



# Sentinel Wetlands in Cuyahoga Valley National Park

## *II. Condition Trends for Wetlands of Management Concern, 2008–2018*

Natural Resource Report NPS/HTLN/NRR—2023/2603





**ON THIS PAGE**

Mixed emergent vegetation at Beaver Marsh.  
NPS/SONIA BINGHAM

**ON THE COVER**

Riverine headwater wetland at Stumpy Basin.  
NPS/SONIA BINGHAM

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# Sentinel Wetlands in Cuyahoga Valley National Park

## *II. Condition Trends for Wetlands of Management Concern, 2008–2018*

Natural Resource Report NPS/HTLN/NRR—2023/2603

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# Executive Summary

Twenty important management areas (wetlands of management concern) and reference wetlands compose the sentinel wetlands at Cuyahoga Valley National Park. These wetlands are monitored more intensively than other wetlands in the program. This is the second report in a two-part series, designed to summarize the results from intensive vegetation surveys completed at sentinel wetlands from 2008 to 2018. The first report (Bingham and Young 2023) characterized the conditions in each wetland and provided baseline reference information for other reports and site-specific projects. In this report, we examine results from five selected metrics more closely within and across three natural wetlands of management concern groups (restoration wetlands, mitigation wetlands, and rare habitat wetlands) using the reference wetlands as overall benchmarks.

We used the Ohio Rapid Assessment Method (ORAM) to evaluate habitat in the sentinel wetlands. In addition, a total of 37 long-term sample plots were established within these wetlands to monitor biological conditions over time using vegetation as an indicator. Multiple plots were located in larger wetland complexes to capture spatial differences in condition. Vegetation was intensively surveyed within the plots using the Vegetation Index of Biotic Integrity (VIBI), where all plant species are identified to the lowest taxonomic level possible (genus or species). The sample plots were surveyed twice, and the five evaluation metrics included the VIBI score, Floristic Quality Assessment Index (FQAI), percent sensitive plant species, percent invasive graminoids, and species richness. For the analysis, VIBI plot locations were rank ordered based on their 2018 scores, the range and average for each metric was examined across the wetlands of management concern groups and plotted against reference wetlands for comparison, and the two survey years (pre-2015 and 2018) were plotted against each other for substantial changes from the established baseline.

Across the sample plot locations, VIBI scores ranged from a low of 7 (Stanford Run SF1) to a high of 91 (Columbia Run 554). The top scoring plots were at four reference wetlands (Stumpy Basin 526, Virginia Kendall Lake 241K, Columbia Run 554, and Boston Mills 683) and one rare habitat wetland (Beaver Marsh BM3). All of these plots fell within an *excellent* condition range in one or both survey years. They each have unique habitats with some specialized plant species. The majority (24) of the sentinel wetlands plots ranked within the *poor* or *fair* ranges. These include the three mitigation wetlands: Brookside 968, Rockside RS2, and Krejci, as well as all plots within the Pleasant Valley and Stanford Run wetlands. Most of the large wetlands had dramatic condition differences within their boundaries—affected by pollution sources, land-use modifications, and/or invasive species in some areas more than others. We documented these wide condition ranges at Fawn Pond, Virginia Kendall Lake, Beaver Marsh, and Stumpy Basin, but the most pronounced within-wetland differences were at Virginia Kendall Lake, which had a 58-point difference between the highest and lowest scoring plot. Fawn Pond is in good condition at most plots and scored very high in comparison to other wetlands within the riverine mainstem hydrogeomorphic class.

The average and range of most metric scores were notably different across the four different wetlands groups. Average values at rare habitat wetlands plots were similar to reference plots for VIBI and FQAI scores, percent invasive graminoids, and percent sensitive metrics. Krejci KR1 and Fawn Pond FP3 had unusually high percent cover of sensitive species (31.0% and 27.9%, respectively) for the mitigation and restoration groupings. However, average overall metric scores across the restoration and mitigation wetlands were generally very low, with Stanford Run being the lowest scoring restoration wetland and Brookside being the lowest scoring mitigation wetland. With restoration efforts completed, the expectation is that mitigation wetlands should be performing much higher. Two of the three mitigation wetlands sites are not meeting the mitigation benchmarks that were created for them by the US Army Corp of Engineers and the Ohio Environmental Protection Agency. Contractor reports state that the wetlands met the criteria within the first five years of establishment. However, upon release from monitoring and maintenance, invasive species have gradually re-established, which has led to condition deterioration over time, and lower metric scores.

VIBI scores stayed the same or improved (only slightly in many cases) in the majority of plots (67.6%) between survey years. The Krecji mitigation wetlands had the largest improvement in VIBI scoring. Scores at six plots decreased by at least 10 points from the baseline survey. Two of the park's most beloved wetlands, Beaver Marsh (at one location) and the Stumpy Basin reference plot, had the two most notable declines in VIBI scores.

In 2018, 11 plots (29.7%) had greater than 25% invasive graminoid cover (e.g. cattail, common reed grass, reed canary grass) and 18 plots (48.7%) experienced an increase in invasive graminoid cover between survey years. A marked increase (>10% cover) in invasive graminoids was documented at eight locations (Rockside 1079RS2, Beaver Marsh BM5, Fawn Pond FP3 and FP4, Brookside 968, Stumpy Basin SB1, and two other Pleasant Valley plots: 1049 and 969). These trends are likely to continue, and biological conditions are expected to deteriorate at these wetlands in response. Regardless of invasive species increases, many of the wetlands showed remarkable resilience over the last decade with fairly stable VIBI categories.

# Acknowledgments

Kevin Skerl and Meg Plona were the resource managers at Cuyahoga Valley National Park who originally selected the park's wetlands of management concern. Reference wetlands were selected by Heartland Network staff following extensive habitat assessments during the earliest stages of the wetlands monitoring protocol. Luke Biscan, Brandon Piper, and Doug Marcum assisted with vegetation surveys over the course of the two monitoring periods evaluated here. Doug Marcum has provided extensive field work and expertise throughout the entire implementation process.

# Introduction

Cuyahoga Valley National Park resource managers selected a set of sentinel wetlands to be able to detect and address common management issues at these important sites. Sentinel wetlands are monitored more intensively than other wetlands in the monitoring program (Bingham et al. 2016). The sentinel wetlands set includes eight reference wetlands (Table 1) and eight wetlands of management concern complexes comprising 15 individual wetlands (Table 2, Figure 1).

**Table 1.** Reference wetlands at Cuyahoga Valley National Park, and their associated hydrogeomorphic classes (HGM). Each wetland has one Vegetation Index of Biotic Integrity (VIBI) plot.

| HGM Type           | Wetland Name (Code)         |
|--------------------|-----------------------------|
| Depressional       | Boston Mills (683)          |
|                    | Langes (124)                |
| Riverine mainstem  | Bath (1427)                 |
|                    | Fitzwater (970)             |
| Riverine headwater | Snowville (398)             |
|                    | Stumpy Basin (526)          |
| Slope              | Columbia Run (554)          |
|                    | Virginia Kendall Lake (241) |

Reference wetlands formed a natural grouping that reflected our perceptions of high quality, least-disturbed examples of a particular hydrogeomorphic (HGM) class, potentially representing the “best

attainable condition” (Stoddard et al. 2006). Wetlands within each HGM class tend to have similar biological communities that respond similarly to disturbances (Fennessy et al. 2007; USEPA 2002). Four hydrogeomorphic (HGM) classes (i.e., riverine mainstem, riverine headwater, slope, depressional) are represented (Figure 2). We classified wetlands of management concern into three groups based on park concerns: rare habitat wetlands, restoration wetlands, and mitigation wetlands. These types reflect park specific concerns around wetlands management, including suitability as rare habitat; ecological restoration projects, often to improve stormwater management function; or sites used as compensatory mitigation. The wetlands of management concern are large wetland complexes that require multiple plots for adequate characterization (Bingham et al. 2016), bringing the total number of sentinel wetlands plots to 37.

This is the second report in a two-part series, designed to summarize the results from intensive vegetation surveys completed at sentinel wetlands from 2008 to 2018. The first report (Bingham and Young 2023) characterized the conditions in each wetland and provided baseline reference information for other reports and site-specific projects. In this report, we examine results from five selected metrics more closely within and across three natural wetlands groups (restoration, mitigation, and rare habitat wetlands of management concern) using the reference wetlands plots as overall benchmarks.



Recent alluvium at the Stumpy Basin 526 reference site, Cuyahoga Valley National Park, Ohio. NPS/SONIA BINGHAM.

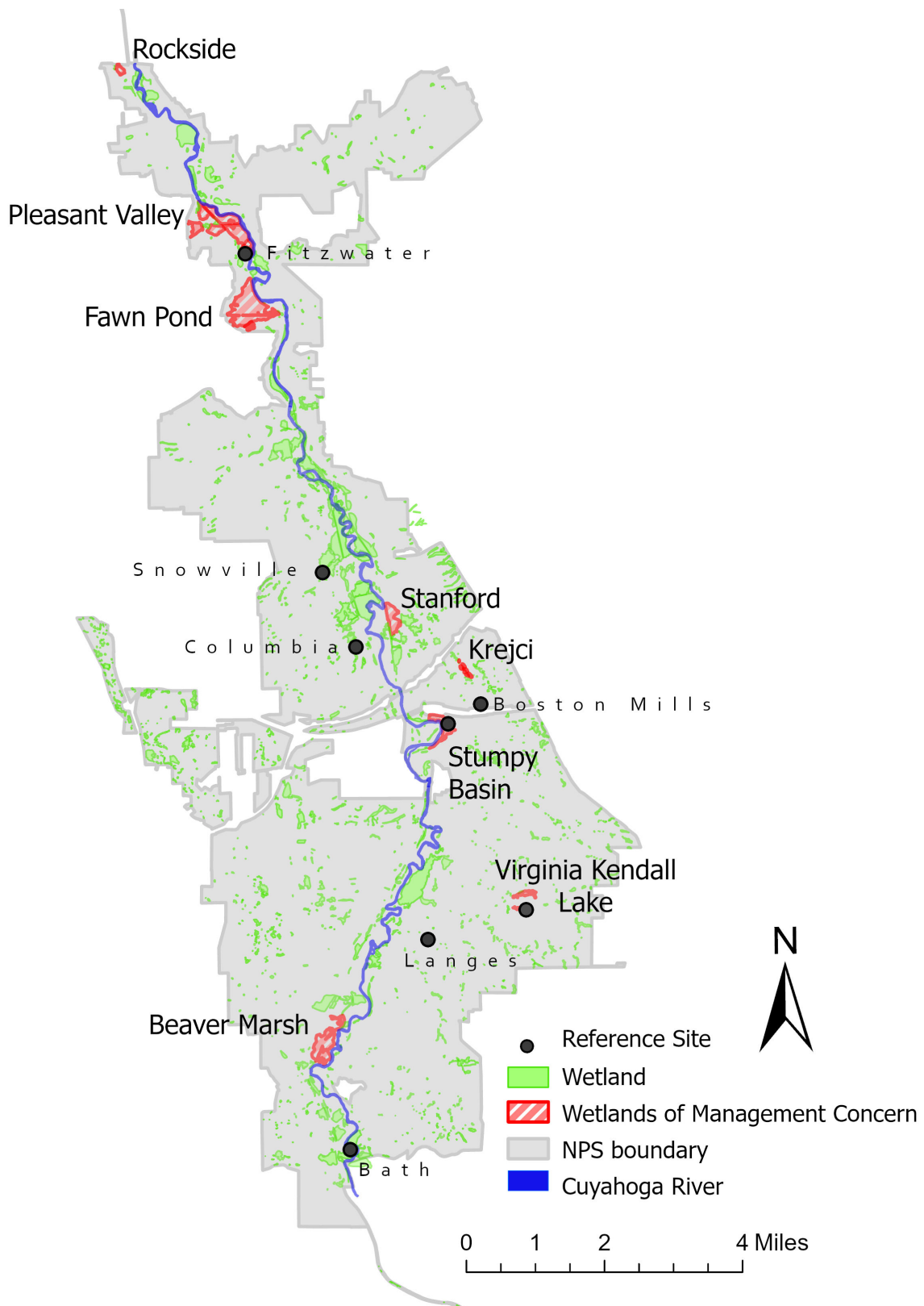


**Figure 1.** Distribution of sentinel wetlands (wetlands of management concern and reference wetlands) across Cuyahoga Valley National Park.

**Table 2.** Wetlands of management concern (WOMC) at Cuyahoga Valley National Park. These are sometimes grouped by management type (WOMC Type) for analysis. Some wetland complexes (n = 8) have multiple individual wetlands (n = 15), and the number of plots selected for each wetland varied based on the number of dominant plant community types and hydrogeomorphic classes.

| WOMC Type    | Wetland Complex Name  | Individual Wetlands (Code)         | # Plots |
|--------------|-----------------------|------------------------------------|---------|
| Rare habitat | Beaver Marsh          | Beaver Marsh (365)                 | 5       |
|              | Stumpy Basin          | *Stumpy Basin (526)                | 3       |
|              | Virginia Kendall Lake | Virginia Kendall Lake North (242)  | 2       |
|              | Virginia Kendall Lake | *Virginia Kendall Lake South (241) | 1       |
| Restoration  | Fawn Pond             | Fawn Pond (977)                    | 5       |
|              | Stanford Run          | Stanford Run (540)                 | 4       |
|              | Pleasant Valley       | Pleasant Valley (969)              | 1       |
|              | Pleasant Valley       | *Pleasant Valley (970)             | 1       |
|              | Pleasant Valley       | Pleasant Valley (1043)             | 1       |
|              | Pleasant Valley       | Pleasant Valley (1047)             | 1       |
|              | Pleasant Valley       | Pleasant Valley (1049)             | 1       |
| Mitigation   | Brookside             | Brookside (968)                    | 1       |
|              | Krejci                | Krejci (1622)                      | 1       |
|              | Krejci                | Krejci (1627)                      | 1       |
|              | Rockside              | Rockside (1079)                    | 1       |
| Total        | –                     | –                                  | 29      |

\*Plots are located within the same wetland as reference wetlands plots.

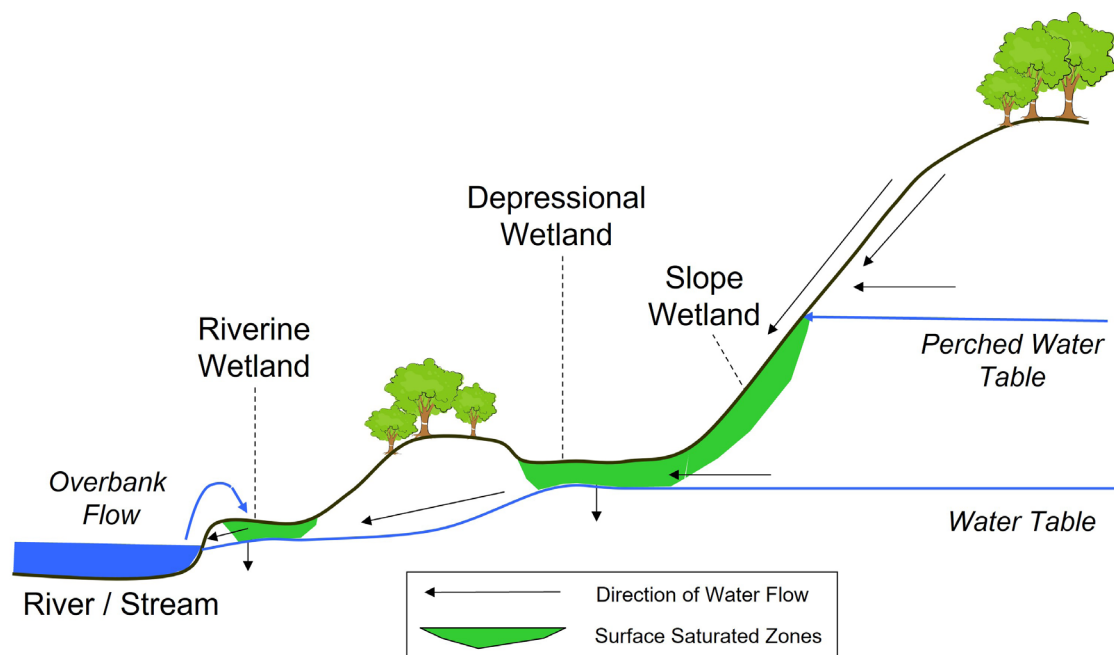


**Figure 2.** Cross-sectional view of dominant wetland hydrogeomorphic classes (depressional, riverine, and slope) in Cuyahoga Valley National Park.

# Evaluation Metrics

A complete table of evaluation metrics is shown in the Appendix. See Bingham et al. (2016) for more details on sampling methods.

## Ohio Rapid Assessment Method

We completed a rapid assessment for each wetland after the initial wetland boundary delineation. An observer walked the perimeter of the wetland, categorizing and scoring six metrics to calculate an Ohio Rapid Assessment Method (ORAM) score (Mack 2001). The ORAM allows general inferences about the overall ecological health of wetlands. ORAM evaluates *habitat condition* based on qualitative, field-observed factors, such as water permanence and habitat intactness. The ORAM is determined as a composite of 16 factors that yield a combined score between 0 and 100. For the purposes of this report, we use scoring ranges that are only slightly modified from the ORAM calibration manual

to eliminate gray zones (Mack 2000): 0.0–29.9 = poor; 30.0–44.9 = fair; 45.0–59.9 = good; and 60.0–100.0 = excellent. Scores within the gray zones were rounded up to the next highest condition rating. See Mack (2001) for additional details and more nuanced specifics on interpretation.

## Vegetation Index of Biotic Integrity

After delineations were complete, we selected and established permanent sample plot locations in each of the individual wetlands. Vegetation was surveyed comprehensively within the plots to characterize the condition of each unique vegetation type/HGM class within the wetland using the Vegetation Index of Biotic Integrity (VIBI; Mack and Gara 2015). Sample plots consisted of between 1 and 10 modules depending on vegetation type, with larger plots in forested wetlands (Figure 3; Bingham et al. 2016). Modules were 10 m x 10 m in size (i.e., 100 m<sup>2</sup>).

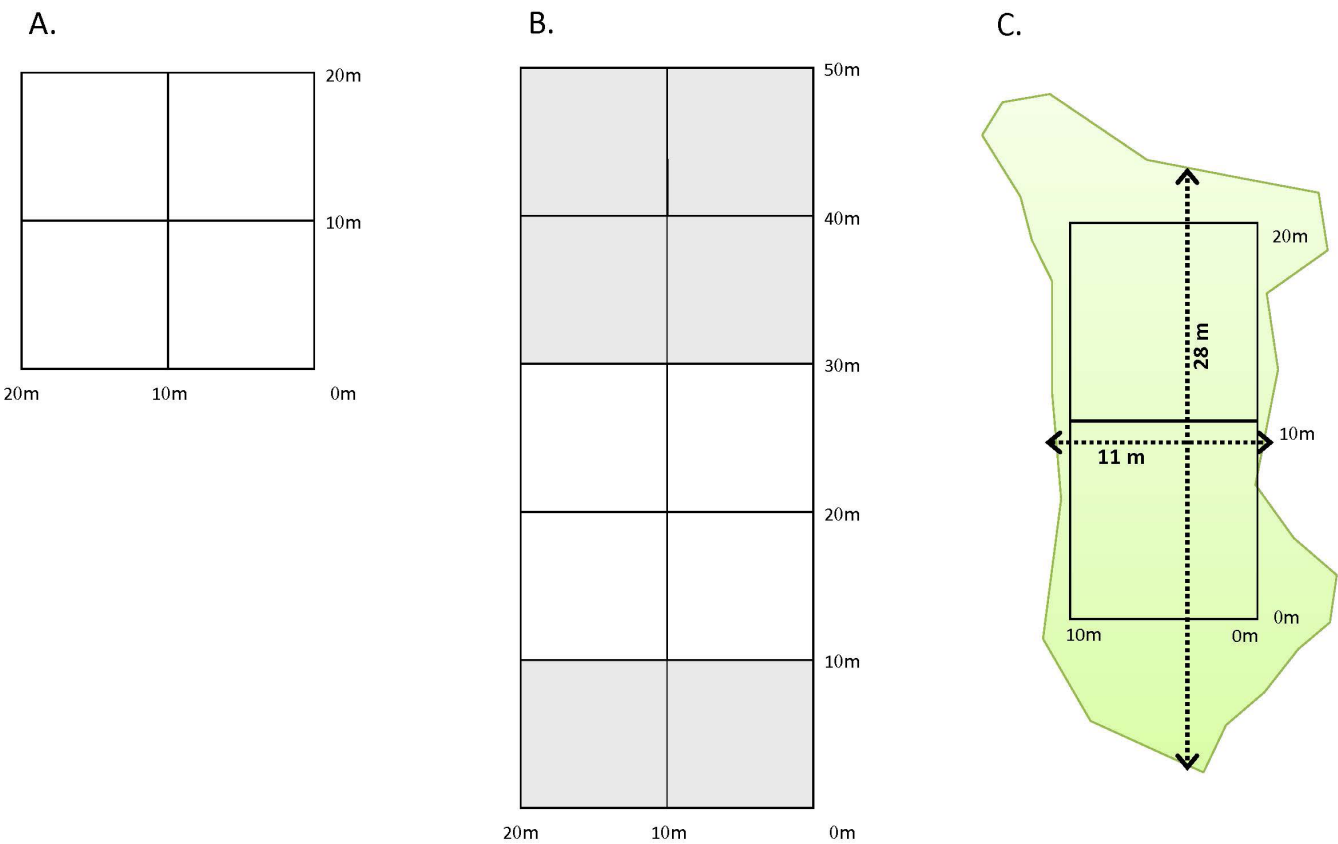


**Figure 3.** The preferred sample plot array (A) for emergent, aquatic bed, and scrub-shrub wetlands, (B) for forested wetlands, and (C) an example alternative sampling plot array for situations where the preferred array was not possible because of wetland shape, size, or vegetative composition.

We used a two-person team to sample vegetation between June 15 and October 15 when key plant identification characteristics were most visible because VIBI calculations require highly accurate identification of plants to species level. The cover of all vascular plant species, the density and identity of woody stems less than 3 ft tall, the diameter and identity of all woody stems greater than 3 ft tall, and biomass (for emergent wetlands only) were measured and recorded separately within each 100-m<sup>2</sup> module. Baseline surveys were completed between June 21, 2008, and September 2, 2015, during the plot setup and establishment phase. Thirty-six of the plots were resurveyed between June 27, 2018, and September 15, 2018, and one plot (1079RS2) was resurveyed the following year on September 17, 2019, because it was part of an additional sample set.

The VIBI is a multi-metric composite index, based on detailed taxonomic identification of plants, that indicates wetland condition. The VIBI is calculated by summing 10 metric scores that are unique to each wetland hydrogeomorphic type. The combined metrics yield a score between 0 and 100. For the purposes of this report, we interpret the VIBI scores for all wetlands as follows: 0–29 = poor; 30–59 = fair; 60–73 = good; and 74–100 = excellent. These ranges were simplified from a more complex table (7) in the original manual. We also refer mostly to condition ratings instead of regulatory categories in the report results. See Mack (2001) and Mack and Gara (2015) for additional details and more nuanced specifics on interpretation. A total of 37 VIBI plots were surveyed across sentinel wetlands; multiple locations were surveyed in large wetlands to capture spatial trends of vegetation health across different HGM classes and dominant plant communities (Table 2).

### Floristic Quality Assessment Index

The Floristic Quality Assessment Index (FQAI) is one of the metrics calculated using the VIBI. It is a weighted richness metric that assigns a Coefficient

of Conservatism (C of C) from 0 to 10 to all species present in the VIBI plot. Higher FQAI scores indicate there are more native plants in the plot with specific ecological requirements (Andreas et al. 2004). FQAI scores between 1 and 19 suggest low vegetative quality, scores between 20 and 35 indicate high vegetative quality, and scores above 35 indicate “natural area” quality (Swink and Wilhelm 1994). An FQAI was completed at all 37 VIBI plots.

### Percent Sensitive Species

The percent sensitive species (% sensitive) metric assesses the relative abundance of high C of C species. The relative cover values of all species with C of C scores of 6, 7, 8, 9, and 10 are summed. Standards are not available for interpreting this metric. The percent sensitive metric was calculated at all 37 VIBI plots.

### Percent Invasive Graminoids

The percent invasive graminoids (% invasive graminoids) metric assesses the relative abundance of selected aggressive graminoids in wetland communities: reed canary grass (*Phalaris arundinacea*), cattails (*Typha angustifolia*, *T. latifolia*, *T. x glauca*), and giant reed (*Phragmites australis*). Japanese stiltgrass (*Microstegium vimineum*) is notably not included. Standards are not available for interpreting this metric. The percent invasive graminoids metric was calculated at all 37 VIBI plots.

### Species Richness

Species richness is the average number of species found in the herb layer (< 1.0 m tall) within a 10-m x 10-m module in a VIBI plot. Modules were averaged for the plot since plot sizes were often different. The species richness metric was calculated at all 37 VIBI plots.

# Data Analysis

Analyses were completed at the level of the sample plot. Based on the way they were selected, plots are representative of the wetland condition within a particular vegetation type/HGM class (Bingham et al. 2016). VIBI plot locations were rank ordered based on their 2018 scores. The range and average for each

evaluation metric was examined across wetlands of management concern types and plotted against reference wetlands for comparison. The two survey years (pre-2015 and 2018) were plotted against each other and plot locations with substantial changes from the baseline were identified and discussed.



Survey tapes marking the boundary of the Krejci 1627KR2 survey plot, Cuyahoga Valley National Park, Ohio.  
NPS/SONIA BINGHAM.

# Results

## Reference Wetlands

We examined reference wetlands scores for three metrics that had pre-established reference quality ranges (ORAM scores > 60, VIBI scores > 74, FQAI scores > 20; Fennessy et al. 2007; Mack and Gara 2015). One riverine mainstem wetland (Fitzwater) scored below documented thresholds for high-quality wetlands for all three metrics (Figure 4). The depressional Langes wetland, riverine headwater wetland at Snowville, and riverine mainstem wetland at Bath only achieved the high-quality threshold for one metric. VIBI scores at both riverine mainstem plots were substantially below ideal reference thresholds. Both wetlands are very dynamic in terms of sediment and the vegetation communities appear

to be in constant transition. Both riverine headwater plots had several feet of new sand deposition over a 10-year period of water level monitoring which makes them susceptible to aggressive plant invasions from seeds cycling into the system from upstream.

Our initial selection of high-quality wetlands was accurate for the depressional Boston Mills wetland and slope wetlands at Virginia Kendall Lake and Columbia Run— all scored above the high-quality threshold on all three metrics. The riverine headwater wetland at Stumpy Basin scored above the high-quality threshold on two metrics. Although not represented in Figure 4, Stumpy Basin met all three thresholds in 2011 during the baseline survey.

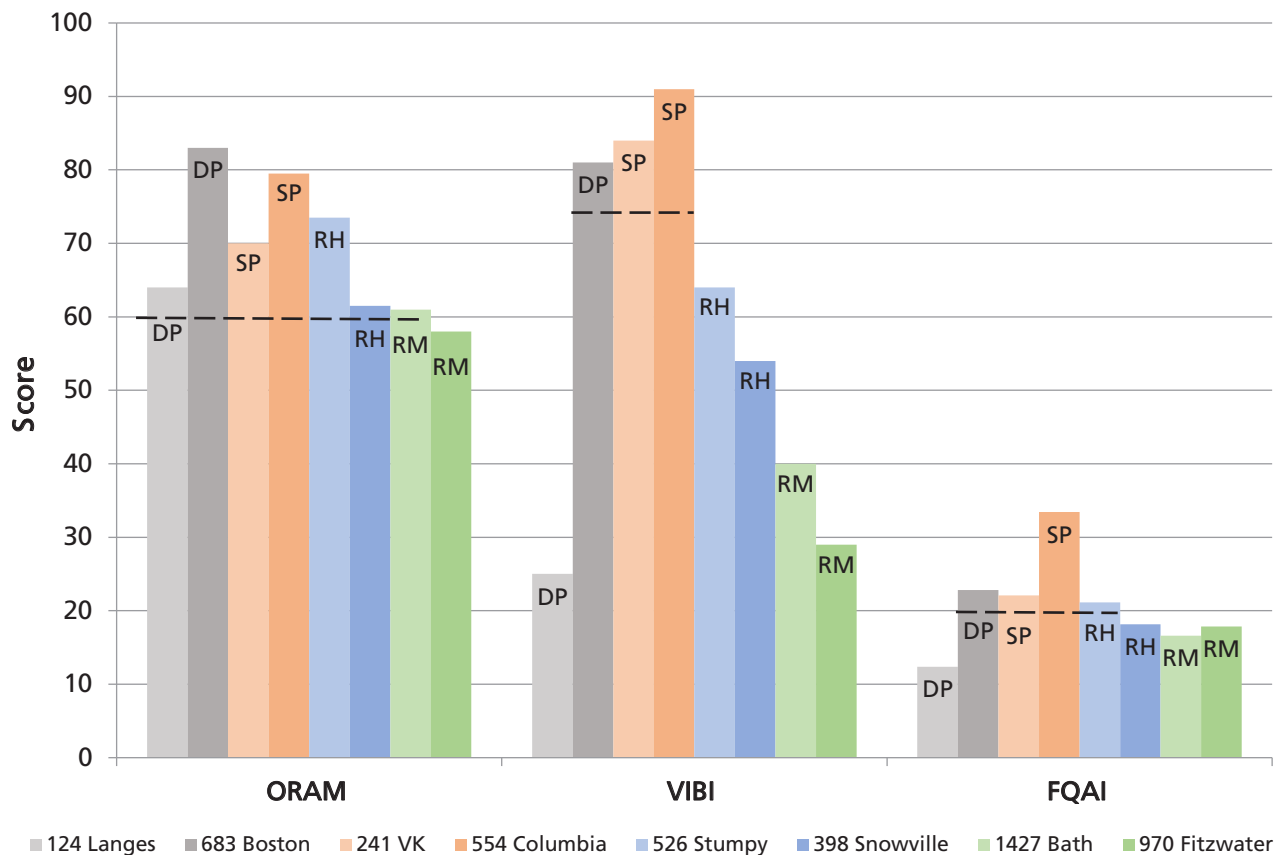


**Figure 4.** Scores for three different indices used to evaluate the vegetation condition of reference wetlands plots. Plots were surveyed in 2018. Indices are Ohio Rapid Assessment Method (ORAM), Vegetation Index of Biotic Integrity (VIBI), and Floristic Quality Assessment Index (FQAI). Two high-quality wetlands were selected within each major hydrogeomorphic (HGM) class (DP = depressional, SP = slope, RH = river headwater, RM = riverine mainstem). The dashed, horizontal lines illustrate documented thresholds for high-quality habitats: ORAM > 60, VIBI > 74, and FQAI > 20. Bars are arranged in the same order as the legend.

High-quality wetland habitats within the riverine mainstem and depressional HGM classes seem to be relatively uncommon at Cuyahoga Valley National Park based on a random sample of 60 wetlands (Bingham, 2015 unpublished data), and the pre-established ranges may be difficult to attain at wetlands within those HGM types. Average VIBI scores were 36.4 and 40.5 for riverine mainstem and depressional HGM types, respectively, compared to 52.3 for riverine headwater wetlands and 59.4 for slope wetlands. FQAI scores also matched this pattern.

## Sentinel Wetland Plot Ranks

The VIBI scores ranged from a low of 7 (Stanford Run SF1) to a high of 91 (Columbia Run 554; Figure 5) across the sentinel wetlands. The top scoring locations were at four reference wetlands (Stumpy Basin 526, Virginia Kendall Lake 241K, Columbia Run 554, and Boston Mills 683), and one rare habitat

wetland (Beaver Marsh BM3). All of these fell within the *excellent* condition range in one or both survey years. However, some reference wetlands and portions of the rare habitat wetlands had unexpectedly low condition ranges. The majority (24) of the sentinel wetlands plots ranked within the *poor* or *fair* ranges. These include the three mitigation wetlands (Brookside 968, Rockside RS2, and Krejci), as well as all plots within the Pleasant Valley and Stanford Run wetlands. Seven plots ranked within the good range. Most of the large individual wetlands had dramatic condition differences within their boundaries—affected by pollution sources, land-use modifications, and/or invasive species. We documented these wide condition ranges at Fawn Pond, Virginia Kendall Lake, Beaver Marsh, and Stumpy Basin, but the most pronounced within-wetland differences were at Virginia Kendall Lake, which had a 58-point difference between VK1 and VK3 (241K).

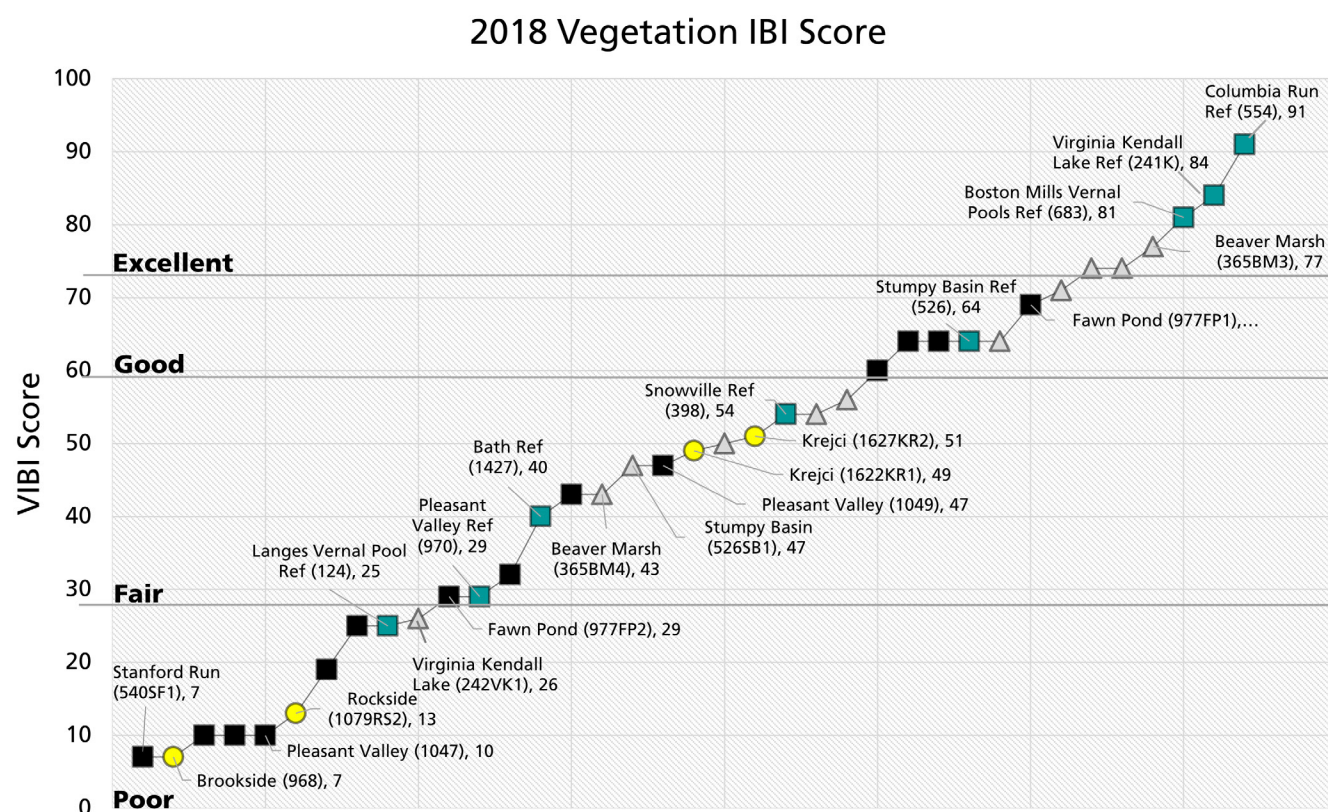


**Figure 5.** Rank order of Vegetation Index of Biotic Integrity (VIBI) scores for sentinel wetlands plots surveyed in 2018. The labels show wetland name (wetland number) and VIBI score. Only the highest and lowest scores in a single wetland complex are labeled when there are multiple plots in the wetland. Narrative condition ranges relate to Ohio EPA's regulatory categories: poor = Category 1, fair = Modified 2, good = Category 2, excellent = Category 3. Wetlands of Management Concern types are coded as follows: black squares = restoration, yellow circles = mitigation, gray triangles = rare habitat, and blue squares = reference.



Spring at Fawn Pond Swamp, Cuyahoga Valley National Park, Ohio. NPS/SONIA BINGHAM.

## **Metric Scores Across Wetland of Management Concern Types**

The average and range of most metric scores were notably different across the four different wetland types (reference wetlands and the three wetlands of management concern types—rare habitat wetlands, mitigation wetlands, and restoration wetlands), and some logical patterns emerged (Figure 6). The reference wetlands, while not perfect, still provide a good benchmark by which performance among the rare habitat, mitigation, and restoration wetlands of management concern types can be compared.

### ***Vegetation Index of Biotic Integrity***

The VIBI scores were variable for reference wetlands plots, with an average of 58.5. Columbia Run 554 scored very high (91), while Langes 124 and Fitzwater 970 scored much lower than expected at 25 and 29, respectively. Variability among the wetlands of management concern types was high as well. Rare habitat wetlands shared a similar average VIBI score (57.8) to reference wetlands but had less variability. Average VIBI scores for mitigation wetlands (30.0) and restoration wetlands (34.9) plots were over 20 points lower than the reference wetlands. The restoration wetlands plots at Fawn Pond were responsible for the high end of the range.

### ***Floristic Quality Assessment Index***

The pattern of FQAI scores across wetlands of management concern types was similar to the VIBI score pattern, with rare habitat wetlands averages (20.0) similar to the reference plots (20.6) and the mitigation (9.0) and restoration (10.1) wetlands plots averaging at least 10 points lower. The restoration wetlands plots had the most variation in FQAI scores, with Fawn Pond plots responsible for the values on the higher end of the range.

### ***Percent Sensitive Species***

Reference wetlands plots spanned across the full range of percent sensitive values. Boston Mills 683 had the most sensitive species cover (49.6%) while Langes 124 had 0.0%. The reference wetlands plot average was still 16.0% cover, which was approximately 6 percentage points higher than the rare habitat wetlands plots (10.1%), 8 points higher than mitigation wetlands plots (7.8%), and 12 points higher than restoration wetlands plots (4.1%). Its noteworthy that the newest mitigation wetlands plot, Krejci KR1, had unusually high coverage of percent sensitive species (31.0%), which improved the mitigation wetlands plot average substantially. Fawn Pond FP3 was also unusually high (27.9%) for the restoration wetlands type.

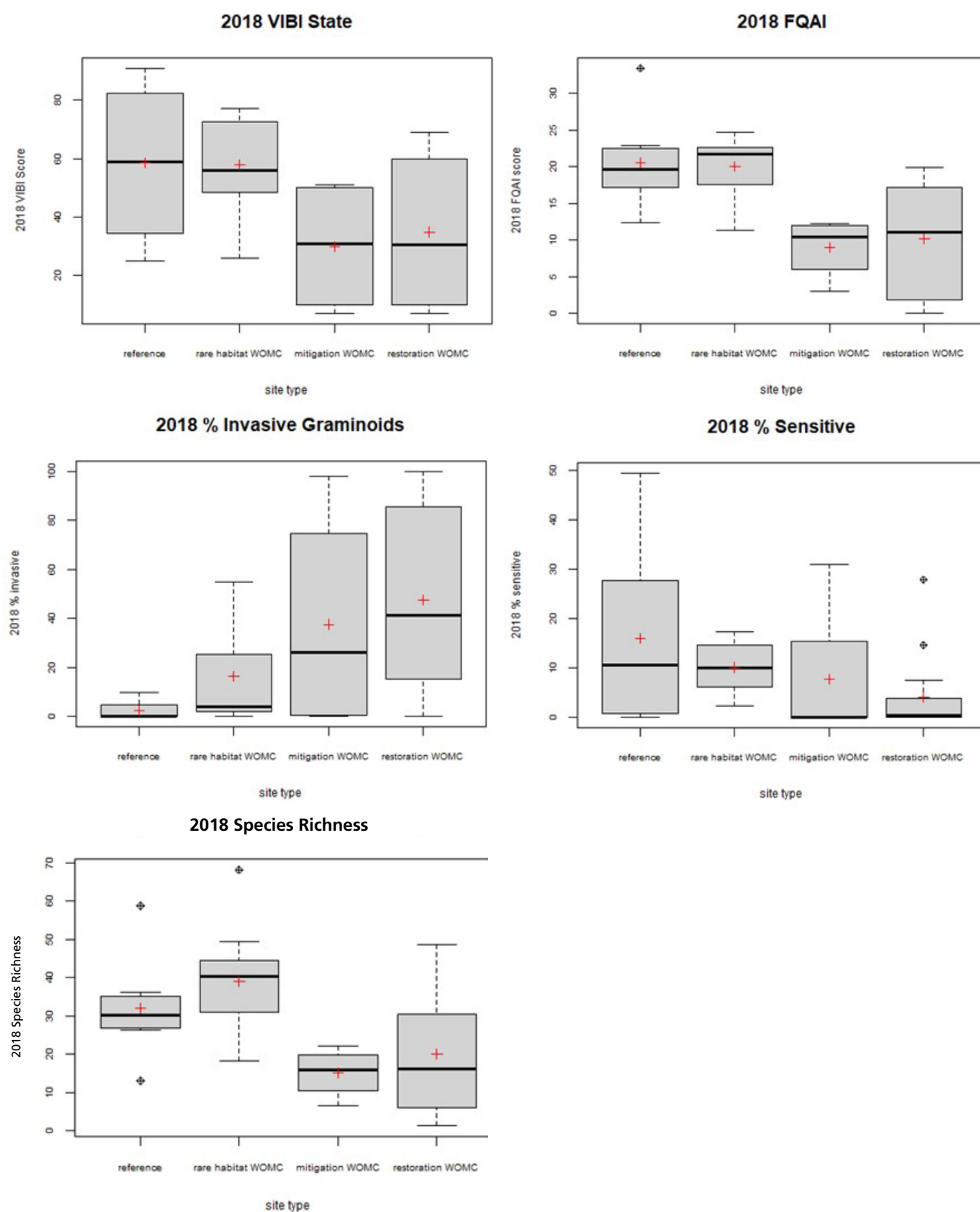


**Figure 6.** Box and whisker plots showing the distribution of the five evaluation metrics across reference wetlands (n = 8) and wetlands of management concern (WOMC) types (rare habitat, n = 11; mitigation, n = 4; and restoration, n = 14) sampled at Cuyahoga Valley National Park in 2018. The boxes indicate the 1st and 3rd quartiles, and the dark lines indicate the median. The means are indicated with red crosses. Points more than 1.5 times the inter-quartile range away from the box are shown with circles.

### **Species Richness**

Average species richness was 32.0 at reference wetlands. The average at rare habitat wetlands plots was higher at 39.1, with the Beaver Marsh and Virginia Kendall Lake plots scoring consistently high. Mitigation wetlands plots averaged 15.1 species, and restoration wetlands plots were just a bit higher at 20.1 species. Most Fawn Pond plots had high richness values, increasing the restoration wetlands plot range and average.

### **Percent Invasive Graminoids**

The average percent invasive graminoid cover was very low at reference wetlands plots (2.5%) but jumped substantially in rare habitat wetlands (16.4%), mitigation wetlands (37.5%), and restoration wetlands (47.3%) plots. Ranges were particularly high at mitigation and restoration wetlands plots. Two plots at Fawn Pond had 0.0% cover (FP1 and FP5) but Stanford Run SF3 had 100% cover. Similarly, Krecji plots had < 1.3% cover but Rockside RS2 and Brookside 968 had over 50% cover.

### **Changes from Baseline Surveys**

Some changes were observed in metric scores between baseline surveys and the 2018 surveys (Figure 7, Appendix A). Because observer error is common in wetland vegetation surveys (Morrison et al. 2019) we focus on plots with *substantial* changes in scoring between sample years—using a >10-point change as our threshold for the VIBI, percent invasive graminoid, percent sensitive species, and species richness metrics, and a > 5-point difference for the FQAI metric. Any changes less than these thresholds are treated as essentially the same condition.

### **Vegetation Index of Biotic Integrity**

We documented only minor changes in VIBI scores for most plots between survey years. The largest improvement in VIBI scoring was documented at the Krecji KR2 mitigation wetland site plot, which increased by 22 points, from 29 to 51. However, six plots increased by > 10 points from the baseline survey (Figure 6). Beaver Marsh BM5 and the Stumpy Basin 526 reference wetlands plot had the two most substantial declines in VIBI scores. Stumpy Basin 526 dropped nearly 26 points, from 90 to 64. Beaver Marsh BM5 dropped 15 points, from 71 to 56.

### **Floristic Quality Assessment Index**

Beaver Marsh BM5 and BM6 and Stumpy Basin SB2 had the most substantial improvements (> 6 points), while the Stumpy Basin 526 reference wetland, Brookside 968 mitigation wetland, and Pleasant Valley 1047 restoration wetland values declined > 6 points.

### **Percent Invasive Graminoids**

We documented an increase in the percent invasive graminoid cover at nearly half of the plots (18) between survey years. Although only eight of those plots had substantial increases (> 10%). The Brookside 968 mitigation wetlands plot had the highest increase (from 66.3% to 97.7%) among all sentinel wetlands and the Rockside RS2 mitigation wetlands plot was a close second moving from 20.7% to 51.6%. Substantial increases were also documented at portions of Stumpy Basin SB1, Beaver Marsh BM5, Fawn Pond FP3 and FP4, and Pleasant Valley 969 and 1049. Interestingly, three plots had substantial decreases: Virginia Kendall Lake VK1, Beaver Marsh BM4, and Fawn Pond FP2. Natural disturbances may be a part of the reason for these decreases.

### **Percent Sensitive Species**

The percent sensitive species cover decreased by > 10% at six plots. The most dramatic change was at Fawn Pond FP3 where sensitive species cover dropped nearly 40 percentage points from 66.5% to 27.9%. Sensitive species cover increased by > 10% at two plots: Virginia Kendall Lake VK4 and Beaver Marsh BM4.

### **Species Richness**

Two plots had substantial declines (> 10 species) in species richness. These two plots, Virginia Kendall Lake VK4 and the Brookside 968 mitigation wetlands plot, experienced disturbances during this timeframe. At Virginia Kendall Lake VK4, beaver activity changed the stream flow and associated wetland hydrology several times since the baseline survey was completed, and several select invasive shrub species were removed from the area. The Brookside 968 plot is being overtaken by *Phragmites australis*. There were no substantial increases in species richness among the sentinel wetlands between the baseline survey year and 2018.

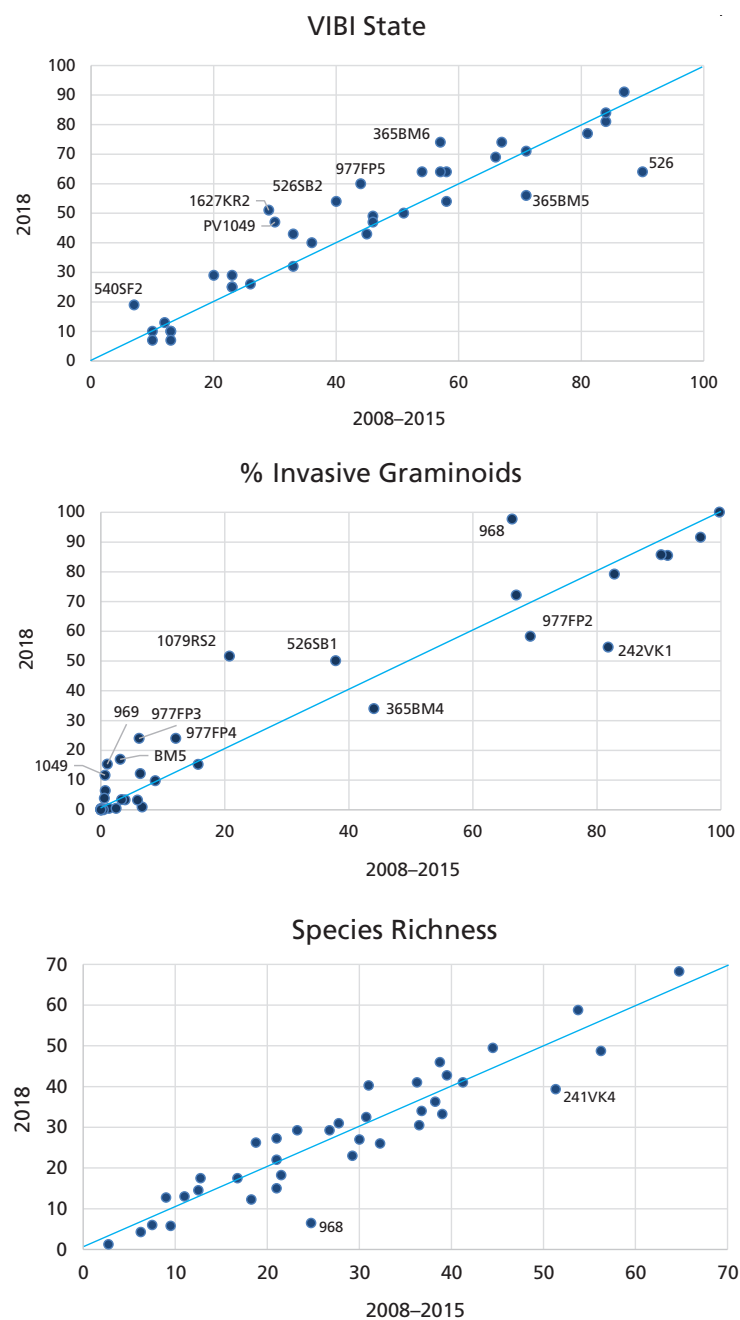


**Figure 7.** Vegetation condition metrics at the 37 sentinel wetland plots: Vegetation Index of Biotic Integrity (VIBI State), Floristic Quality Assessment Index (FQAI), percent invasive graminoid cover, percent sensitive species cover, and the average herbaceous species richness per 10-m<sup>2</sup> plot. The X axis shows data collected from baseline surveys between 2008 and 2015. The Y axis represents data collected in 2018. Plots with substantial changes from baseline surveys are noted in the charts. For most metrics this was an increase or decrease of 10 points or 10%. However, plots that changed by 5 points were noted for the FQAI.

# Discussion

## Reference Wetlands

Not all reference wetlands scored within pre-established reference quality ranges. Program data indicate that riverine HGM classes are quite vulnerable to environmental disturbances making reference quality wetlands rare. Similarly, many depressional wetlands have been previously disturbed. With the lower scoring reference wetlands removed and replaced, mean metric values for this sentinel wetlands group would increase. However, average group scores were almost always higher than the three wetlands of management concern types and may still represent some of the best available reference wetlands of those particular HGM types.

## Rare Habitat Wetlands of Management Concern

The rare habitat wetlands plots (at Stumpy Basin, Beaver Marsh, and Virginia Kendall Lake) come close to and in some cases even exceed reference conditions. This confirms their unique geology and rare habitat. Average values were similar to reference wetlands plots for VIBI and FQAI scores, percent invasive graminoids, and percent sensitive metrics. Species richness values greatly exceeded reference wetlands. However, localized impairments are still present and those were documented by lower scoring metrics at certain plots. With invasive plants controlled at rare habitat wetlands, the wetlands might exceed average reference conditions. Prioritization of invasive plant removal would have large payoffs over time. Some removal work has already been completed at these wetlands and this work may continue to influence VIBI metric scores over time.

## Restoration and Mitigation Wetlands of Management Concern

Average metric scores across the restoration and mitigation wetlands sets were generally very low—Stanford Run was the lowest scoring restoration wetland and Brookside was the lowest scoring mitigation wetland. While most survey plots within these types scored substantially lower than reference conditions, Fawn Pond (restoration wetland) plots scored well with the exception of plot FP2, which is affected by stormwater and invasive species. If Fawn

Pond is selected for restoration, care should be taken to minimize disturbance in areas already performing well. Krejci (mitigation wetland) scored much higher than the other mitigation wetlands and management of invasive species colonization is critical to continue that trajectory.

With restoration efforts completed, the expectation is that mitigation wetlands should be performing much higher. Two of the three mitigation wetlands plots are not meeting mitigation benchmarks that were created for them by the US Army Corp of Engineers and the Ohio Environmental Protection Agency. Contractor reports state that the wetlands met the criteria within the first five years of establishment. However, upon release from monitoring and maintenance, invasive species have gradually re-established, which has led to VIBI score deterioration over time. Managers should carefully consider whether to allow wetland mitigation on NPS property if the park does not have staff or another long-term funding source to continue invasive species control efforts once contractors are released from monitoring. Based on current trends at mitigation wetlands in the park, it is recommended that future mitigation projects are maintained free of listed invasive species for a period of at least 10 years to increase the chances of long-term success.

If Cuyahoga Valley National Park wetlands are proposed as mitigation sites, park managers should develop the primary objectives for the restoration (emergent, shrub, or forested habitat) to be in line with the park's desired future conditions (NPS 2022). The quantitative vegetation data available at these plots can be used to develop or review proposed plant species lists.

## Invasive Graminoids

In 2018, 11 plots (29.7%) had > 25% invasive graminoid cover and 18 plots (48.7%) experienced an increase in invasive graminoid cover between survey years. A marked increase (> 10%) was documented at eight plots (Rockside RS2, Beaver Marsh BM5, Fawn Pond FP3 and FP4, Brookside 968, Stumpy Basin SB1, and two other Pleasant Valley wetlands (1049 and 969). In most cases, the species were *Phragmites australis* (common reed) or *Phalaris arundinacea* (reed canary grass). These

trends are likely to continue, and biological condition is expected to deteriorate at these locations in response. Regardless of increased invasive species cover, many wetlands showed remarkable resilience over the last decade with fairly stable VIBI categories.

### **Intra-observer Error**

Many plots had minor improvements in VIBI and FQAI scores in 2018 in comparison with their baseline. While we may be documenting actual

improvements in some cases, some of the scoring increases could be related to intra-observer error over the two survey years. The development of plot lists, taxonomic cheat sheets, and a reference herbarium between the survey rounds improved taxonomic efficiencies during the second survey. Therefore, as with this report, more emphasis should be placed on plots with substantial departures from the baseline surveys.

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# Appendix A. Sentinel Wetland Metric Scores

**Table A1.** Metric scores at Sentinel Wetlands for the baseline surveys between 2008 and 2015 and the follow up survey in 2018. Plot ID = wetland ID and plot number, HGM = hydrogeomorphic class; FQAI = Floristic Quality Assessment Index score; VIBI = Vegetation Index of Biotic Integrity; %invasive = percent cover of reed canary grass (*Phalaris arundinacea*), cattails (*Typha angustifolia*, *T. latifolia*, *T. x glauca*), and giant reed (*Phragmites australis*); Avg herb richness/module = average number of species in each 10-m x 10-m module.

| Wetland Type                                | Plot ID    | Wetland Name  | HGM | Survey Date | Modules | FQAI  | %Sensitive | %Invasive | VIBI State | VIBI Category | Avg Herb Richness/Module |
|---------------------------------------------|------------|---------------|-----|-------------|---------|-------|------------|-----------|------------|---------------|--------------------------|
| Reference wetlands                          | 124        | Langes        | DP  | 9/8/2014    | 4       | 9.80  | 0.00       | 0.00      | 23         | 1             | 11.00                    |
|                                             | 124        | Langes        | DP  | 8/30/2018   | 4       | 12.39 | 0.00       | 0.00      | 25         | 1             | 13.00                    |
|                                             | 683        | BostonMills   | DP  | 8/8/2014    | 10      | 19.10 | 58.58      | 0.00      | 84         | 3             | 21.00                    |
|                                             | 683        | BostonMills   | DP  | 7/17/2018   | 10      | 22.80 | 49.58      | 0.00      | 81         | 3             | 27.25                    |
|                                             | 241K (VK3) | VK Lake South | SP  | 8/12/2009   | 4       | 20.00 | 28.13      | 3.35      | 84         | 3             | 38.25                    |
|                                             | 241K (VK3) | VK Lake South | SP  | 8/20/2018   | 4       | 22.08 | 19.28      | 3.42      | 84         | 3             | 36.25                    |
|                                             | 554        | Columbia      | SP  | 9/10/2014   | 4       | 29.70 | 21.83      | 0.00      | 87         | 3             | 53.75                    |
|                                             | 554        | Columbia      | SP  | 7/18/2018   | 4       | 33.43 | 27.18      | 0.00      | 91         | 3             | 58.75                    |
|                                             | 526        | Stumpy        | RH  | 8/31/2011   | 10      | 27.20 | 40.39      | 0.00      | 90         | 3             | 36.75                    |
|                                             | 526        | Stumpy        | RH  | 7/12/2018   | 10      | 21.14 | 28.22      | 0.42      | 64         | 2             | 34.00                    |
|                                             | 398        | Snowville     | RH  | 9/15/2014   | 4       | 15.50 | 1.66       | 0.69      | 58         | Mod 2         | 23.25                    |
|                                             | 398        | Snowville     | RH  | 8/31/2018   | 4       | 18.15 | 2.10       | 6.40      | 54         | Mod 2         | 29.25                    |
|                                             | 1427       | Bath          | RM  | 8/14/2014   | 10      | 12.30 | 0.21       | 0.00      | 36         | Mod 2         | 18.75                    |
|                                             | 1427       | Bath          | RM  | 8/30/2018   | 10      | 16.60 | 0.50       | 0.00      | 40         | Mod 2         | 26.25                    |
|                                             | 970        | Fitzwater     | RM  | 8/21/2014   | 10      | 15.00 | 0.00       | 8.75      | 23         | 1             | 27.75                    |
|                                             | 970        | Fitzwater     | RM  | 7/5/2018    | 10      | 17.84 | 1.13       | 9.75      | 29         | 1             | 31.00                    |
| Rare habitat wetlands of management concern | 365BM2     | Beaver Marsh  | RM  | 7/11/2011   | 4       | 17.80 | 8.34       | 5.90      | 71         | 3             | 39.50                    |
|                                             | 365BM2     | Beaver Marsh  | RM  | 8/22/2018   | 4       | 21.95 | 10.09      | 3.22      | 71         | 2             | 42.75                    |
|                                             | 365BM3     | Beaver Marsh  | RM  | 8/8/2011    | 4       | 22.40 | 17.10      | 6.35      | 81         | 3             | 44.50                    |
|                                             | 365BM3     | Beaver Marsh  | RM  | 8/27/2018   | 4       | 23.37 | 15.21      | 12.12     | 77         | 3             | 49.50                    |
|                                             | 365BM4     | Beaver Marsh  | RM  | 8/2/2011    | 10      | 16.60 | 2.58       | 44.02     | 33         | Mod 2         | 26.75                    |
|                                             | 365BM4     | Beaver Marsh  | RM  | 8/28/2018   | 10      | 15.93 | 15.00      | 33.99     | 43         | Mod 2         | 29.25                    |
|                                             | 365BM5     | Beaver Marsh  | RM  | 7/18/2011   | 4       | 15.40 | 18.07      | 3.11      | 71         | 2             | 31.00                    |
|                                             | 365BM5     | Beaver Marsh  | RM  | 8/28/2018   | 4       | 21.75 | 7.94       | 16.95     | 56         | Mod 2         | 40.25                    |
|                                             | 365BM6     | Beaver Marsh  | RM  | 8/9/2011    | 8       | 15.60 | 4.52       | 6.65      | 57         | 2             | 38.75                    |

**Table A1 (continued).** Metric scores at Sentinel Wetlands for the baseline surveys between 2008 and 2015 and the follow up survey in 2018. Plot ID = wetland ID and plot number, HGM = hydrogeomorphic class; FQAI = Floristic Quality Assessment Index score; VIBI = Vegetation Index of Biotic Integrity; %invasive = percent cover of reed canary grass (*Phalaris arundinacea*), cattails (*Typha angustifolia*, *T. latifolia*, *T. x glauca*), and giant reed (*Phragmites australis*); Avg herb richness/module = average number of species in each 10-m x 10-m module.

| Wetland Type                                            | Plot ID  | Wetland Name   | HGM | Survey Date | Modules | FQAI  | %Sensitive | %Invasive | VIBI State | VIBI Category | Avg Herb Richness/Module |
|---------------------------------------------------------|----------|----------------|-----|-------------|---------|-------|------------|-----------|------------|---------------|--------------------------|
| Rare habitat wetlands of management concern (continued) | 365BM6   | Beaver Marsh   | RM  | 8/23/2018   | 8       | 23.10 | 11.52      | 0.94      | 74         | 3             | 46.00                    |
|                                                         | 526SB1   | Stumpy Basin   | SP  | 9/26/2011   | 4       | 17.10 | 1.24       | 37.87     | 46         | Mod 2         | 29.25                    |
|                                                         | 526SB1   | Stumpy Basin   | SP  | 7/16/2018   | 4       | 15.77 | 9.64       | 50.11     | 47         | Mod 2         | 23.00                    |
|                                                         | 526SB2   | Stumpy Basin   | RM  | 9/19/2011   | 10      | 16.10 | 1.28       | 3.90      | 40         | Mod 2         | 36.25                    |
|                                                         | 526SB2   | Stumpy Basin   | RM  | 7/4/2018    | 10      | 22.06 | 2.39       | 3.33      | 54         | Mod 2         | 41.00                    |
|                                                         | 526SB3   | Stumpy Basin   | SP  | 8/24/2011   | 10      | 20.00 | 2.43       | 0.00      | 51         | Mod 2         | 30.75                    |
|                                                         | 526SB3   | Stumpy Basin   | SP  | 7/11/2018   | 10      | 19.25 | 3.62       | 0.25      | 50         | Mod 2         | 32.50                    |
|                                                         | 242VK1   | VK Lake North  | SP  | 8/4/2009    | 4       | 9.80  | 1.65       | 81.81     | 26         | 1             | 21.50                    |
|                                                         | 242VK1   | VK Lake North  | SP  | 8/16/2018   | 4       | 11.32 | 4.30       | 54.69     | 26         | 1             | 18.25                    |
|                                                         | 242VK2   | VK Lake North  | RH  | 7/21/2009   | 10      | 22.40 | 6.61       | 0.57      | 57         | 2             | 64.75                    |
|                                                         | 242VK2   | VK Lake North  | RH  | 8/14/2018   | 10      | 24.73 | 14.48      | 3.84      | 64         | 2             | 68.25                    |
|                                                         | 241VK4   | VK Lake South  | RH  | 8/5/2009    | 3       | 20.50 | 1.87       | 2.44      | 67         | 2             | 51.33                    |
|                                                         | 241VK4   | VK Lake South  | RH  | 8/16/2018   | 3       | 20.36 | 17.34      | 0.49      | 74         | 3             | 39.33                    |
| Mitigation wetlands of management concern               | 1622KR1  | Krejci         | DP  | 10/6/2014   | 4       | 12.00 | 26.09      | 0.20      | 46         | Mod 2         | 12.75                    |
|                                                         | 1622KR1  | Krejci         | DP  | 8/13/2018   | 4       | 11.78 | 30.97      | 0.25      | 49         | Mod 2         | 17.50                    |
|                                                         | 1627KR2  | Krejci         | DP  | 10/6/2014   | 4       | 11.00 | 0.09       | 1.28      | 29         | 1             | 21.00                    |
|                                                         | 1627KR2  | Krejci         | DP  | 8/13/2018   | 4       | 12.23 | 0.00       | 0.49      | 51         | Mod 2         | 22.00                    |
|                                                         | 1079RS2  | Rockside       | DP  | 8/19/2015   | 4       | 6.15  | 0.00       | 20.71     | 12         | 1             | 12.50                    |
|                                                         | 1079RS2  | Rockside       | DP  | 9/17/2019   | 4       | 8.95  | 0.09       | 51.61     | 13         | 1             | 14.50                    |
|                                                         | 968PV968 | Brookside / PV | DP  | 6/27/2008   | 4       | 9.19  | 0.00       | 66.32     | 13         | 1             | 24.75                    |
|                                                         | 968PV968 | Brookside / PV | DP  | 6/27/2018   | 4       | 3.00  | 0.00       | 97.73     | 7          | 1             | 6.50                     |
| Restoration wetlands of management concern              | 977FP1   | Fawn Pond      | SP  | 7/31/2013   | 10      | 16.60 | 0.00       | 0.06      | 66         | 2             | 56.25                    |
|                                                         | 977FP1   | Fawn Pond      | SP  | 9/15/2018   | 10      | 18.22 | 0.28       | 0.00      | 69         | 2             | 48.75                    |
|                                                         | 977FP2   | Fawn Pond      | RM  | 8/8/2013    | 4       | 8.49  | 0.00       | 69.26     | 20         | 1             | 16.75                    |
|                                                         | 977FP2   | Fawn Pond      | RM  | 9/14/2018   | 4       | 10.97 | 0.34       | 58.29     | 29         | 1             | 17.50                    |
|                                                         | 977FP3   | Fawn Pond      | RM  | 9/11/2013   | 4       | 13.60 | 66.53      | 6.16      | 58         | Mod 2         | 30.00                    |
|                                                         | 977FP3   | Fawn Pond      | RM  | 9/13/2018   | 4       | 17.18 | 27.91      | 23.98     | 64         | 2             | 27.00                    |

**Table A1 (continued).** Metric scores at Sentinel Wetlands for the baseline surveys between 2008 and 2015 and the follow up survey in 2018. Plot ID = wetland ID and plot number, HGM = hydrogeomorphic class; FQAI = Floristic Quality Assessment Index score; VIBI = Vegetation Index of Biotic Integrity; %invasive = percent cover of reed canary grass (*Phalaris arundinacea*), cattails (*Typha angustifolia*, *T. latifolia*, *T. x glauca*), and giant reed (*Phragmites australis*); Avg herb richness/module = average number of species in each 10-m x 10-m module.

| Wetland Type                                           | Plot ID | Wetland Name    | HGM | Survey Date | Modules | FQAI  | %Sensitive | %Invasive | VIBI State | VIBI Category | Avg Herb Richness/Module |
|--------------------------------------------------------|---------|-----------------|-----|-------------|---------|-------|------------|-----------|------------|---------------|--------------------------|
| Restoration wetlands of management concern (continued) | 977FP4  | Fawn Pond       | RM  | 9/11/2013   | 4       | 14.30 | 1.15       | 12.09     | 54         | Mod 2         | 36.50                    |
|                                                        | 977FP4  | Fawn Pond       | RM  | 9/11/2018   | 4       | 14.30 | 7.48       | 23.98     | 64         | 2             | 30.50                    |
|                                                        | 977FP5  | Fawn Pond       | RM  | 8/12/2013   | 10      | 20.60 | 2.97       | 0.41      | 44         | Mod 2         | 41.25                    |
|                                                        | 977FP5  | Fawn Pond       | RM  | 9/11/2018   | 10      | 19.87 | 3.87       | 0.00      | 60         | 2             | 41.00                    |
|                                                        | 969     | Pleasant Valley | SP  | 9/10/2008   | 10      | 10.90 | 0.00       | 1.04      | 45         | Mod 2         | 32.25                    |
|                                                        | 969     | Pleasant Valley | SP  | 6/26/2018   | 10      | 11.14 | 0.66       | 15.34     | 43         | Mod 2         | 26.00                    |
|                                                        | 970PV   | Pleasant Valley | RM  | 9/24/2008   | 10      | 12.30 | 0.00       | 15.68     | 33         | Mod 2         | 21.00                    |
|                                                        | 970PV   | Pleasant Valley | RM  | 7/5/2018    | 10      | 9.18  | 0.00       | 15.22     | 32         | Mod 2         | 15.00                    |
|                                                        | 1043    | Pleasant Valley | SP  | 8/27/2008   | 4       | 8.28  | 0.00       | 90.35     | 23         | 1             | 18.25                    |
|                                                        | 1043    | Pleasant Valley | SP  | 6/27/2018   | 4       | 11.33 | 0.40       | 85.68     | 25         | 1             | 12.25                    |
|                                                        | 1047    | Pleasant Valley | RM  | 7/30/2008   | 4       | 7.54  | 0.00       | 82.82     | 13         | 1             | 9.50                     |
|                                                        | 1047    | Pleasant Valley | RM  | 6/25/2018   | 4       | 1.89  | 0.00       | 79.18     | 10         | 1             | 5.75                     |
|                                                        | 1049    | Pleasant Valley | RM  | 9/17/2008   | 10      | 15.80 | 25.69      | 0.68      | 30         | Mod 2         | 39.00                    |
|                                                        | 1049    | Pleasant Valley | RM  | 6/28/2018   | 10      | 17.99 | 14.69      | 11.64     | 47         | Mod 2         | 33.25                    |
|                                                        | 540SF1  | Stanford        | RH  | 8/28/2015   | 4       | 3.92  | 0.00       | 96.70     | 10         | 1             | 6.25                     |
|                                                        | 540SF1  | Stanford        | RH  | 9/4/2018    | 4       | 0.76  | 0.00       | 91.62     | 7          | 1             | 4.25                     |
|                                                        | 540SF2  | Stanford        | RH  | 8/28/2015   | 4       | 5.58  | 2.35       | 91.39     | 7          | 1             | 9.00                     |
|                                                        | 540SF2  | Stanford        | RH  | 9/7/2018    | 4       | 7.64  | 1.83       | 85.44     | 19         | 1             | 12.75                    |
|                                                        | 540SF3  | Stanford        | RH  | 8/28/2015   | 4       | 2.04  | 0.00       | 99.75     | 10         | 1             | 2.75                     |
|                                                        | 540SF3  | Stanford        | RH  | 9/7/2018    | 4       | 0.00  | 0.00       | 100.00    | 10         | 1             | 1.25                     |
|                                                        | 540SF4  | Stanford        | RH  | 9/2/2015    | 4       | 3.74  | 0.00       | 66.98     | 13         | 1             | 7.50                     |
|                                                        | 540SF4  | Stanford        | RH  | 9/6/2018    | 4       | 1.06  | 0.00       | 72.14     | 10         | 1             | 6.00                     |

The Department of the Interior protects and manages the nation's natural resources and cultural heritage; provides scientific and other information about those resources; and honors its special responsibilities to American Indians, Alaska Natives, and affiliated Island Communities.

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**National Park Service**  
**U.S. Department of the Interior**



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**Natural Resource Stewardship and Science**

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