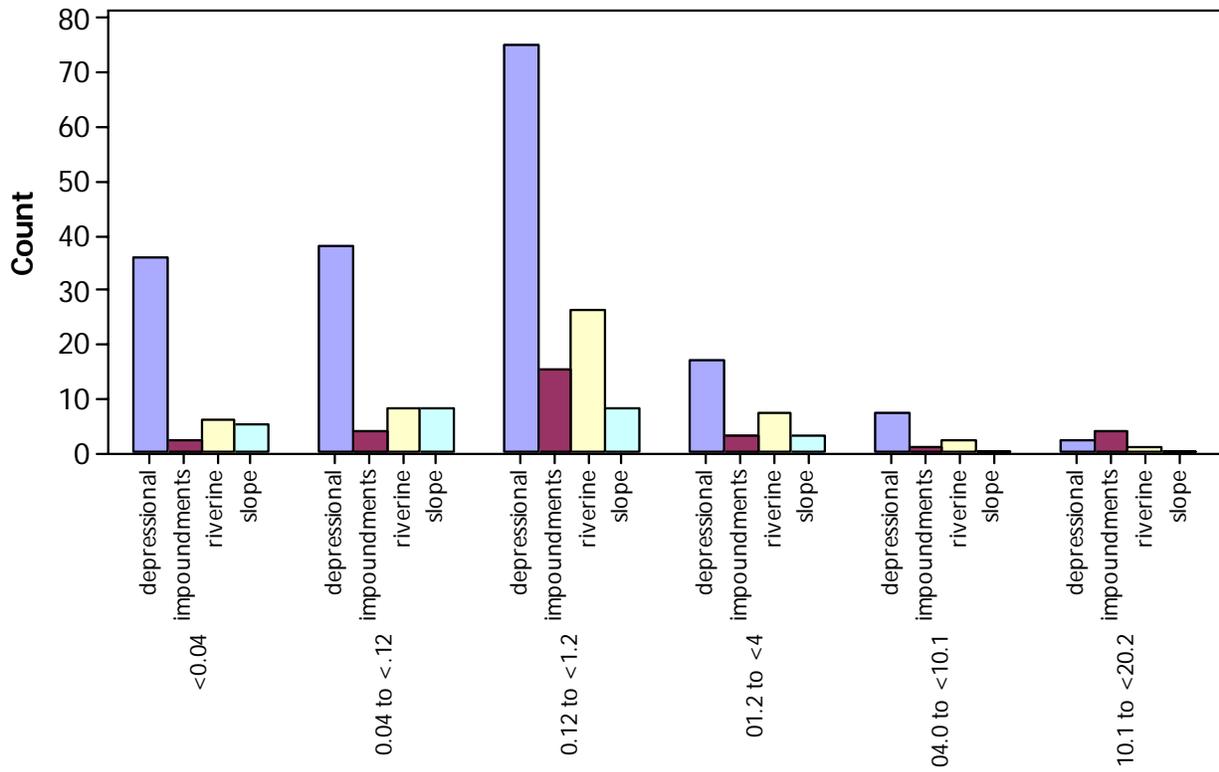


Figure 4. The size distribution of wetlands within the major HGM classes.

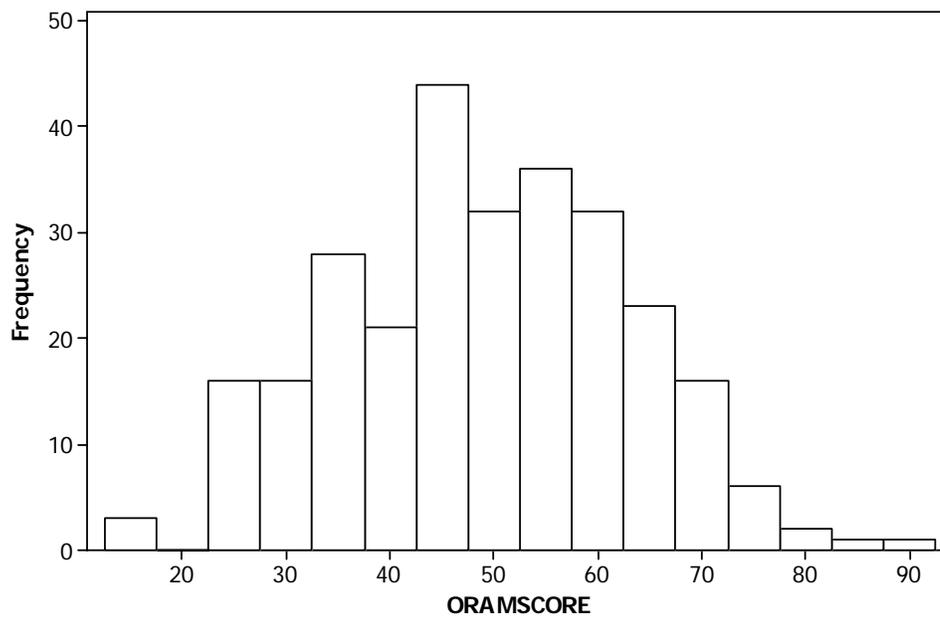


Figure 5. Frequency histogram of ORAM scores.

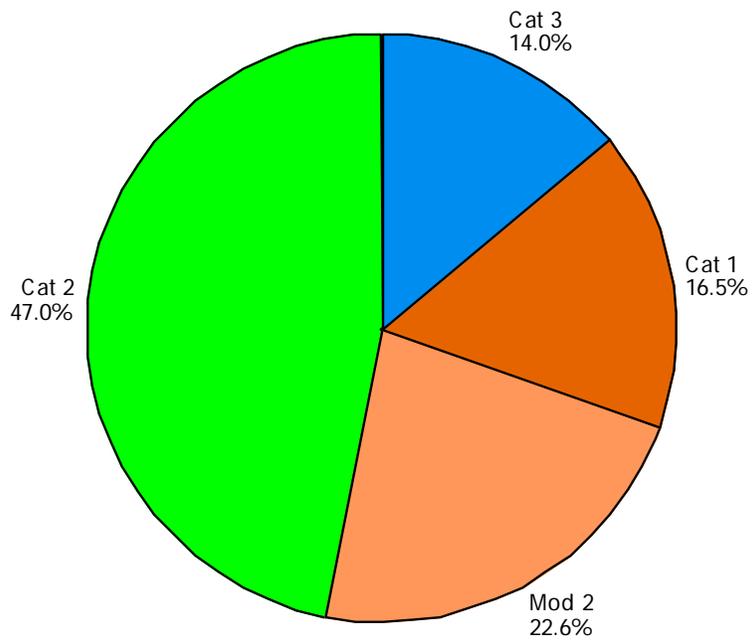


Figure 6. The percentage of individual wetlands by Ohio's antidegradation condition classes.

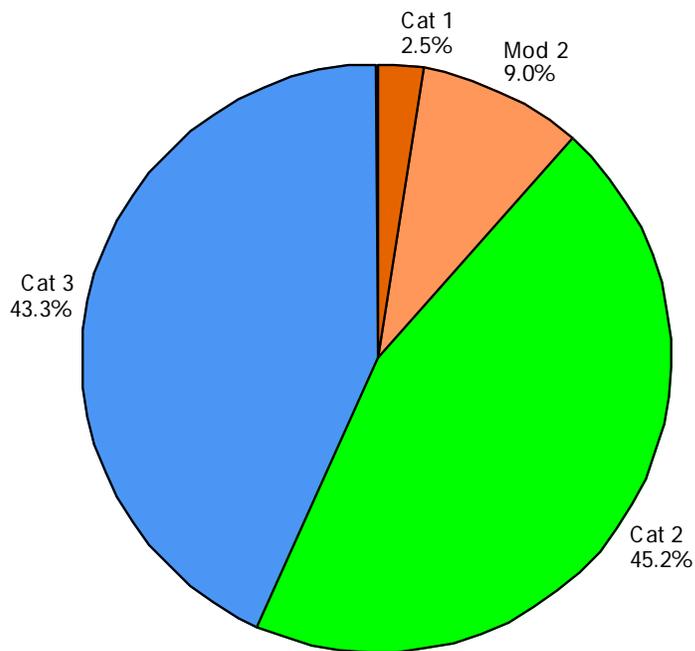


Figure 7. The percentage of wetland acres by Ohio's antidegradation condition classes.

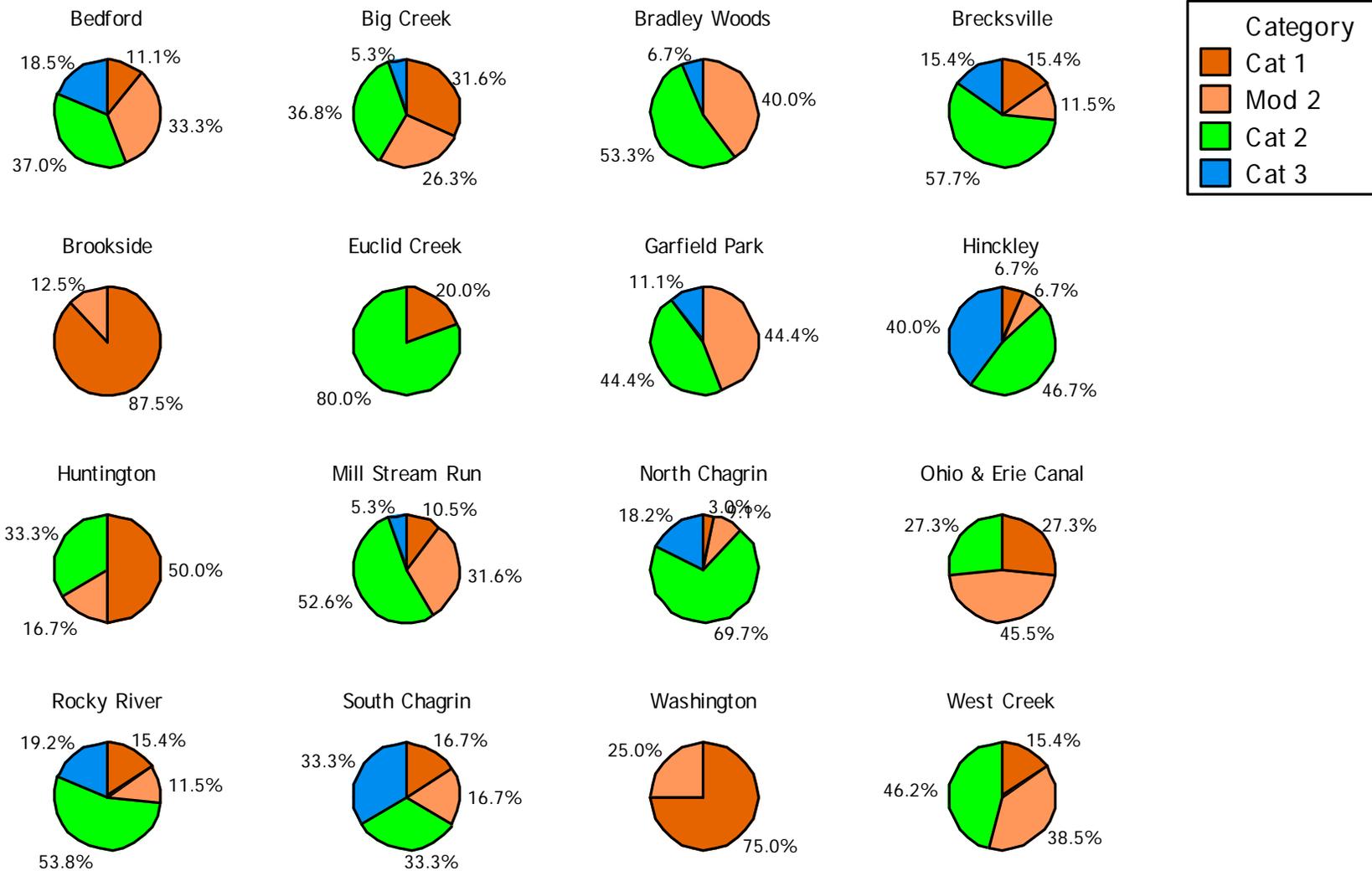


Figure 8. The percentage of individual wetlands in Ohio's antidegradation classes by Cleveland Metroparks reservations.

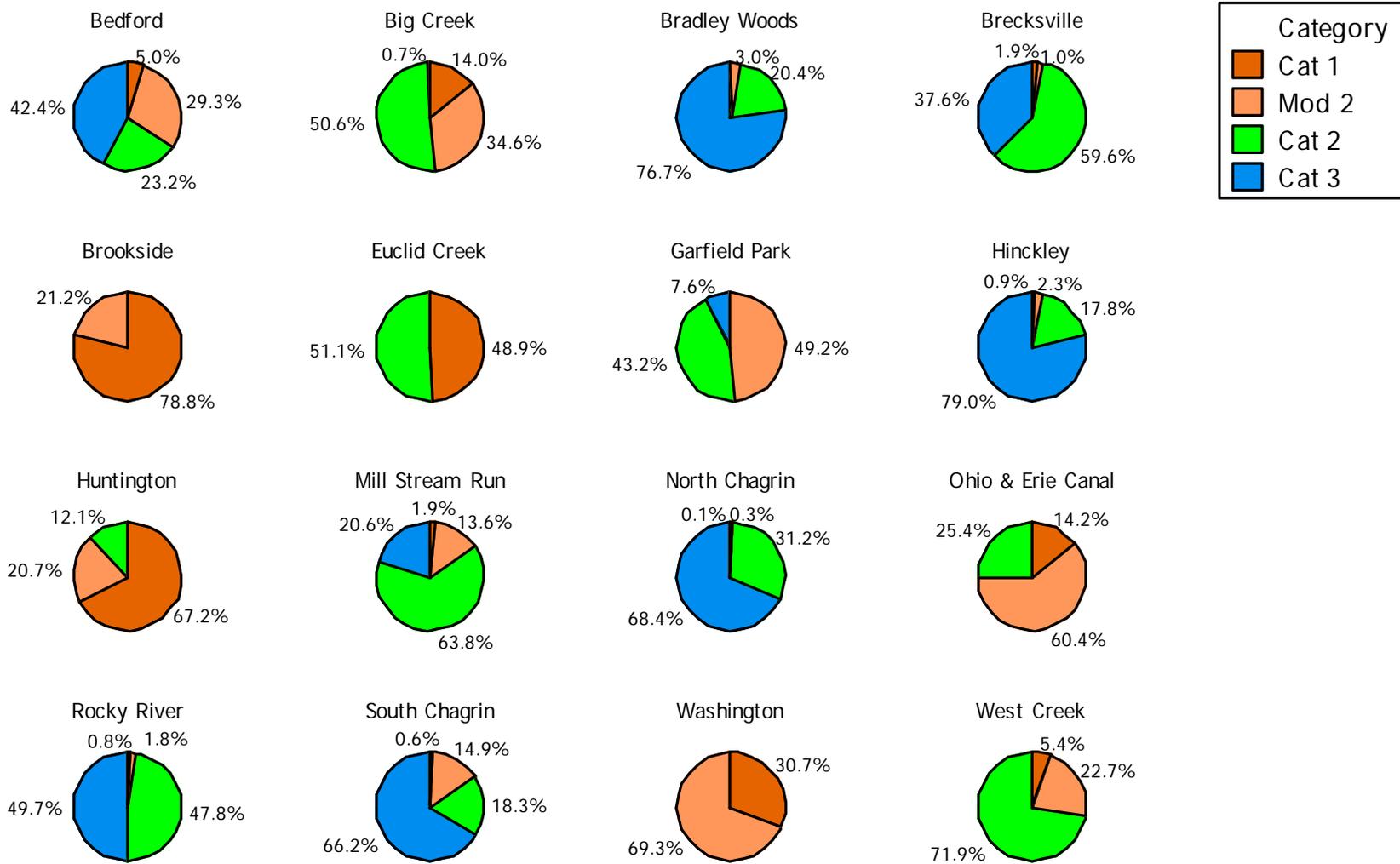


Figure 9. The percentage of wetland acreage in Ohio's antidegradation classes by Cleveland Metroparks reservations.

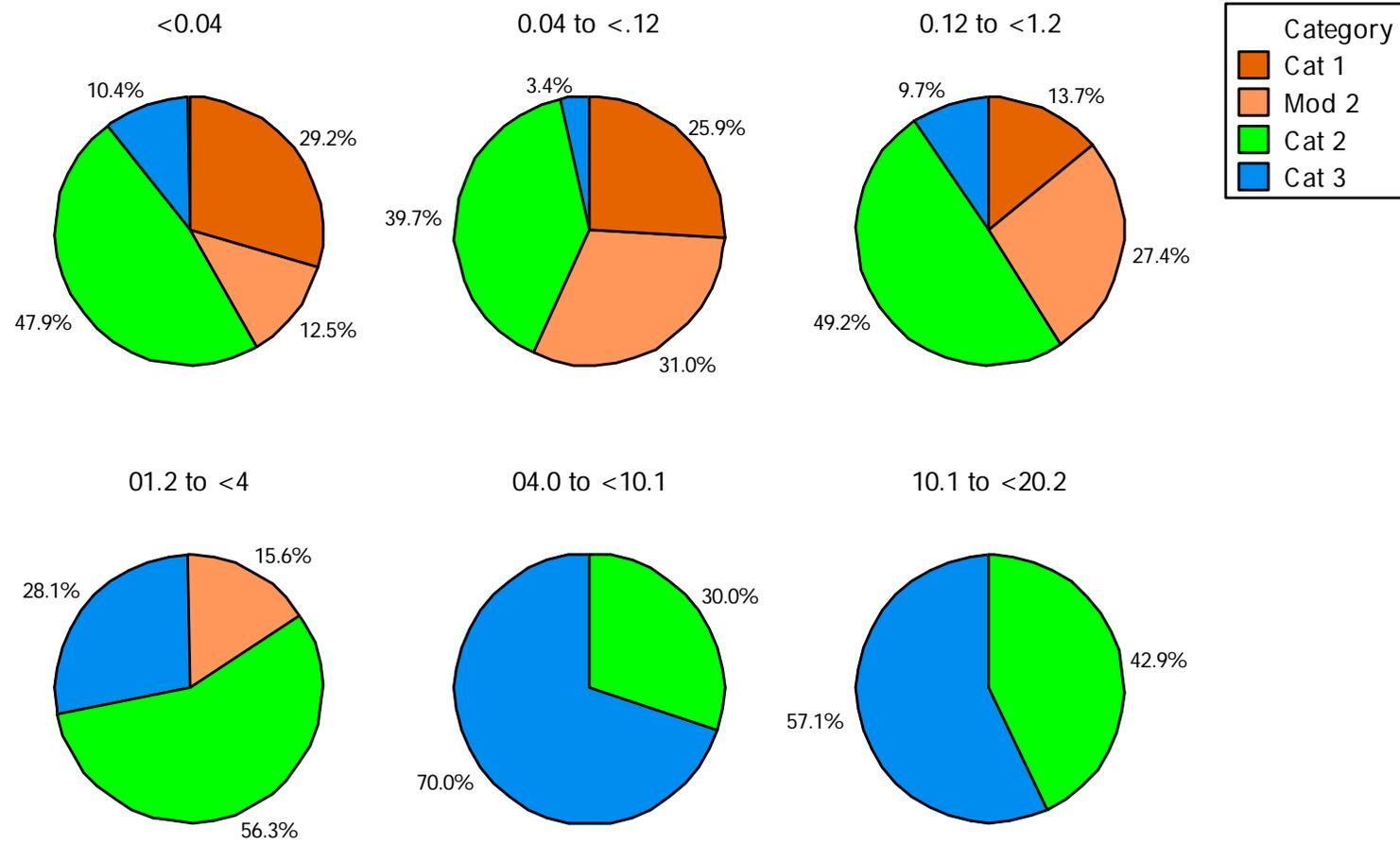


Figure 10. The percentage of wetlands by Ohio's antidegradation categories by size classes (hectares).

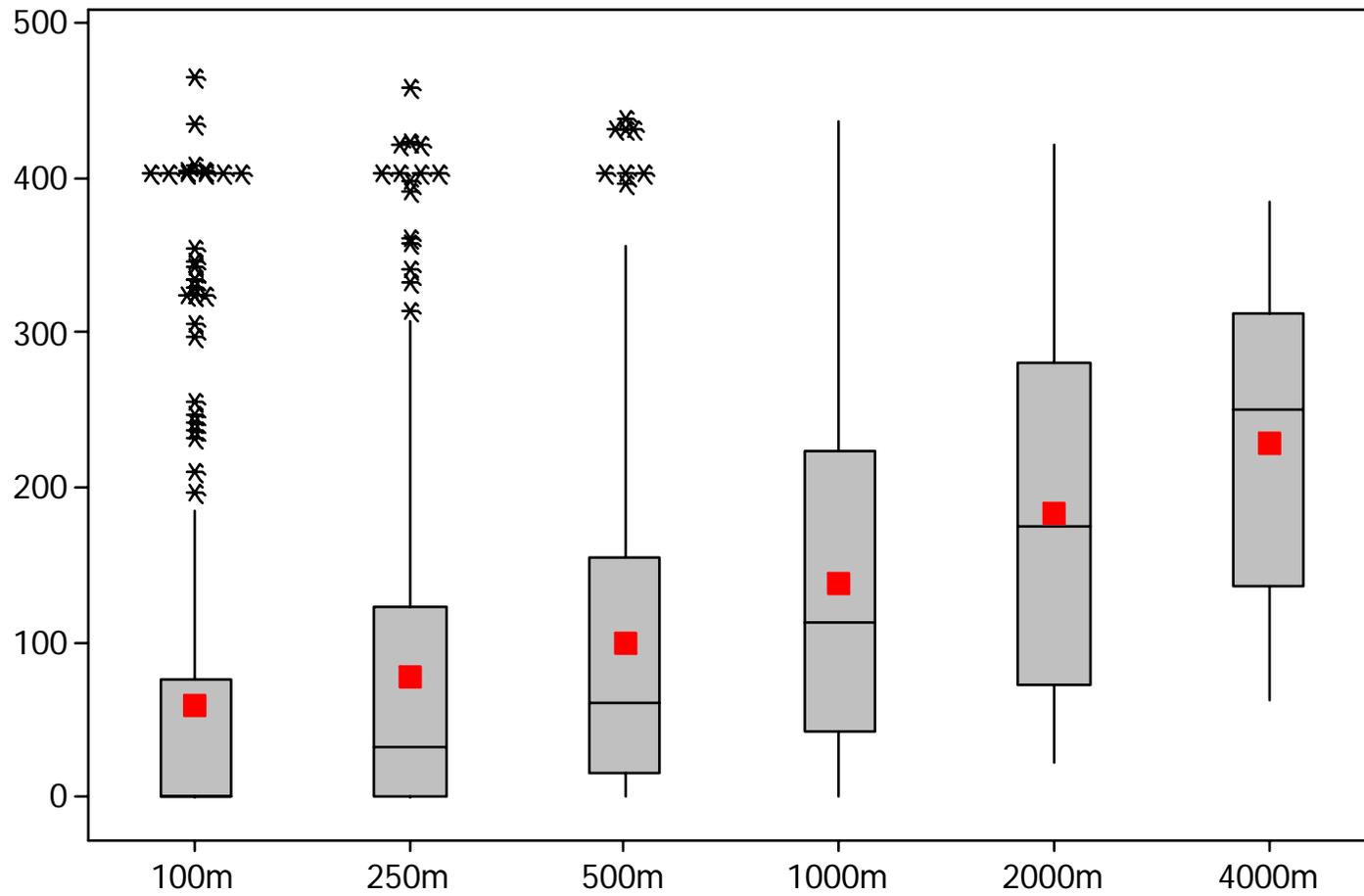


Figure 11. Box and whisker plot of LDI scores for each buffer distance.

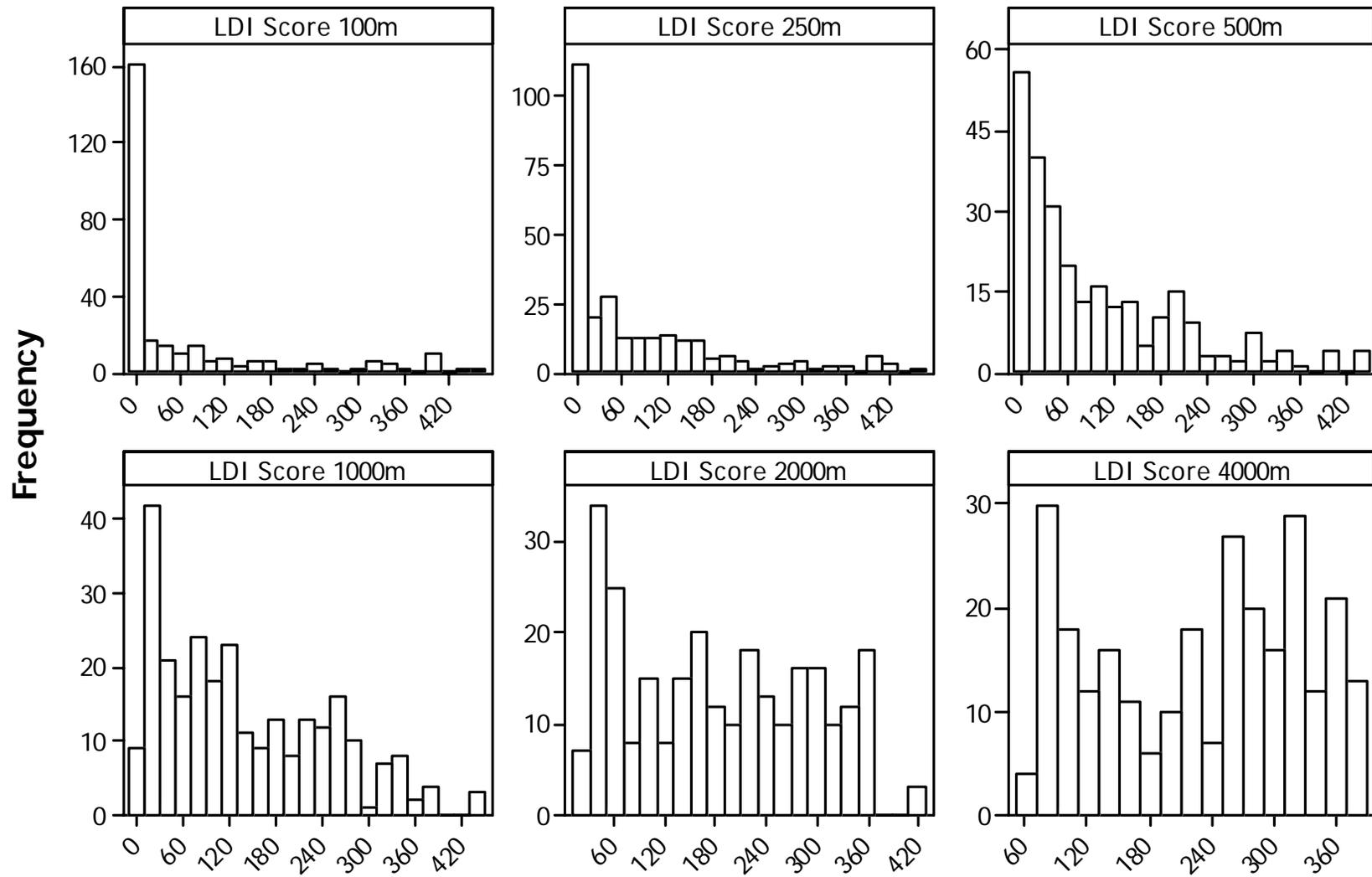


Figure 12. Histograms of LDI scores by different buffer distances (100 m, 250 m, 500 m, 1000 m, 2000 m, 4000 m).

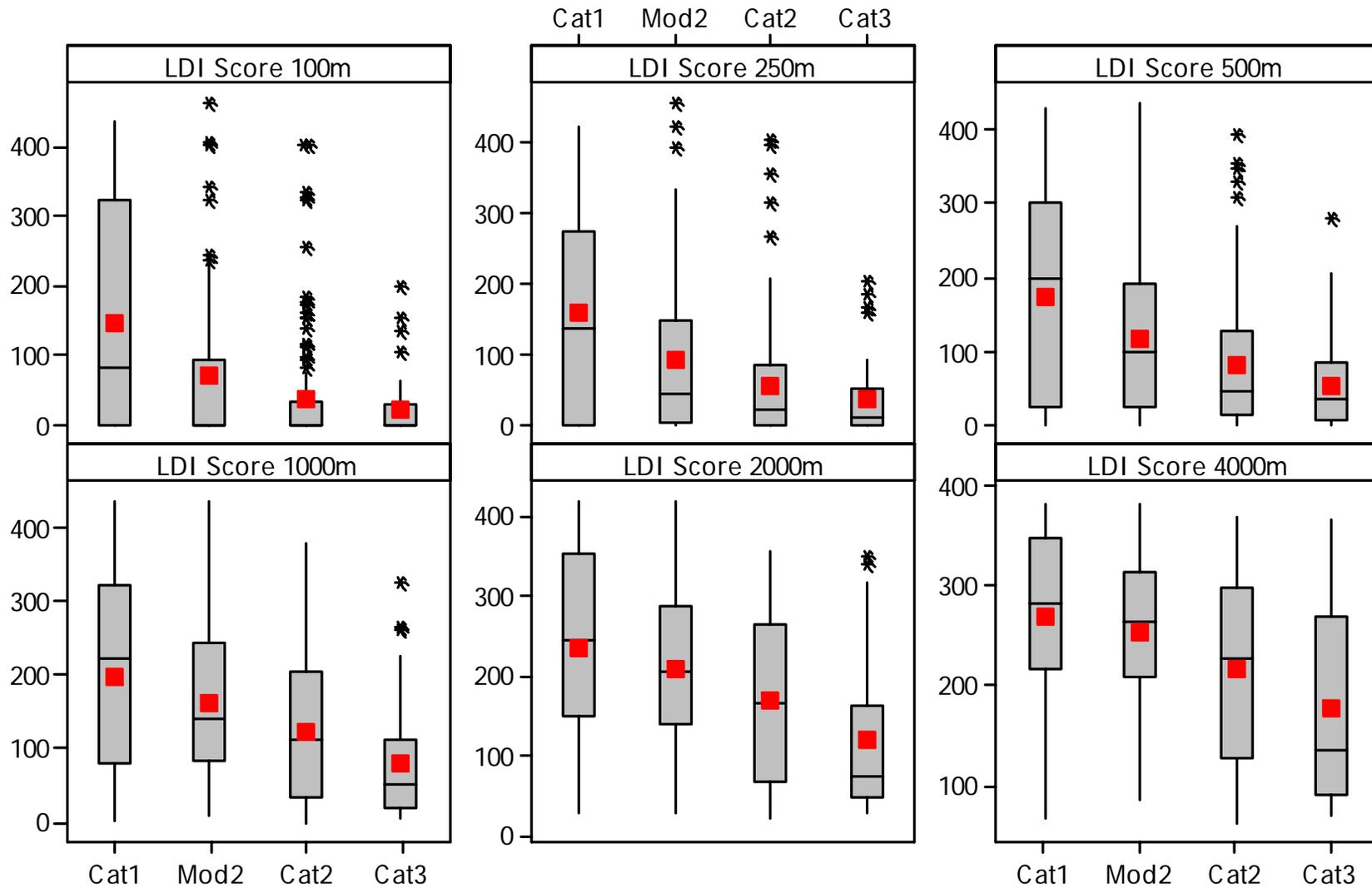


Figure 13. Box and whisker plots of LDI scores for different wetland condition categories at different buffer distances (100 m, 250 m, 500 m, 1000 m, 2000 m, 4000 m).

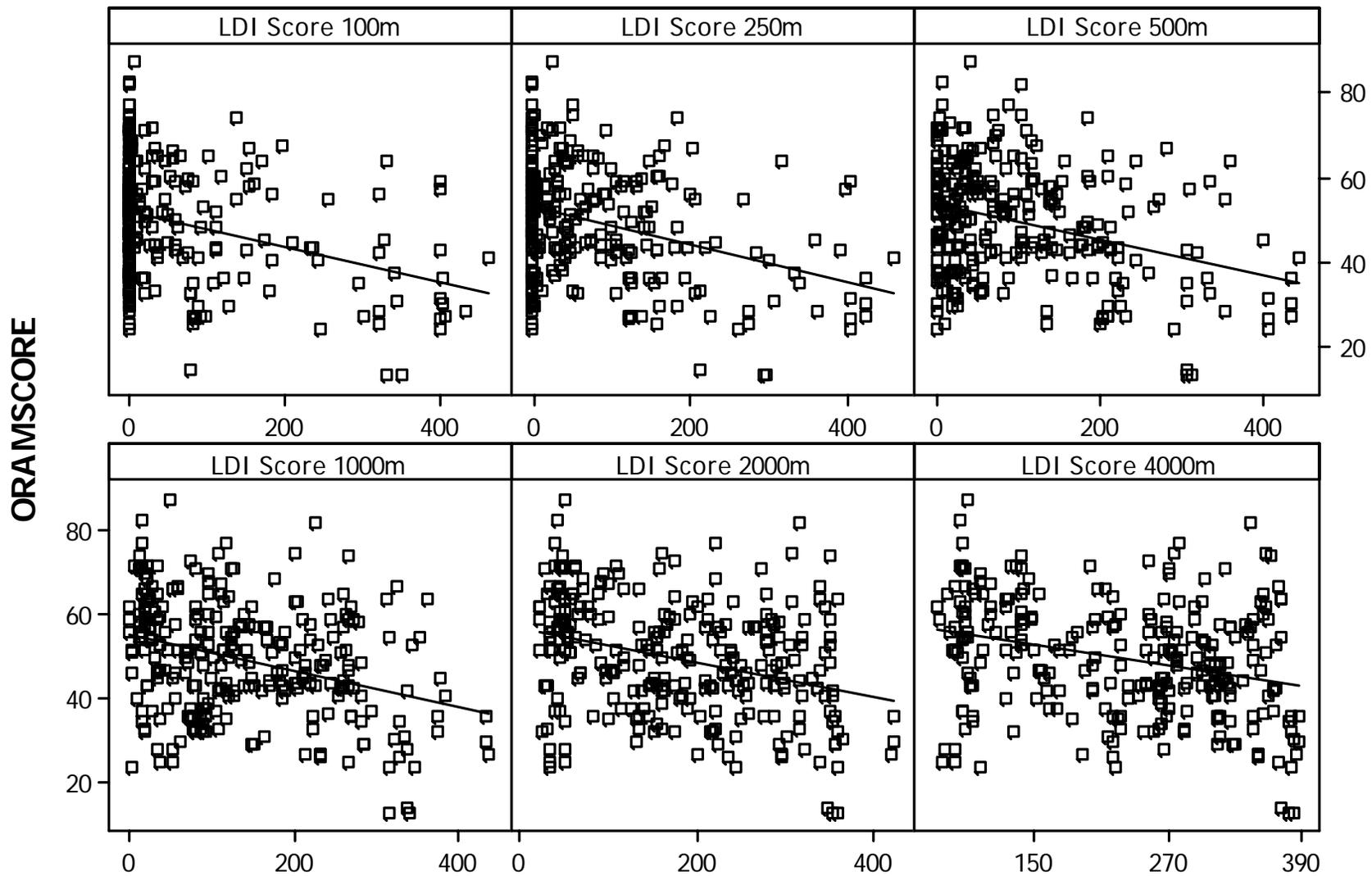


Figure 14. Scatterplots (and regression lines) of LDI scores and ORAM scores. 100 m $R^2= 10.9\%$, 250 m $R^2= 12.2\%$, 500 m $R^2= 11.4\%$, 1000 m $R^2= 11.0\%$, 2000 m $R^2= 10.5\%$, 4000 m $R^2= 8.6\%$.

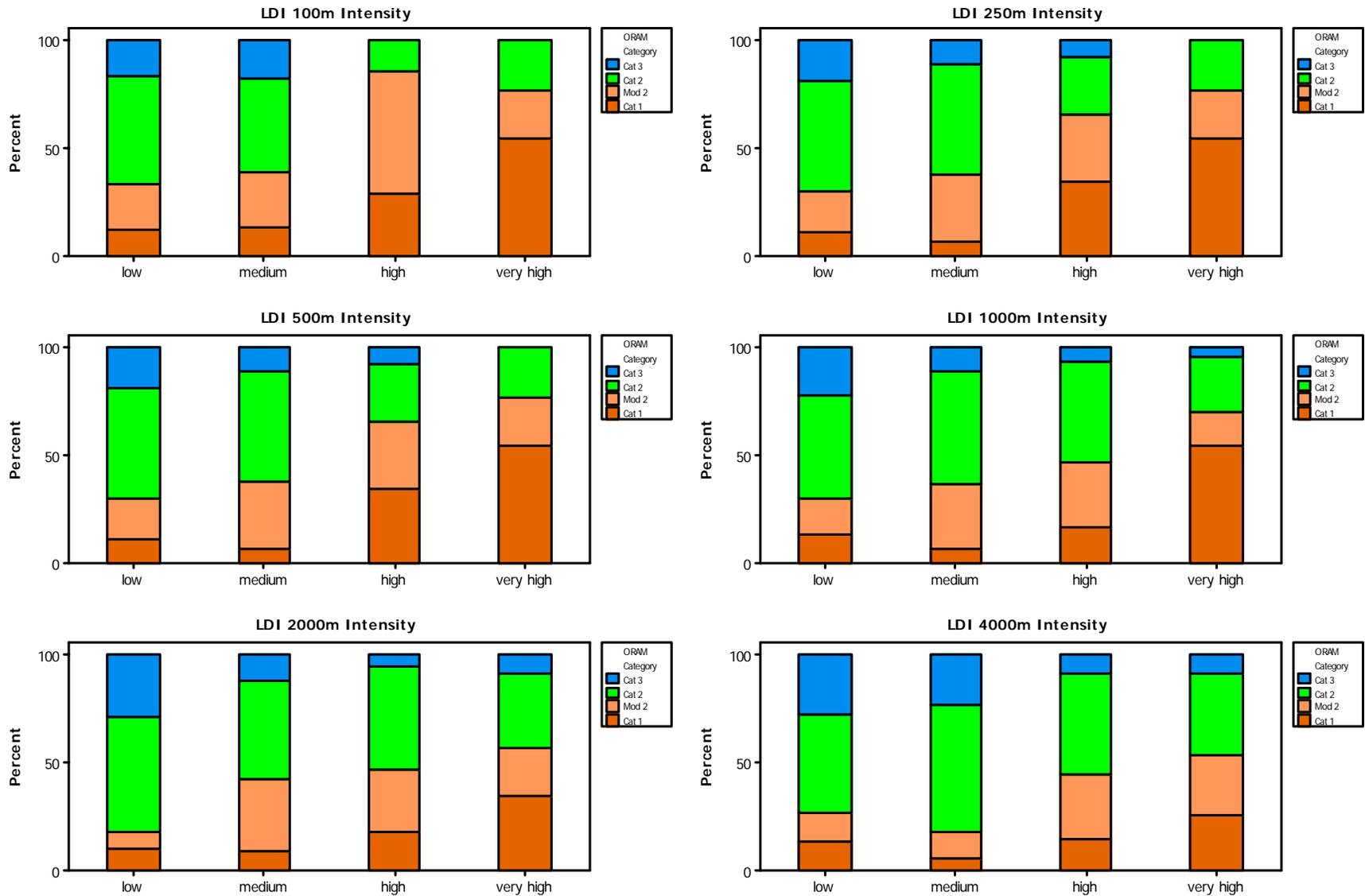


Figure 15. Charts of LDI intensity for different buffer distances by condition category. Note that when very high land uses are present within 100m of wetland there are no Category 3 wetlands and few Category 2 wetlands. However, when very high intensity land uses are present at 1000 to 4000 m, Category 3 wetlands can still persist.

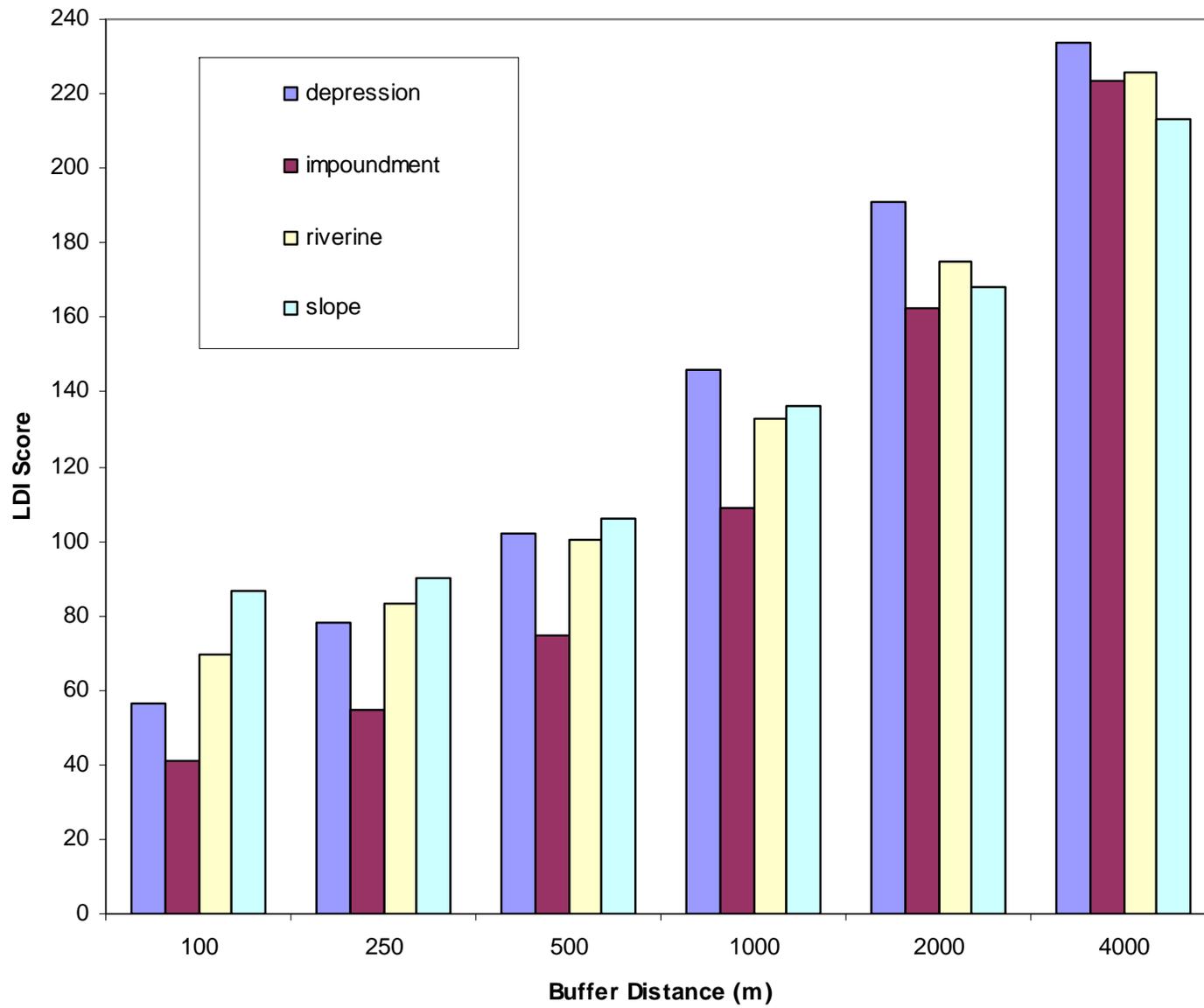


Figure 16. Mean LDI scores for each buffer distance stratified by HGM class.

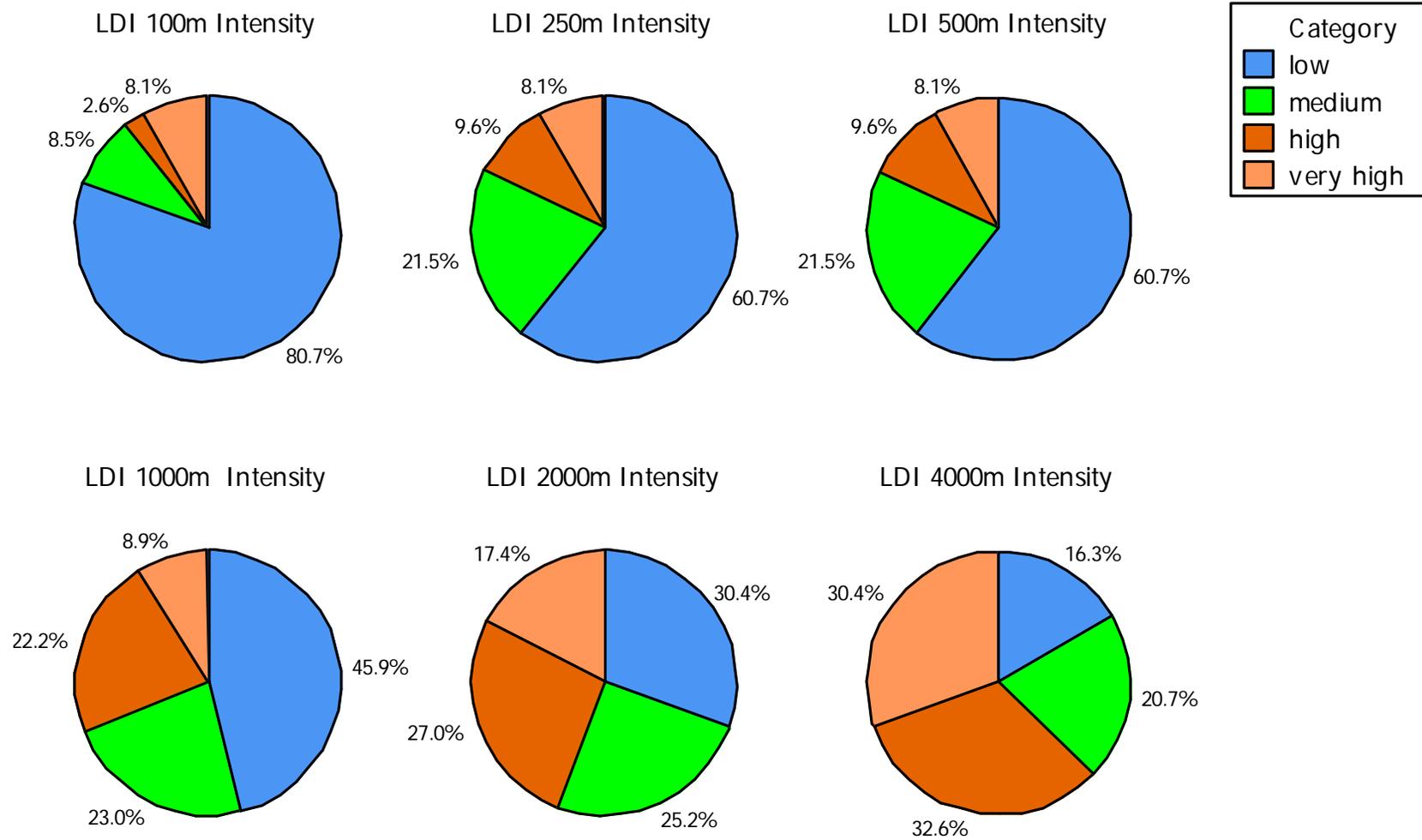


Figure 17. Pie charts of LDI scores for different buffer distances (100 m, 250 m, 500 m, 1000 m, 2000 m, 4000 m). “Low”, “medium”, “high”, and “very high” refer to the intensity of the land uses within the buffer distance. Low = 0-99, medium = 100-199, high = 200-299, very high = 300+.

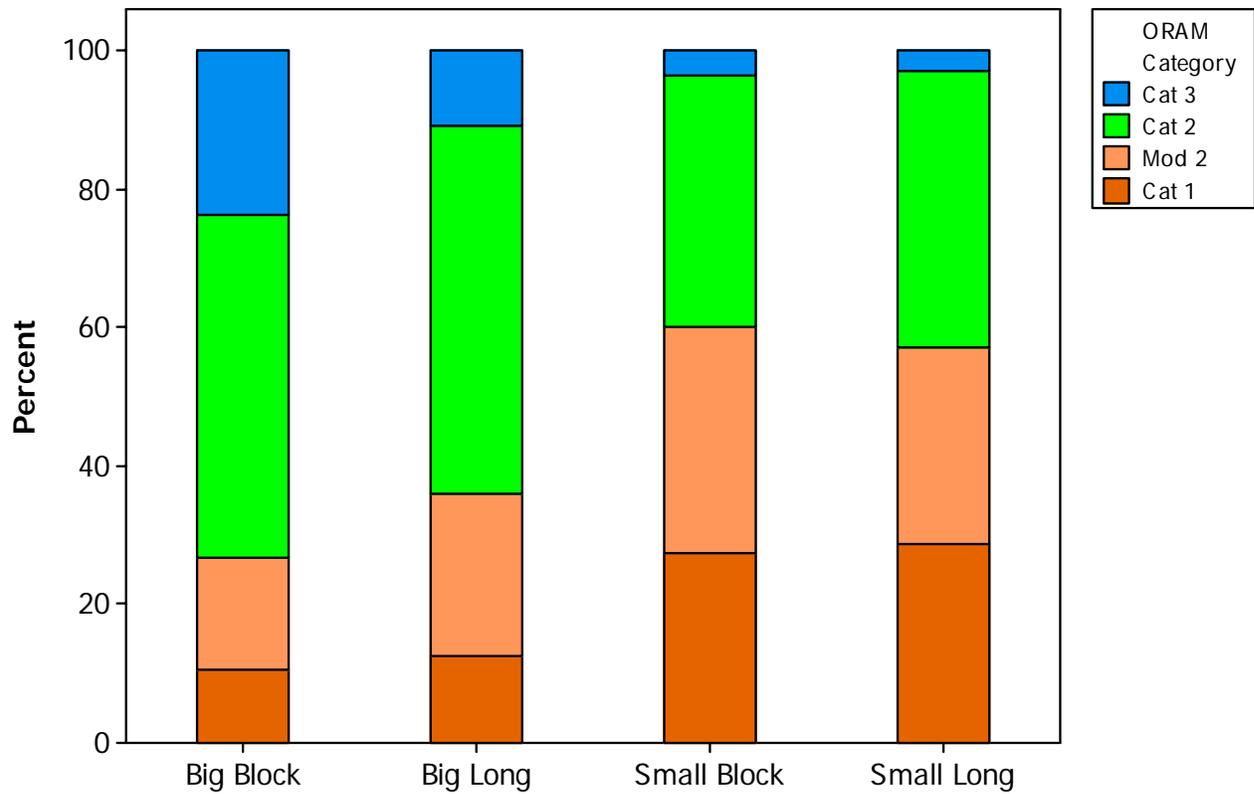


Figure 18. Percent of wetlands in each condition category by reservations grouped by size and shape. Refer to text for definitions of categories. Note that many Category 2 wetlands and a few Category 3 wetlands are still present in small urban reservations.

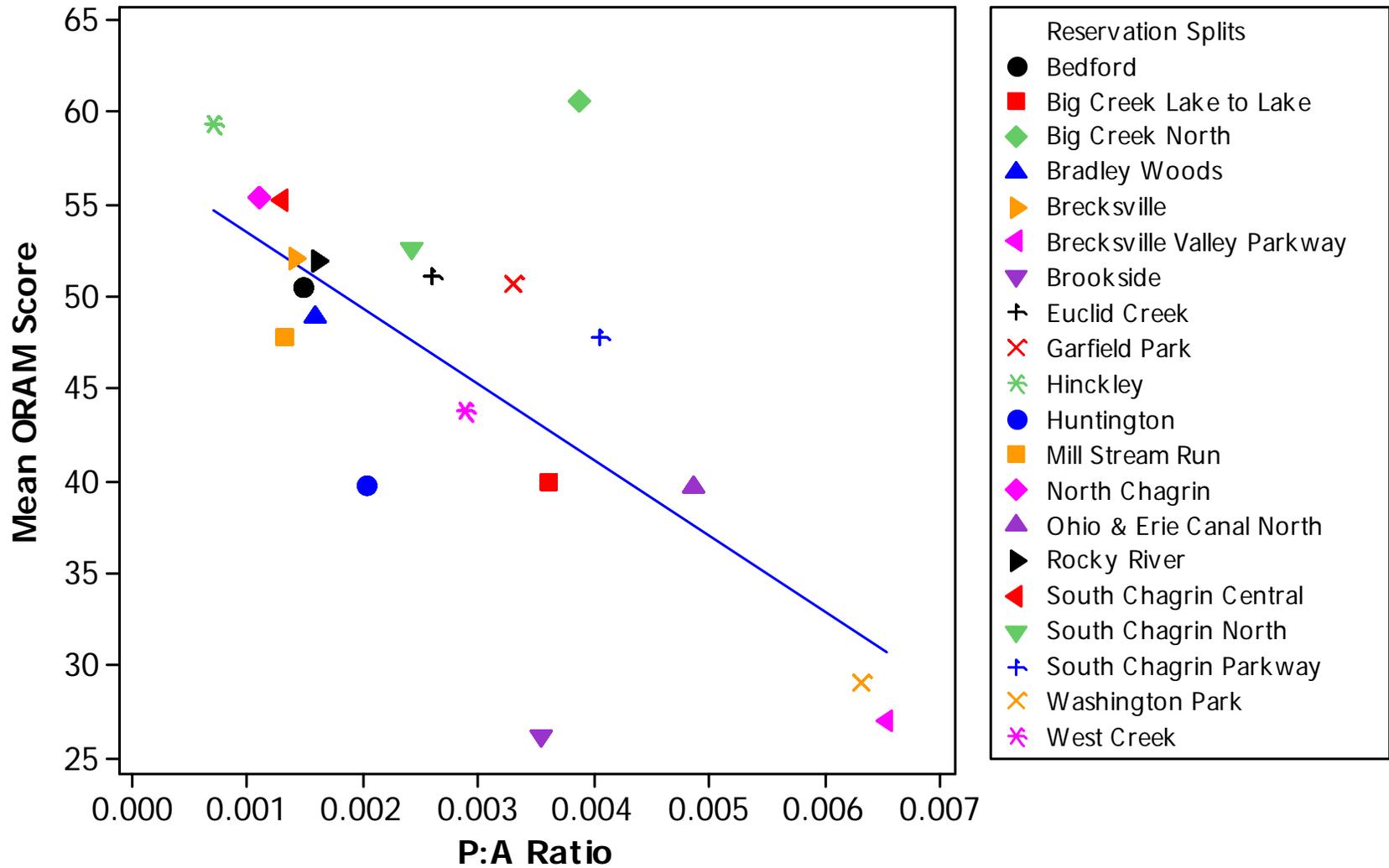


Figure 19. Scatterplot (and regression line) of mean ORAM score versus perimeter:area ratio.

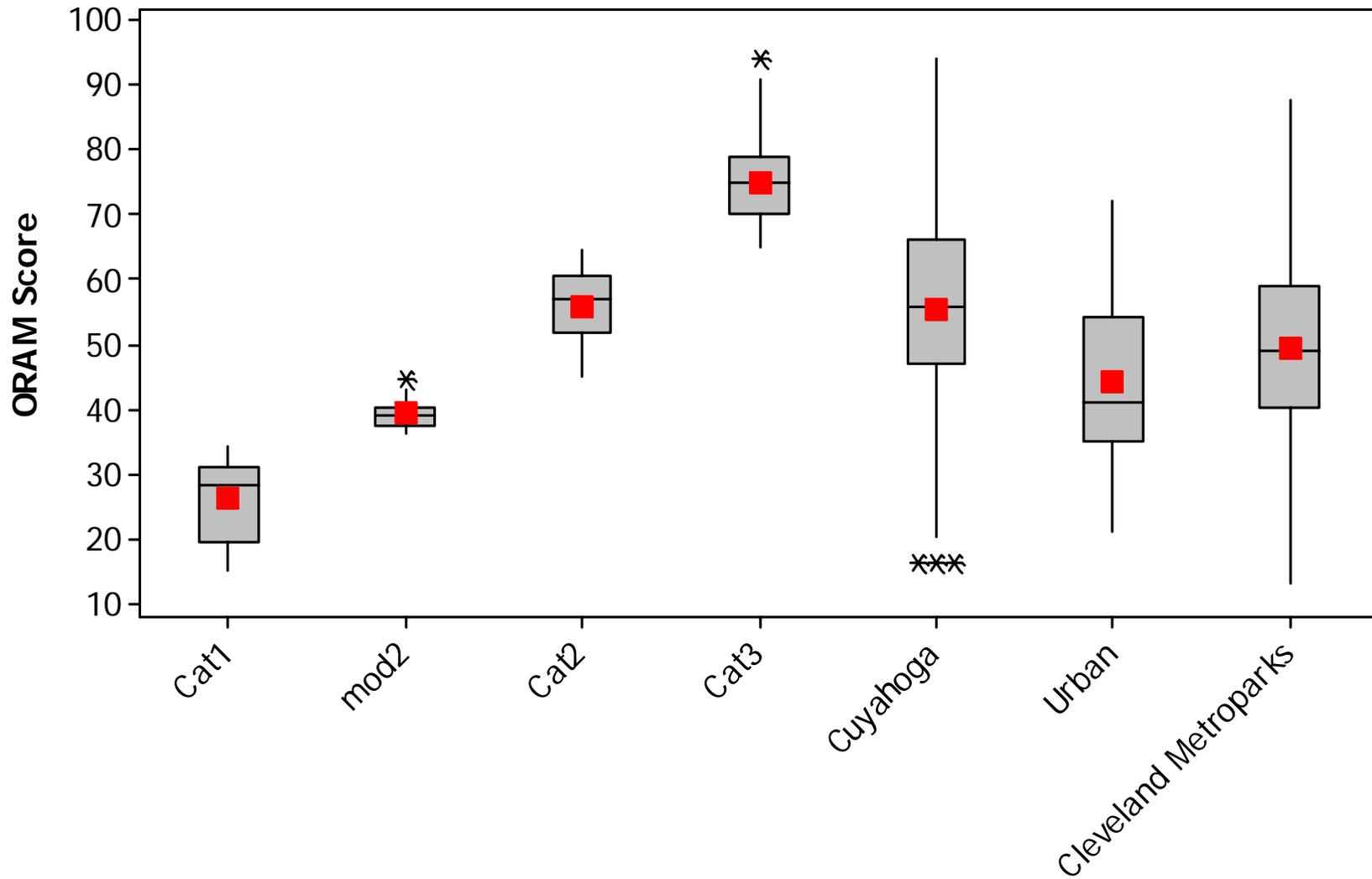


Figure 20. Comparison of ORAM scores in Cleveland Metroparks with Cuyahoga watershed and urban wetlands and mean scores from Ohio EPA reference wetland data.