Supporting Actionable Decision-Making For Wetland Permitting In New York From Urban To Rural Environments

EPA Wetland Program Development Grant Final Report

New York Natural Heritage Program

A Partnership between the NYS Department of Environmental Conservation
& the SUNY College of Environmental Science and Forestry

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The New York Natural Heritage Program

The NY Natural Heritage Program is a partnership between the NYS Department of Environmental Conservation (NYS DEC); the NYS Office of Parks, Recreation and Historic Preservation; and the State University of New York College of Environmental Science and Forestry. Our mission is to facilitate conservation of rare animals, rare plants, and significant ecosystems. We accomplish this mission by combining thorough field inventories, scientific analyses, expert interpretation, and the most comprehensive database on New York's distinctive biodiversity to deliver the highest quality information for natural resource planning, protection, and management.

NY Natural Heritage was established in 1985 and is staffed by more than 25 scientists and specialists with expertise in ecology, zoology, botany, information management, and geographic information systems.

NY Natural Heritage maintains New York's most comprehensive database on the status and location of rare species and natural communities. We presently monitor 182 natural community types, 866 rare plant species including mosses, and 478 rare animal species across New York, keeping track of more than 14,200 locations where these species and communities have been recorded. The database also includes detailed information on the relative rareness of each species and community, the quality of their occurrences, and descriptions of sites. The information is used by public agencies, the environmental conservation community, developers, and others to aid in land-use decisions. Our data are essential for prioritizing those species and communities in need of protection and for guiding land-use and land-management decisions where these species and communities exist.

In addition to keeping track of rare species location, NY Natural Heritage has developed models of the areas around these locations important for conserving biodiversity, and models of the distribution of suitable habitat for rare species across New York State.

NY Natural Heritage has developed two notable online resources for biodiversity conservation: Conservation Guides include the biology, identification, habitat, and management of many of New York's rare species and natural community types; and NY Nature Explorer lists species and communities in a specified area of interest. We also manage and maintain data on invasive species, one of the greatest threats to biodiversity statewide. iMapInvasives is online tool available to land managers and the public for invasive species reporting and data management.

In 1990, NY Natural Heritage published Ecological Communities of New York State, an all-inclusive classification of natural and human-influenced communities. From 40,000-acre beech-maple mesic forests to 40-acre maritime beech forests, sea-level salt marshes to alpine meadows, our classification quickly became the primary source for natural community classification in New York and a fundamental reference for natural community classifications in the northeastern United States and southeastern Canada. This classification, which has been continually updated as we gather new field data, has also been incorporated into the National Vegetation Classification that is being developed and refined by NatureServe, The Nature Conservancy, and Natural Heritage Programs throughout the United States (including New York).

NY Natural Heritage is an active participant in NatureServe – the international network of biodiversity data centers. NatureServe's network of independent data centers collects and analyzes data about the plants, animals, and ecological communities of the Western Hemisphere. Known as natural heritage programs or conservation data centers, these programs operate throughout all the United States and Canada, and in many countries and territories of Latin America. These programs work with NatureServe to develop biodiversity data, maintain compatible standards for data management, and provide information about rare species and natural communities that is consistent across many geographic scales.

SUPPORTING ACTIONABLE DECISION-MAKING FOR WETLAND PERMITTING IN NEW YORK FROM URBAN TO RURAL ENVIRONMENTS

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Final Report

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A report prepared by the

New York Natural Heritage Program

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Cover photos (top left to right): blue flag iris (*Iris versicolor*); silver maple-ash swamp; shallow emergent marsh (foreground) and green ash tree dieback due to Emerald Ash Borer (*Agrilus planipennis*) infestation; Bottom: deep emergent marsh. Photos taken by NYNHP staff.

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PROJECT SUMMARY

Understanding factors that influence wetland condition is essential for effective management, developing appropriate restoration benchmarks, and monitoring wetland change. However, New York State (NYS) lacks formal and specific wetland assessment protocols and an understanding of how wetland condition varies among urban and rural environments. To meet this need, the New York Natural Heritage Program (NYNHP) has developed a three-tiered sampling approach to assess the condition of NYS wetlands. We refined those methods during this project and developed new protocols for assessing adjacent buffer condition and digitizing the immediate upland area of influence. At the broadest scale (Level 1), our statewide rasterized Landscape Condition Assessment (LCA) model depicts cumulative stressors associated with anthropogenic development (resolution: 30 m x 30 m pixel); high scores indicate more development/stressors (i.e., LCA>1350 is "highly developed"). We recalibrated and streamlined our New York Rapid Assessment Method (NYRAM ver. 5) that produces a wetland condition score based on stressors observed in the field and a modified LCA score with high values indicating poor condition (Level 2). Level 3 0.1-ha relevé plot surveys provide vegetation structure data and floristic quality (FQ) metrics such as weighted mean coefficient of conservatism. We developed novel automated protocols for digitizing the Area of Influence (AOI); that is, the adjacent upland that drains to a specific point in a wetland. Metrics calculated for the AOI such as maximum impervious surface and canopy cover, were compared to other Level 1 scores calculated for the contiguous wetland buffer. New rapid field protocols assessed buffer condition on the ground at 25-meter intervals from the biological wetland edge (0 m – 50 m). We expanded our statewide coverage by including partner data from the Adirondack Park Agency, New York City-based Natural Areas Conservancy, and our National Wetland Condition Assessment surveys. Using existing data, we developed a new metric to reflect wetland integrity across these multiple datasets (Level 2.5). We compared performance (significance) of all metrics using cross-level validation and developed thresholds for describing wetland condition (good, fair, and poor). Our growing wetland database includes >200 survey sites ranging from pristine dwarf shrub bogs to urban maple-ash swamps and includes a diverse flora of 800+ vascular plant species. Good floristic quality and wetland condition were negatively correlated with increasing stressors in the landscape. Recalibrating NYRAM resulted in a more robust metric that strongly correlates with FQ; and when combined with threshold analysis, we find wetlands in good condition generally have FQ scores >5.6 and NYRAM scores <38. We saw significant correlations between FQ and our AOI variables, but they performed no better than scores calculated for the contiguous wetland buffer. Further, wetlands in poor condition tended to have sparse canopy cover in the buffer immediately surrounding the wetland (<30%). Emergent and deciduous shrub wetlands strongly reflected stressors in the surrounding landscape with nearly a twofold difference in FQ scores between moderate- and minimally-developed environments. Unfortunately, localized Level 1 AOI-specific scores used in this project did not provide a clear method for quantifying the impacts from site-specific activities in upland areas on wetland condition. However, increased canopy cover in the upland buffer of the AOI was positively correlated with floristic quality. These results suggest wetland condition is influenced by several factors including land use history, landscape condition (LCA), and the overall integrity of the upland buffer (e.g., natural buffer width and canopy cover).

Research Relevance

Wetland condition and function reflect flooding conditions, landscape setting (e.g., headwater or lowland), disturbance, and human-mediated stressors. A great benefit of the New York State regulatory freshwater wetland program is its ability to influence development in areas adjacent to wetlands up to 100 feet (30.5 m) away. The importance of protecting a certain distance (buffer) between a wetland and any development for the benefit of wetland condition is well documented (e.g. Houlahan and Findlay 2004, Houlahan et al. 2006, Chu and Molano-Flores 2013). Yet we are lacking strong and specific NY-based information that quantifies the importance of development setback distances for maintaining wetland condition. Quantitative information on the relationship between activities located in upland areas and their impacts on wetland condition and wetland functions could inform regulatory actions taken in adjacent uplands.

One of our primary project goals aims at developing an understanding of how wetland anthropogenic development in the adjacent upland buffer potentially influences wetland ecological condition. The need to better understand this connection is relevant for proposed activities in DEC's regulatory decision making as well as for understanding wetland resiliency and their capacity to perform ecosystem services such as ameliorating extreme flooding. Wetlands in New York State reflect current and historical land use - factors that strongly influence present-day wetland condition (Middleton 2003, Bruland and Richardson 2005). Wetland alterations aimed at dewatering reduce flood duration, depth and extent of flooding, making altered wetlands susceptible to invasion by competitively dominant non-native species (Ehrenfeld et al. 2003). Only select plant species possess traits that permit persistence during periods of inundation and soil anoxia (Grime 1977, Blom and Voesenek 1996, Kozlowski 2002, Magee and Kentula 2005, Toogood and Joyce 2009). Plants can therefore be one proxy for wetland condition (Euliss et al. 2004) particularly in developed landscapes where water tables have been lowered (e.g., ditching, undercut rivers) and urbanized catchments generate "flashy" wetland hydroperiods (Findlay and Houlahan 1997, Ehrenfeld et al. 2003, Groffman et al. 2003, Grabas and Rokitnicki-Wojcik 2015). Habitat fragmentation and reduced natural land cover in upland buffers may also influence wetland structure and function (Pickett et al. 2001). For example, interception by trees immediately reduces precipitation throughfall by more than 15% (Chapin et al. 2002). In practice, a 70% reduction in buffer canopy cover could cause a 10% increase in throughfall and potential runoff. Assessing buffer integrity and wetland quality in a range of urban and rural environments is crucial for monitoring wetland condition.

Present-day landscape stressors can influence wetland condition, but legacies of past land use can play an important role, too. Historical land use/land cover data (LULC) suggests that nearly a quarter of our survey sites were actively used for cropland, pasture, or urban/exurban development (Price et al. 2007). These types of land use significantly decrease the native seed bank and alter edaphic processes (Middleton 2003, Bruland and Richardson 2005). Despite these past and present impacts, anthropogenically altered wetlands can maintain a diverse flora with relatively low exotic species abundance (Ehrenfeld 2005) because the physiological stressors of flooding can act as an establishment barrier to upland plant species (van der Valk 1981, Keddy 1992, Lockwood et al. 2007). Shading in woodland environments may be an additional barrier to the colonization or dominance of understory invasive plants (Martin et al. 2009, Schramm and Ehrenfeld 2010, Stinson and Seidler 2014), whose superior competitive traits make them poorly suited for less than optimal growing conditions (Grime 1977, Davis et al. 2000; e.g., low light levels, anoxic soils). Therefore, a decrease or low proportion of hydrophytes can be an indication wetland dewatering. Similarly, dominance of generalist plant species, such as those with low coefficient of conservatism ("C") values (<4), may signal ecosystem degradation or anthropogenic disturbance (Swink and Wilhelm 1994).

New York State and our partners in New York City need calibration information for wetland condition at the urban end of the landscape spectrum to best understand the effects of development on wetland condition and the condition of all wetlands statewide. Therefore, our secondary goal focuses on expanding our dataset to better reflect NYS's urban-rural environment. To meet this goal our field sampling targeted a watershed with highly urbanized areas and we incorporated partner data from the Adirondacks and New York City. Using this expanded dataset, we recalibrated our wetland assessment metrics including floristic quality (Level 3), rapid wetland condition assessment (Level 2), and Landscape Condition Assessment (Level 1), and developed preliminary thresholds for identifying reference wetlands. Characterizing wetland condition is therefore crucial for understanding and mitigating potential impacts of human-mediated alterations (e.g., urbanization, invasive insects) to ecosystem structure and function. Finally, we use the findings from the above goals to develop a set of draft rules for conservation action that can be used by the DEC freshwater wetland program. These are based on wetland type, surrounding environmental characteristics, and individual/cumulative buffer impacts.

Project Objectives

1) Compile and process data previously collected by NYNHP, Adirondack Park Agency, and New York City-based Natural Areas Conservancy (NAC). Data include vegetation plot surveys (Level 3), NYNHP's New York Rapid Assessment Method for assessing wetland condition ("NYRAM", Level 2), and generating landscape-scale metrics (Level 1).

2) Generate a remote, automated protocol for delineating the upland "Area of Influence" (AOI) relative to a wetland sampling point. Develop field protocols for rapidly assessing condition of the upland adjacent area AOI and use AOI data to generate a quantitative metric describing AOI condition.

3) Survey new wetland sites along an urban-rural gradient following our established three-tier framework, and applying our new protocols for quantifying upland buffer condition.

4) Use the expanded urban-rural dataset to refine our three-tiered metrics for assessing wetland condition in NYS.

METHODS

The methods presented here are part of a three-tiered sampling approach (Level 1, 2, 3); similar methods have been employed by federal and state agencies in an effort to develop environmental monitoring protocols (Jacobs 2010, Faber-Langendoen et al. 2012, PA DEP 2014). For Level 1 (L1), the New York Natural Heritage Program (NYNHP) developed a statewide Landscape Condition Assessment (LCA) model that cumulatively depicts key anthropogenic stressors across the NYS landscape at a 30 x 30-m resolution (Figure 1; Feldmann and Howard 2013). Rapid assessment methods (RAMs) developed for Level 2 (L2) classify and catalog anthropogenic stressors using basic quantitative air photo interpretation and qualitative field surveys. Our established New York Rapid Assessment Method (NYRAM) provides users with a relatively quick procedure for assessing the quality and condition of New York State (NYS) wetlands (Shappell et al. 2016). NYRAM field methods employ a stressor checklist that was modeled after established RAM procedures developed for Mid-Atlantic States (Jacobs 2010, PA DEP 2014). We developed new protocols for assessing wetland buffer ecological integrity through a rapid field protocol, and remotely delineate immediate upland Area of Influence (AOI) that drains to a specific location in a wetland. Level 3 (L3) relevé sampling protocols modified after Peet et al. (1998) captured detailed vegetation structure and floristic biodiversity. Level 1 and Level 3 data were used to refine and support the Level 2 RAMs presented here.

Level 1 Metrics

Our previous work has demonstrated strong correlations between landscape stressors modeled in the LCA and on-the-ground floristic quality metrics (Shappell et al. 2016). Our established L1 LCA scores use zonal statistics calculations to produce a mean score based on a 540-m radius buffer (hereafter, "LCA540") around each Level 3 site. The ArcGIS (10.3) Zonal Statistics tool produces basic descriptive statistics (mean, max, min, and variance) based on pixel scores within a defined area (polygon). LCA zonal statistics were also calculated for each site's upland AOI and tested for performance compared to LCA540 via cross-level validation (for example, does LCA-AOI correlate more strongly with floristic metrics compared to the LCA540 score?). Additional rasterized layers tested in developing AOI metrics include 2011 impervious surface, 2001 canopy cover (NLCD

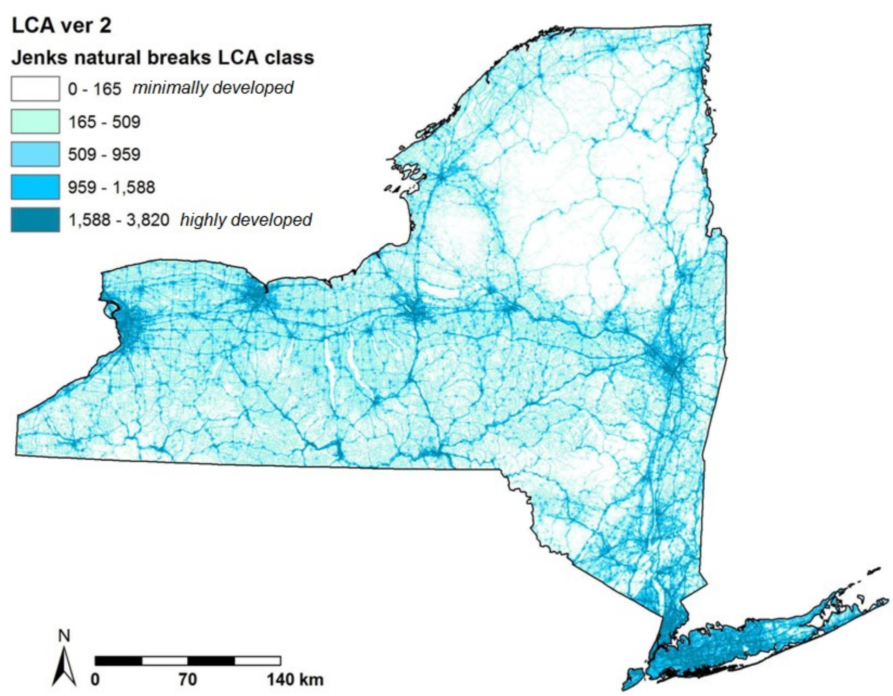

Figure 1: The landscape condition assessment (LCA) model developed by Feldmann and Howard (2012) incorporates 13 human land use input classes. White and mint green/aqua colors indicate least developed/most natural while medium to dark blue show highly developed areas. Model resolution: 30 m x 30 m. Color categories follow Jenks (1967) natural breaks. This GIS rasterized spatial data layer may be downloaded at nynhp.org/data.

2011, Homer et al. 2015), and topographic range based on the statewide digital elevation model (DEM 10m). Proportion of wetland area in the original AOI was assessed as a possible covariate (not applicable to the upland-clipped AOI, Figure 2).

Contiguous wetland polygon data, available for a subset of our dataset, were used to develop additional Level 1 metrics. For the Genesee watershed polygons were based on unpublished NYS DEC wetland boundaries (2016); elsewhere, they were developed by dissolving adjacent wetland polygons (NWI 2016). Wetlands that met the following criteria were removed from the final contiguous wetland dataset: very large wetlands (>2125 ha/5250 ac); those with more than one sample point/polygon; and sites within linear riverine corridors (headwater complexes and backwater soughs were retained). The final contiguous wetland dataset included 151 sites. Outward, upland buffers extending 50-, 75-, and 100-meters (328 ft) from the wetland boundary were created and used to calculate zonal statistics describing percent (%) canopy cover (2001) and impervious surface (2011). The "upland" Area of Influence (AOI) was created by "erasing" the area where the AOI and contiguous wetland polygon overlapped (hereafter referred to as the upland AOI). To compare contiguous buffer scores with upland AOI buffer scores we clipped buffer polygons to the upland AOI boundary (Figure 2).

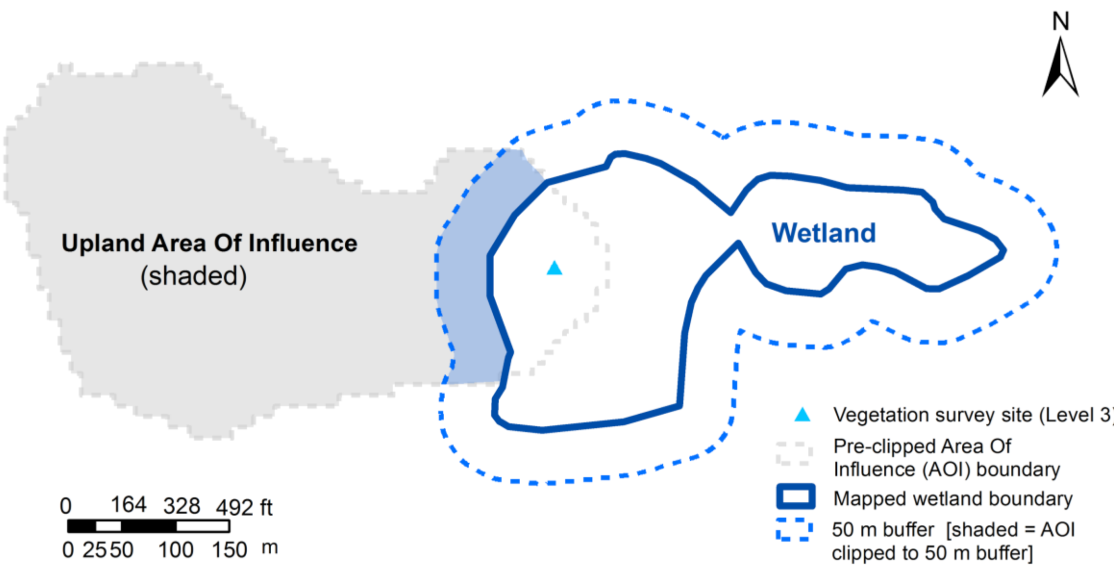

Figure 2: Level 1 metrics generated remotely are centered on our vegetation survey sites (Level 3). A digitized Area of Influence ("AOI", described below) was generated for each survey site (n = 295); upland AOIs were generated for sites with contiguous wetland polygon data (n = 151). Upland (outward) buffers were used to described canopy cover and impervious surface in the adjacent uplands. Data analysis explored whether metrics from the contiguous buffer (blue dashed) or AOI-clipped buffer (blue shading) correlated more strongly with floristic quality (Level 3) and wetland condition (Level 2).

Estimating the Upland Area of Influence (AOI) in GIS

An important goal of this project was to develop a way to estimate, in a GIS, the upland area immediately adjacent a wetland that we hypothesize is most likely to have the greatest effect on the assessed area within the wetland. We developed a series of Python scripts to accomplish this goal. These are provided in Appendix D and we describe the steps these scripts follow in the text below.

The method requires only two initial inputs: the sample points at each wetland; and a digital elevation model (DEM) that describes the topography in and around each wetland. The method also requires many ArcGIS python tools as well as an additional toolbox called Terrain Analysis Using Digital Elevation Models, or TAUDEM (Tarboton 2016).

In order to have the best elevation models possible, we researched the availability of LiDAR – derived elevation models from the New York State GIS clearinghouse. While coverage for the state for these very high resolution DEMs continues to increase (see https://gis.ny.gov/elevation/lidar-coverage.htm), at the time of this analysis, many of our wetlands were not covered by DEMs created by LiDAR. Thus, in our final models, we used the 10-meter DEM that was available throughout the state.

The steps to create the AOI for a point within a wetland are as follows:

1. Buffer the point 1000 meters to create a circle polygon.

2. Clip out a disk from the DEM using this circle polygon.

3. Within the disk, complete a 'pit removal' step to ensure water flows throughout. This uses the TauDEM tool "PitRemove."

4. Calculate flow direction for the entire disk. This uses the TauDEM tool "DinfFlowDir."

5. Using flow direction, calculate the contributing area within the disk to a 50-meter circle at the center of the disk (the sample point). This uses the TauDEM tool "AreaDinf."

6. Convert the contributing area raster to polygon and clip the contributing area to a 540-meter radius, our specific area of interest.

The step that calculates the contributing area is the key step. Contributing area is the specific catchment area for the target point. This means that all water that flows to the target point within the 1000-meter disk will flow over the lands described by this tool. At all other spots on the ground, water flows elsewhere.

Basic descriptive metrics calculated for each AOI aimed to illustrate their physical characteristics such as area (ha) and range in elevation (max-min). Using publicly available rasterized data layers and the Zonal Statistics tool in ArcGIS (e.g., mean, minimum, maximum, range) we calculated and retained the following metrics for Level 1 analysis of the AOI: mean LCA (hereafter named "LCA-AOI"); percent canopy cover (NLCD 2001); and maximum impervious surface cover (NLCD 2011). The latter score reflects the maximum potential impact of impervious surface on the wetland. We incorporated this score into our final buffer rapid assessment score. Using Level 3 floristic quality as our response variable, we compare LCA540 scores to LCA-AOI scores to see which Level 1 LCA metric had a stronger correlation.

Level 2 Protocols

New York Rapid Assessment Method (NYRAM)

NYRAM version 4.2 incorporates onscreen (Part A) and field (Part B) components that broadly assess hydrology, fragmentation, vegetation composition, and water quality (Appendix A). The field stressor checklist encompasses a broad range of potential stressors that may influence natural wetland structure (e.g., plant species composition) and function (e.g., ground water recharge, nutrient cycling), while providing flexibility for practitioners to document unique stressors present at their assessment site. Variables are weighted and rolled into a final score with low scores indicative of minimal anthropogenic disturbance and good ecological condition.

One of the goals of this project was to assess performance of our Level 2 NYRAM scores in urban settings. Since it was last assessed in 2016 (NYRAM ver. 4.2, Shappell et al. 2016), our NYRAM dataset has tripled, including greater coverage across NYS and along an urban-rural gradient. This recalibration process relied on cross-level validation (e.g., NYRAM vs. floristic quality scores), and explored the utility of replacing the original onscreen assessment (Part A) with an automated LCA540. Using LCA scores for Part A would make the method more rapid and eliminate potential variance among observers. Field methods for NYRAM remain the same, but metric recalibration, including scaling the final score to range between 1 and 100, are significant. This updated NYRAM metric will hereafter be referred to as "NYRAM5".

Upland Adjacent Area Rapid Assessment Method (UP-RAM)

A primary goal of this project was to develop a rapid protocol to characterize the ecological condition of uplands immediately adjacent to the wetland edge. For the purpose of this study we used a biological definition for identifying the wetland edge, the location where wetland plants are no longer the dominant species (i.e., <50% facultative wetland [FACW] and obligate [OBL] species). The first buffer plot ("BP0") was placed at the nearest wetland boundary relative to the Level 3 survey site (Figure 3). Subsequent buffer plots (BP) were placed 25 m and 50 m upslope of BP0. Buffer plot strata composition and stressor check list variables were modeled after NWCA 2016 buffer plot protocols. Although we occasionally used paper field forms (see field forms in Appendix B), we primarily used a Geopaparazzi digital application form developed in-house for this methodology. Digital buffer plot data were then uploaded to our NYNHP wetland database.

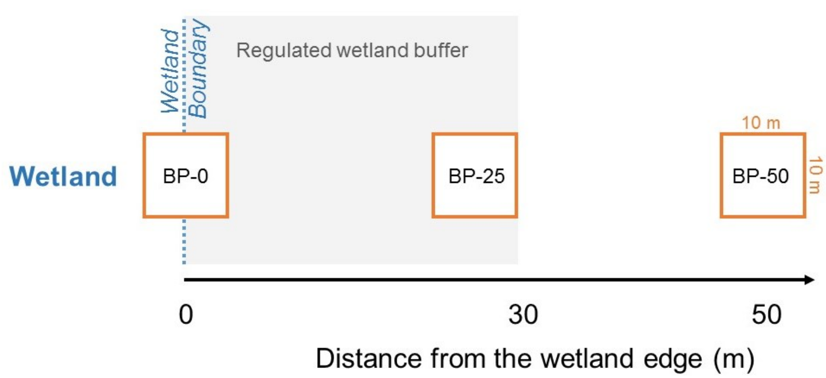

Figure 3: Schematic of the adjacent areas rapid assessment buffer plot layout. The biological wetland boundary was identified as the location where wetland plants were no longer dominant.

Adjacent area upland RAM (UP-RAM) metrics were developed to reflect heterogeneity within the upland adjacent area, focusing on 25 meters from the biological wetland edge. Field variables comprised approximately half of a given site's RAM score (51% ± 5%). Maximum impervious surface scores for the digitized Area of Interest (AOI) were also included in the score. Higher RAM scores indicate greater edge permeability (i.e., less structural complexity), greater abundance of anthropogenic land use, stressors, invasive plants, and upslope impervious development. We sampled all BP0 and BP25 (n = 34), but access constraints prevented us from completing BP50 strata cover for five of the survey sites. The final metric therefore used quantitative data from BP0 and BP25 and qualitative land use land cover (LULC) classes form all three buffer plots. The proportion of plots with "natural" LULC was used as a crosscheck in developing the field portion of UP-RAM (pre-score), with intact natural buffers scoring lower than those dominated by human land use. Field pre-scores were capped at 80 pts and the remote AOI metric at 30 points; to aid interpretation final UP-RAM scores were scaled to range from zero to 100. Final scoring methods for UP-RAM are outlined in Appendix B, Table 2, and Table 3 and adapted from previous RAM methods as well as Tiner (2011).

Level 3 Protocols

Our protocols are modified after the Carolina Vegetation Survey (Peet et al. 1998) approach of sampling subplots within a larger 20 x 50 m relevé macroplot. In four 10 m x 10 m subplots, we collected a complete species list by strata with percent cover and tree diameter for stems ≥10 cm DBH (Diameter at Breast Height = 1.3 m). Within the entire relevé macroplot, we recorded percent cover for all residual species not observed in the focused subplot surveys. Live and dead tree canopy basal area (m^2ha^{-1}) was calculated based on tree DBH. New field surveys completed under this project took place between June and September during 2016 and 2017.

Field sampling

Study area

New sample sites focused on non-tidal freshwater systems primarily within the Genesee watershed and Rochester, NY, metro area (Figure 4). Watershed selection followed NYS DEC Division of Water's established rotating assessment cycle and targeted a watershed that would meet our urban-rural requirements. The Genesee watershed spans approximately 100 miles from its source

Table 1: Weighting for the adjacent area upland rapid assessment method (UP-RAM) was adapted from established protocols, including NYRAM, NWCA 2011 buffer plot weighting, and buffer width scoring (Tiner 2011, NovaWET).

Natural buffer		**Invasive dominance**		**Buffer Plot [BP] land use class weighting**			
Width (m)	pts	Cover class (%)	pts	LU class	BP0 pts	BP25 pts	BP50 pts
<8	8	Absent	0	Natural	0	0	0
8-15	4	<10	2	Light	6	2.64	1.38
15-100	2	10-40	4	Active	12	5.28	2.76
>100	0	40-75	6	Intensive	20	8.80	4.60
		>75	8	Impervious	30	13.20	6.90

headwaters in Pennsylvania to Lake Ontario. The Mount Morris dam on the Genesee River divides the southern portion (upper basin) from the northern portion (lower). Moving south from the urban center of Rochester, NY, exurban and rural land uses tend to dominate. The Genesee watershed spans two main ecoregions: the lower basin within the Eastern Great Lakes Lowlands; and the upper basin in the Northern Allegheny Plateau. Agriculture and forest land covers dominate the watershed (52% and 40%, respectively) with wetlands only accounting for about 1% (Genesee/Finger Lakes Regional Planning Council 2004).

Sample frame

Our sample frame included the following National Wetland Inventory (NWI) non-tidal, non-riverine freshwater community types: emergent (EM); broad-leaved deciduous (FO1) and needle-leaved evergreen (FO4) forested wetlands; and scrub-shrub (SS) (U.S. Fish and Wildlife Service 2015). To ensure we captured a range in anthropogenic development, we stratified our sample frame by Landscape Condition Assessment (LCA) score and wetland size. Adjacent polygons of the target wetland types were merged prior to polygon size (ha) and mean LCA calculations in ArcGIS (ESRI 2014). Wetlands were then binned by wetland size (<12, 12-28.3, >28.3 ha) and polygon mean LCA score (LCA <600; 600-1200; and >1200). The size bins follow the Jenks natural breaks classification method (Jenks 1967) and the LCA bins were developed following Shappell et al. (2016). Because we were targeting the upland adjacent area, we limited our sample frame polygons to >40 and <140 m from the wetland edge, effectively producing a narrow ring in which the sample draw (points) could be placed.

Sample draw and site evaluation

We submitted the pool of potential wetlands to EPA statistician Tony Olsen to prioritize wetland site selection. The final sample pool used the Generalized Random Tessellation Stratified (GRTS) sample design (Stevens and Olsen 2004) stratified by pre-field LCA bins and wetland size bins. The GRTS method produced a spatially balanced sample draw and provided up to 10 random sample points within each wetland relative to wetland size. Wetland sites and sample points were surveyed in numerical order of the sample draw with overdraw (back up) points used when a site did not meet our evaluation criteria or we were unable to secure permission to access the land. Because this project targeted an urban-rural gradient, sample points surrounded by agriculture (>2/3) were removed from the sample frame during preliminary site evaluation. This study focused on non-riverine vegetated wetlands that were further than 30 m from large rivers flowing surface water (Conte-Ecology, U.S. Geological Survey 2015). Selected sites ranged in hydroperiod classes (*sensu* Cowardin et al. 1979) from temporarily flooded to semipermanently flooded, however, 74% of all sample points were classified as saturated to semipermanently flooded by NWI maps (U.S. Fish and Wildlife Service 2015).

Securing landowner access was a critical step in the site selection process. During this project, approximately 225 access request letters were mailed to land owners in the Genesee watershed and Rochester metro area. About one in three landowners replied to our letters, which is a relatively good response rate. Of those that responded, 26% agreed to grant access and 5% denied access. Thanks to private landowners' generosity, nearly 80% of our sampled points occurred on private land.

Partner data

We worked closely with the Adirondack Park Agency (APA) as they developed and implemented wetland assessment protocols for a USEPA Wetland Program Development Grant (CD-972080-00).

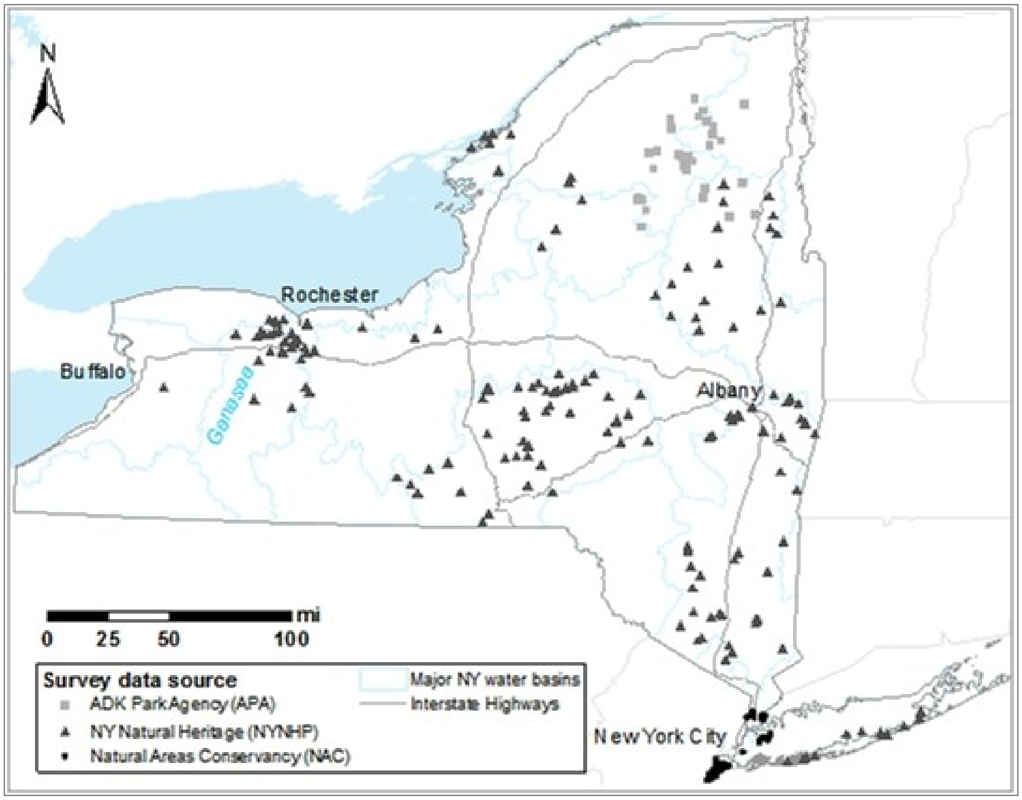

Figure 4: The Rochester metro area and Genesee watershed were targeted during this project's 2016-2017 sampling season. Sample sizes from the various data sources are outlined in Table 2: A summary of compiled data based on data source: New York Natural Heritage Program (NHP), US Environmental Protection Agency National Wetland Condition Assessment (2011, 2016), Adirondack Park Agency (APA), and New York City-based Natural Areas Conservancy (NAC). Data collected by NYNHP for NWCA is included as "NYNHP" data in the results and discussion. Field surveys for this project were conducted 2016-2017.

Following our same Level 3 and NYRAM protocols, they surveyed 36 sites within the Adirondack Park between 2013 and 2016. Our NYNHP database serves as a repository for their vegetation plot data, so processing included final QAQC and taxonomy updates as needed. A backlog of NYRAM field forms completed during the APA WPDG were finished and entered into our wetland condition database. Wetland data collected in 2012 by NYNHP as part of a NYS DEC Division of Water grant was also updated to match current taxonomy.

In June 2016 NYNHP completed a final report classifying ecological assessment plot data collected by the Natural Areas Conservancy (NAC) in New York City, NY (Edinger et al. 2016). We selected a subset of their non-estuarine dataset based on the following criteria: >25% plant cover, >50% hydrophyte cover (FAC, FACW, OBL, as defined by the National Wetland Plant List, (US Army Corps of Engineers 2018)), and points were a minimum of 400 meters apart. Based on these parameters, some of NAC's "upland" sites met our biological definition of a wetland community. Data preparation included taxonomy crosswalk from NAC's standard (USDA PLANTS) to NYNHP's standard (Werier 2017). Tree stem area data were converted to percent cover based on species-specific DBH × cover data in our database, and crosschecked by comparing transformed cover to average cover for a given community. Residual species noted as presence absence data were assigned a cover value of 0.01%. Among the NAC sites 261 plant species were observed, 15% of which are nonnative invasive species. Forested wetlands are the most prevalent community class in the NAC dataset used for analysis (94%), followed by emergent, and scrub-shrub systems.

The New York Natural Heritage Program also assisted the first USEPA National Wetland Condition Assessment (NWCA) efforts in 2011 and led the NYS NWCA surveys in 2016. Data from 15 high quality NWCA 2011 sites were used to develop Element Occurrence Records (EORs) in NatureServe's online Biotics database. Data processing from these 2011 survey was minimal and limited to taxonomy updates. Following the 2016 season, we manually entered all of our Level 3 vegetation survey and NYRAM wetland assessment data (Level 2). Our current NWCA dataset includes 25 unique sites distributed across New York State, including palustrine as well as estuarine communities. Vegetation survey methods are outlined in the NWCA 2016 field operation manuals (US EPA 2016).

Table 2: A summary of compiled data based on data source: New York Natural Heritage Program (NHP), US Environmental Protection Agency National Wetland Condition Assessment (2011, 2016), Adirondack Park Agency (APA), and New York City-based Natural Areas Conservancy (NAC). Data collected by NYNHP for NWCA is included as "NYNHP" data in the results and discussion. Field surveys for this project were conducted 2016-2017.

	Level 1	Level 2		Level 3	
Data source	LCA540 & Remote AOI	NYRAM	UP-RAM (field)	Plot surveys	Survey years
NYNHP	144	90	34	144	2012-2017
NWCA	25	14		25	2011 and 2016
APA	36	36		36	2013-2016
NAC	91			91	2012-2015
Total *n*	296	140	34	296	

Statistical Analysis

Biodiversity metrics

Vascular plant nomenclature was updated prior to analyses per Werier (2017). Richness values ("*S*") presented here includes vascular and nonvascular plants identified to genus or species. Each species is assigned a coefficient of conservatism value ("*C*" value) that reflects a species' fidelity to a remnant plant assemblage in NYS (i.e., 10 = highly conservative/narrow ecological tolerance, 0 = cosmopolitan) (Swink and Wilhelm 1994). *C* values for a given site were averaged ("mean *C*": $\overline{C}$), and weighted by the proportion ("*p*") of cover they contributed to a given site ($\overline{C_{wt}}$, Equation 1). NYS botanists produced these C-values (reported by Ring 2016) with funds from the EPA Wetland Program Development Fund (EPA CD96294900-0). As with other studies, we have found C-value metrics perform more strongly in wetland systems than Floristic Quality Assessment Indices (e.g. Matthews et al. 2005, Miller and Wardrop 2006, Bried et al. 2013, Shappell et al. 2016, Chamberlain and Brooks 2016), so we use them exclusively, referring to them as our floristic quality metrics.

Equation 1

$$\overline{C}_{wt} = \sum_{i=1}^{S} \frac{p_i C_i}{S}$$

Calibration of reference metrics

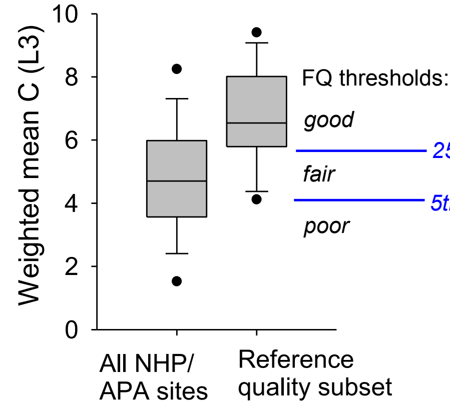

Figure 5: Level 3 weighted mean C scores varied greatly among within our dataset. A subset of reference quality sites (n = 82) were selected and used to develop condition thresholds. Median = horizontal line; points = the 5th and 95th percentiles.

All NYRAM wetland sites were assigned a Best Professional Judgment (BPJ) disturbance rating of very high (6) to least disturbed (1). Proxy BPJ ratings were developed for 10 sites where detailed Element Occurrence Record (EOR) ratings were available (NYNHP Biotics database, 2018). NYRAM and EOR rating aligned at 23 sites where data co-occurred, supporting our qualitative categorization of "excellent/very good" quality sites (1/2 or A/B). Reference standards presented here follow NWCA protocols (NWCA 2011 technical support), which develops thresholds based on reference site percentiles. For example, Figure 3 illustrates the full spread in our NHP/APA Level 1 scores; by comparison, the range in LCA540 scores is narrower in our high quality wetlands. To accommodate the expanded urban dataset provided by NAC, we used the 75th percentile of our poor quality sites (disturbance rating = 5/6) as our upper threshold for "poor". Therefore, our final LCA540 thresholds are <300, 300-1350, and >1350. As a crosscheck mean LCA scores calculated for NYS urban areas/clusters (US census 2010) falls just above our upper threshold (1420 ± 20 standard error). By contrast, LCA scores for the Adirondack and Catskill Parks averages 135 (± 20), well within our minimally-disturbed LCA class, and NYS agricultural districts (Cornell IRIS 2018) fall in the middle with an average LCA score of 679 (± 6).

Level 2.5 RAM

While recalibrating our NYRAM metrics we identified key factors that contributed to wetland condition scores, including invasive species richness and dominance, LCA540 scores, and the encroachment of upland plant species. The latter phenomenon is indicative of urban wetlands (e.g. Groffman et al. 2003) and therefore particularly pertinent to our expanded urban dataset. Field data used in this metric were collected during Level 3 vegetation sampling (NHP, APA, NAC), but have the potential for rapid collection without completing an intensive vegetation survey. Invasive species

Table 3: Level 2.5 RAM (Equation 2) scores include weighted scoring, outlined below. Data from the Level 3 vegetation surveys were used to calculate nonnative invasive plant relative dominance (INVRDOM = invasive cover/total site cover) and relative hydrophyte richness (% FAC, FACW, and OBL).

Invasive weighted scoring		Hydrophyte weighted scoring	
Relative dominance	Weight (INV_w)	Relative richness ($S_{\%WET}$)	Weight (WET_w)
<1%	-15	>75%	-2
< 5%	-8	50-75%	0
< 20%	-3	<50%	2
20-75%	0	<40%	7
>75%	+15	<25%	17

richness (S_{INV}) and their relative contribution to total plant cover were calculated for all sites (INV_{RDOM} = % invasive cover/total site cover). Invasive richness scores are capped at a maximum of 15 species (observed max = 12). The relative contribution of hydrophytes ($S_{\%WET}$) to site richness (*S*) counted all facultative and obligate wetland plant species (FAC, FACW, OBL; NWPL 2016).

Equation 2

$$Level\ 2.5\ RAM = \left[INV_w + S_{INV[\max 15]}\right] + \left[WET_w\right] + \left[log_{10}(LCA540 + 1) * 15\right] + 21$$

Data analysis

Trends among and within indictors from each of the three levels were analyzed using correlation analysis and pairwise comparisons. Unless noted, data are presented as mean ± one standard error of the mean (SEM). Analyses were completed in SPSS (IBM Corp 2015), and supported by SigmaPlot graphing software (Systat Software Inc. 2008). Scatter plot graphs were used to ensure the majority of the data points fell within the 5th and 95th percentiles or confidence intervals (correlation or regression), and that a few outliers were not driving the significant correlation trend; based on these guidelines outliers were removed prior to final analysis. Boxplot graphs presented here indicate the median line, 5th and 95th percentiles (error bars), and outliers (dots or asterisks).

Nonparametric correlation analysis employed Spearman rank, the correlation coefficient (hereafter r_s), with values ranging from +1 to -1, and zero indicating no correlation. A significance level of $p < 0.01$ was used for Spearman's correlation analysis. Similarly, Tukey or Dunnett adjustments were applied to pairwise analysis of variance (ANOVA) tests (Zar 1999). A significance level of $p < 0.05$ was used for linear regression and one-way ANOVA analyses. Data that violated ANOVA assumptions were transformed or analyzed with Kruskal-Wallace (K-W) one-way analysis of variance on ranks using a significance level of $p < 0.05$. Significant pairwise differences are indicated in figures by differing letters on the boxplot or the x-axis label.

RESULTS AND DISCUSSION

Our results begin by focusing on our 2016-2017 survey sites where we developed and deployed our upland rapid assessment buffer plots. Wetlands in this subset of the data were distributed along an urban-rural gradient and were generally in fair or poor condition. Prior to UP-RAM analysis, we performed cross-level validation (e.g., floristic quality vs. NYRAM) testing and confirming our metric's utility in an urban/exurban environment. We then combined all of our previous data as well as our partner's data, assessing metric performance (correlations) among our three-tiered metrics. The combined dataset is then divided to discuss differences among wetland community types, Level 1 buffer metrics (e.g., % canopy composition), and historical land use legacies.

Summary of new survey sites and adjacent area metrics

Our three-tiered assessment and UP-RAM protocols were completed at 34 sites during the 2016-2017 field seasons. Nearly all survey sites were in the Genesee watershed and Rochester metro area (n = 32, hereafter our "Genesee" sites) with two additional sites sampled in eastern NYS. Wetland size among our Genesee wetlands ranged from 5.9 to 126.2 hectares, with an average size of 24.5 ha (60.6 ac). Each of the LCA×Size bins had a minimum sample size of four wetlands, with the exception of medium and large urban wetlands, which only had two sites and one site, respectively.

Large wetlands with high LCA scores were less common in the initial sample frame due to the inherent nature of urban development. Additionally, large areas of unfragmented green space tend to have lower LCA scores even if they are in urban areas because they act as a natural buffer for themselves. Final LCA540 scores reflect our desired development gradient – from a large wetland in a nature preserve (LCA540 = 84) to our smallest urban wetland (LCA540 = 1924; mean = 1028 ± 85). As a crosscheck we confirmed that the contiguous wetland LCA scores developed for the sample frame were positively correlated with the final LCA540 scores ($r_s = 0.836$, $n = 32$, $p<0.001$).

Forested deciduous swamps (FO1), particularly silver maple-ash swamps (n = 12) and headwater floodplain complexes (n = 5), were the most common communities. Swamps were primarily mature forests, with standing live basal area averaging 35.5 m^2ha^{-1}. In forests hardest hit by the invasive Emerald Ash Borer (*Agrilus planipennis*) the proportion of dead standing basal area surpassed 20%. Nonnative invasive plants were present in all study sites, averaging 6 species and 14% relative cover per site. Multiflora Rose (*Rosa multiflora*) occurred in nearly every macroplot (81%), followed by Common Buckthorn (*Rhamnus cathartica*, 66% of sites), invasive shrub honeysuckles (*Lonicera morrowii* and *L. maackii*), and Common Privet (*Ligustrum vulgare*). Deciduous shrub swamps (PSS1) and emergent marsh (PEM) wetlands comprised only 10% and 20%, respectively, of our random sample points. Cattails (*Typha* spp.) dominated two of the emergent wetlands.

Indicator performance

Wetlands in the Genesee dataset were generally in fair condition with weighted mean C scores averaging 3.6 (±0.3). Only five sites in this dataset had stressor scores low enough to be considered in "good" condition (NYRAM5 < 53). Cross-level analysis identified strong relationships between floristic quality, LCA, and NYRAM5 scores. In this relatively small urban dataset (n = 34), mean C scores correlated equally strong with LCA-AOI and LCA540 (both: $r_s = -0.440$, $p = 0.009$), but weighted C had a marginally stronger negative trend with LCA-AOI compared to LCA540, though neither were significant ($r_s = -0.333$ vs. $r_s = -0.295$, $p > 0.05$). Our updated NYRAM5 metric expressed significant negative correlations with both mean- and weighted-mean C ($r_s = -0.442$ and $r_s = -0.533$, respectively), and both LCA metrics (both: $r_s > 0.580$, $p < 0.001$). These findings support our previous research (Shappell et al. 2016) and the metrics' utility for validating the AOI UP-RAM scores. In this subset of the data no significant correlations were observed between UP-RAM and the Level 2.5 metric or NYRAM5 ($p > 0.05$), so it was not used in analysis of the UP-RAM.

<u>Upland adjacent area metrics</u>

Wetlands in poor condition tended to have buffers in poor condition. Rapid assessment pre-scores based on field data were significantly correlated with wetland floristic quality scores (Figure 6A). This trend was strengthened by the inclusion of an AOI metric reflecting the maximum impact of impervious surface development within the upland area of influence (Figure 6). Impervious surface scores alone were weakly correlated with floristic quality compared to the combined UP-RAM score ($r^2 = 0.255$ vs. $r^2 = 0.392$, respectively). The minimum distance between our Level 3 wetland survey macroplot and the wetland edge ranged from 20 to 100 meters (63 m ± 5 m). Active management practices such as lawn mowing were observed along the biological wetland edge at seven sites (21%; e.g., Figure 8, right). Only 12% of sites had natural cover at 50 m and less than a third of sites had natural land cover extending 30 m from the wetland edge (Figure 7).

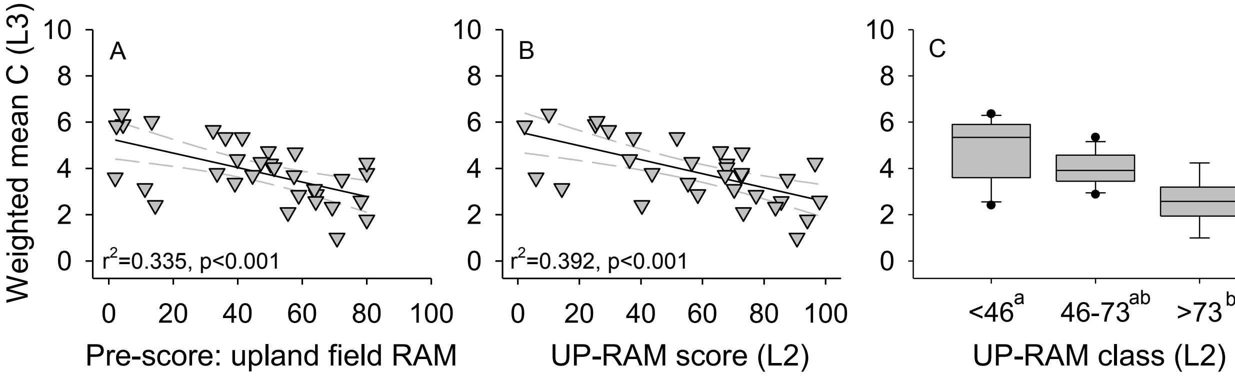

Figure 6: A) Degraded upland buffer condition was associated with lower wetland floristic quality scores, shown here as weighted mean C [F1,30 = 15.118; y = 5.29 – (0.0313*x)]. B) This trend was strengthened by including maximum impervious surface value in the final UP-RAM [F1,30 = 19.374; y = 5.589 – (0.03102*x)]. C) UP-RAM threshold classes demonstrate significant difference among the highest quality wetlands (<46, n = 14) and wetlands in poor condition (>73, n = 9). Letters beside the UP-RAM class indicate significant pairwise difference (K-W: H = 13.547, p = 0.001).

Observed UP-RAM scores ranged from 2.2 to 98 with lower scores indicating lower impervious development in the AOI and greater ecological integrity of the upland adjacent area. General land use/land cover type such as natural, actively managed, and impervious surface were scored for all three BPs (0, 25, and 50-m) and included as part of the pre-score field RAM (Figure 6). As expected, we see significantly higher scores where human land use dominated more than a third of the 50-m buffer (Figure 7). Floristic quality scores also declined with declining buffer condition (Figure 6 B-C). Wetlands in poor condition tended to also have poor buffer condition (NYRAM vs. UP-RAM: r_s = 0.678, p < 0.001), a trend that was particularly strong for deciduous forested wetlands (n = 21, r_s = 0.709, p < 0.001). Buffer condition increased slightly with increasing canopy cover in the 50-m upland buffer (r_s = -0.303, p = 0.086). Excluding sites with "excellent" buffers (UP-RAM<15), we see buffer condition scores tends to improve with increasing canopy cover (n = 27, r_s = -0.389, p = 0.049). Interestingly, LCA-AOI and LCA540 had similar, positive correlations with NYRAM5 scores (r_s = 0.587 and r_s = 0.605, respectively; p <0.001), suggesting the more easily calculated LCA540 score is a good proxy for development in the AOI.

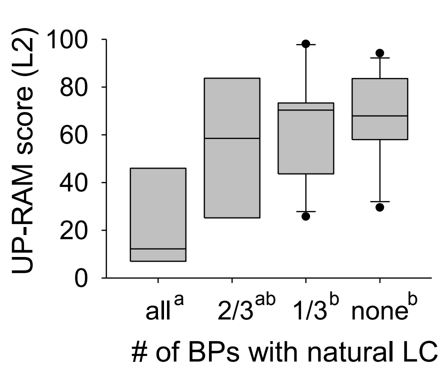

Figure 7: Upland rapid assessment (UP-RAM) scores were higher when natural land cover was <60% within 50 meters of the biological wetland edge ($F_{3,28}$ = 3.914, p = 0.019).

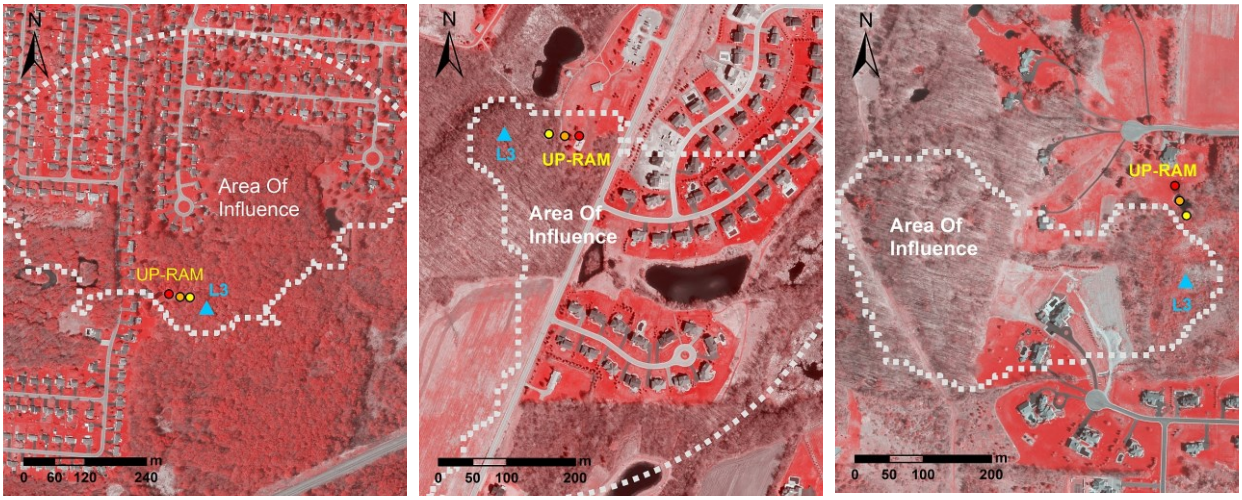

Figure 8: Example survey sites from the Genesee watershed, illustrating the digitized "Area of Influence" (AOI: dashed white line) relative to the Level 3 (L3) vegetation surveys. AOI size from left to right: 35.9 ha, 24.5 ha, and 12.8 ha. Upland buffer plots (BP) were placed at the nearest upland/ wetland boundary relative to L3. At some sites (right), buffer plots were placed just outside of the AOI due to either accessibility (permission) or boundary proximity. Consecutive UP-RAM points reflect the biological wetland boundary (BP0: yellow) and upslope placement of BP25 (orange) and BP50 (red).

Combined analysis of all NHP and partner data

There were significant relationships among all of our three-tiered wetland assessment metrics (Figure 9). Recalibrating NYRAM produced strong correlations between our wetland condition assessment (NYRAM5) and floristic quality scores (Figure 9A). Compared to the original metric (NYRAM4.2: $r^2 = 0.432$, $F_{1,137} = 106$), we see improved model fit as demonstrated by a narrower (smaller) standard error of the regression value (1.472 vs. 1.619). Using thresholds we can classify wetland condition as good, fair, and poor (NYRAM5 <38, 38-70, and >70; Table 4). When combined with weighted mean C thresholds, we identify our highest quality wetlands as those with weighted mean C scores >5.6 and NYRAM5 scores <38 (Figure 9A). Wetland condition scores exhibited a three-fold increase in highly developed landscapes (mean NYRAM5: 79 ± 3, n = 12) compared to minimally developed landscapes (22 ± 2, n = 60; Figure 9C).

One of the primary drivers for developing the wetland integrity index (Level 2.5) was to have a metric comparable to NYRAM that we could apply to our partners' data. We succeeded in finding significant positive correlation between the two rapid wetland metrics highlighting the potential utility of this new method, particularly in urban settings ($r_s = 0.879$, n = 140, $p < 0.001$). The wetland integrity index (Level 2.5) exhibited a stronger negative correlation with Level 3 mean C (Figure 9D) compared to weighted mean C ($r_s = -0.628$, $p < 0.001$ vs. $r_s = -0.506$, $p < 0.001$, respectively). We see a slight positive correlation between Integrity scores (L2.5) and AOI impervious surface ($r_s = 0.536$, n = 295, $p < 0.001$), however separating the NHP/APA and NAC datasets shows only the former has a significant positive correlation ($r_s = 0.591$, $p < 0.001$; $r_s = -0.121$, $p > 0.05$, respectively).

Size of the AOI ranged from 0.8 to 62.4 ha (20.1 ± 1 ha) and was not correlated with any of our floristic quality metrics (n = 295, $p > 0.05$). Wetland condition NYRAM5 scores, however, were

Table 4: This table summarizes common metrics used in this reporting. Our wetland program employs USEPA's three-tiered approach to wetland assessment, from broad landscape-scale metrics that can be generated remotely (Level 1), to rapid assessment methods (Level 2), and intensive vegetation plots surveys (Level 3). Landscape Condition Assessment (LCA) is a spatial model depicting cumulative stressors in the landscape; LCA540 is the average pixel score within 540-m of the Level 3 survey point. The wetland integrity Index (Level 2.5) uses select Level 3 vegetation data that could be rapidly assessed in the field, plus a modified LCA540 score. Condition classes were developed based on the reference percentile method described in the methods. Excellent and very poor scores indicated in brackets [] were not significantly different and therefore combined with the neighboring group for analysis. We recommend a minimum of two different assessment levels be used to accurately characterize wetland condition.

Level	Metric/Variable	Score range	Excellent	Good	Fair	Poor	Very poor
L1	Landscape Condition Assessment [LCA540]	0-2358*	[<80]	<300‡	300-1350	>1350	
L2	New York Wetland Condition Rapid Assessment Method for [NYRAM5]	1-100	[<14]	<38	38-53	>53	[>70]
	Upland Buffer Rapid Assessment Method [UP-RAM]**	1-100		<46	[46-73]	>73	
L2.5	Wetland Integrity RAM	1-100	[<14]	<37	37-61	>61	
L3	Weighted mean C [floristic quality]	1-10		>5.6	3.7-5.6	<3.7	
	Mean C [floristic quality]	1-10		>5.1	3.7-5.1	<3.7	

*2358 is not the maximum possible score, just the maximum LCA540 score observed in this dataset.
‡ In suburban and urban settings, "minimally" disturbed wetlands have LCA540 scores <600.
**Scores are preliminary as they are based on a relatively small sample size.

significantly and similarly correlated with LCA-AOI ($r_s = 0.840$) and LCA540 ($r_s = 0.875$). These results suggest that LCA540 is a good proxy for LCA-AOI, and that the former score adequately reflects developmental in the upland adjacent area. As expected, AOI and 540 scores are highly correlated ($r_s = 971$).

When examining the New York City-based NAC dataset compared to our NHP/APA data, we find AOI area is smaller (12.3 ha vs. 23.4 ha; $F_{1,293}=30.6$, $p < 0.001$) and wetlands compromise a smaller proportion of the AOI (5% vs. 30%) in the NAC (NYC) wetlands. As expected maximum impervious surface scores were higher in the NAC dataset (44.3 vs. 17.5). Interestingly, invasive relative cover did not differ between the New York City-based dataset and the rest of our NHP/APA data, both averaging ~9%, though it should be noted this comparison does not include naturalized nonnative plants. Mean coefficient of conservatism scores were also lower in the NAC dataset (3.6 vs. 5.0; K-W: $H = 48$, $p < 0.001$) as was the proportion of wetland plants (52% vs. 84%; K-W: $H = 112$, $p < 0.001$).

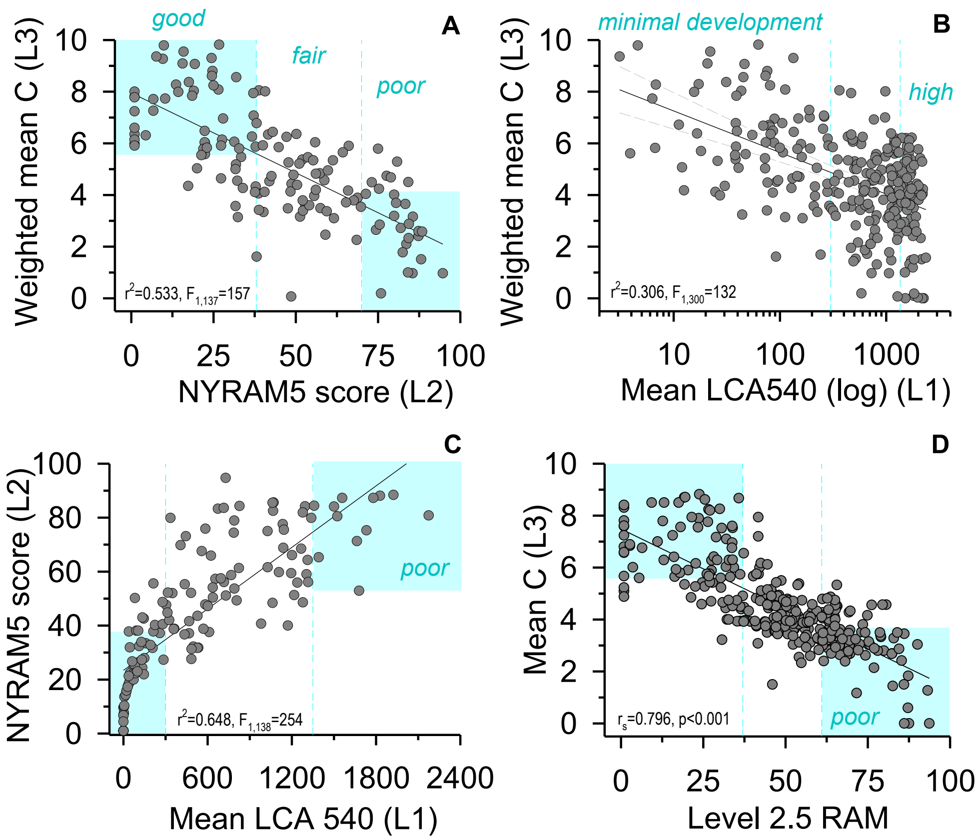

Figure 9: Wetland condition metrics were significantly correlated across all levels of our three-tiered assessment. A) Rapid wetland condition assessment scores (NYRAM5, Level 2) decline with weighted mean C (Level 3). Dashed aqua lines delineate significant thresholds for good (NYRAM5 < 38, n = 59), fair (n = 30), and poor condition (NYRAM >53, n = 51; K-W: H = 120.6, p < 0.001). Aqua boxes identify where x- and y-axis thresholds intersect, here as the upper (>5.6) and lower (<4.1) thresholds for weighted mean C. B) Floristic quality decreases with increasing levels of landscape development (LCA540); dashed aqua lines indicate thresholds at which weighted mean C scores are significantly different (ANOVA: $F_{2,298}$ = 60.9, p < 0.001). C) Potential reference quality wetlands can rapidly be identified as those in minimally developed landscapes (LCA < 300) and in good condition (NYRAM5 < 38); dashed aqua lines indicate thresholds at which NYRAM5 scores are significantly different (K-W: n = 140, H = 91.7, < 0.001). D) Level 2.5 rapid wetland integrity index is useful for identifying good and poor condition wetlands along an urban to rural gradient; dashed aqua lines indicate thresholds at which mean C scores are significantly different (K-W: n = 302, H = 169, < 0.001). Aqua shading indicates intersection of upper and lower thresholds.

Wetland assessment scores by community

Assessment metrics varied greatly among wetland community classes (Table 5). Evergreen shrub and forested wetlands in this dataset occurred predominately in the Adirondack Park, encompassing the following communities: dwarf shrub bogs (SS3); black spruce tamarack bogs; hemlock-hardwood swamps; and northern white cedar swamps (FO4). These communities are dominated by plants well suited for the unique abiotic environment in which they live and their narrow ecological tolerance is reflected in their high coefficient of conservatism scores. Correlations between LCA540 and mean C were slightly stronger for evergreen forested systems compared to weighted mean C (r_s = -0.779 vs. -0.627, respectively, p < 0.001), suggesting the former may be a more appropriate metric for this system. Evergreen forested swamps in minimally- and low/moderately-developed environments differed significantly across all quality metrics ($p < 0.005$). Evergreen shrub swamps (dwarf shrub bogs) in our dataset were all in excellent or good condition (minimum $\overline{C}_{wt} = 7.8$) so we did not see meaningful correlations with the other metrics.

Deciduous forested wetlands and shrub swamps in this dataset tended to occur in moderate-developed landscapes (LCA > 300). And although our dataset includes 12 reference-quality hardwood swamps (excellent/very good), those deemed to be in "excellent" condition were exceedingly rare; high NYRAM5 scores reflect the general fair/poor condition of this community type (Table 5). Additionally, unlike the other wetland types, deciduous forested swamps have a noticeable difference between weighted- and mean C scores (Table 5), a trend that reflects canopy species' higher cover and proportional weighting. Correlation between LCA540 and FQ scores indicate a marginally stronger negative trend with $\overline{C}_{wt}$ ($r_s = -0.221$, $p = 0.018$, $n = 124$) compared to $\overline{C}$ ($p = 0.024$). Wetland condition (NYRAM5) was the only metric to differ significantly across all three LCA classes ($F_{2,39} = 3045$, $p < 0.001$); integrity scores were significantly lower in minimally developed landscape ($F_{1,123} = 3095$, $p < 0.001$). These results indicate the condition and integrity RAMs are key tools for accurately capturing subtle changes in deciduous forested wetland systems.

Native-dominated emergent marshes were generally in fair condition, but we saw a range in community-specific scores from sedge meadows ($\overline{C}_{wt} = 5.3 \pm 0.3$) to shallow emergent marshes ($\overline{C}_{wt} = 3.3 \pm 0.2$; Appendix C). Emergent floristic quality scores in minimally developed environments averaged 5.6 (± 2.1, n = 37), and declined significantly with increasing landscape development ($r_s = -0.690$, p <001, n = 63). As expected, invaded marshes tended to occur in highly developed landscapes and score poorly on the condition/integrity indices (Table 5). Quality metrics in deciduous shrub swamps (SS1) indicate they are similarly sensitive to landscape stressors. Comparing minimally- (LCA540 < 300, n = 27) to moderate/highly-developed landscapes (LCA540 > 300, n = 22), we see robust differences across all of our quality metrics. For example, average Level 2 scores more than double in developed landscapes (SS1 condition: 20 vs. 59; SS1 integrity: 26 vs. 55). Although the magnitude of response differs among wetland types, these results highlight the utility of these metrics relative to landscape development and wetland condition.

Contiguous Wetland: Size, Buffer, and AOI Metrics

Table 5: General description of sampling effort and community composition across palustrine wetland types as classified by Cowardin et al. (1979). Mean Landscape Condition Assessment score (LCA) is an average LCA for the 540-m area surrounding a given sample point. Rapid Assessment Method (RAM) grand score is the final Level 2 metric (see Appendix B). For both LCA and RAM, higher values indicate poor condition. Weighted Mean C is the average coefficient of conservatism for all identified plants within a plot, weighted by their abundance. Unless noted, data are presented as the sample mean ± standard error of the mean.

		Level 1		**Level 2**	**Level 2.5**	**Level 3**	
Wetland type	*n**	*LCA 540 score*	*AOI Area (ha)*	NYRAM5 score	Integrity RAM	Weighted mean C ($\overline{C}_{wt}$)	Mean C ($\overline{C}$)
Emergent, persistent (EM1)	63	412 ± 60	27.8 ± 2.3	41 ± 4	39 ± 2	4.6 ± 0.3	4.6 ± 0.2
Emergent, invaded (EM5)	5	1328 ± 143	18.8 ± 3.6	71 ± 23	73 ± 3	1 ± 0.2	2.7 ± 0.3
Deciduous swamp (FO1)	124	1245 ± 51	15.7 ± 1.4	59 ± 3	59 ± 1	4.4 ± 0.1	3.7 ± 0.1
Evergreen swamp (FO4)	27	298 ± 73	19 ± 3.0	31 ± 5	32 ± 4	6.2 ± 0.2	6.1 ± 0.2
Decid. scrub-shrub (SS1)	49	442 ± 70	27.3 ± 2.5	37 ± 5	39 ± 3	5.1 ± 0.3	5.0 ± 0.2
Everg. scrub-shrub (SS3)	12	130 ± 76	12.4 ± 4.0	21 ± 4	20 ± 4	8.1 ± 0.2	7.8 ± 0.2

* NYRAM *n* from EM1 to SS3: 26, 42, 25, 27, and 11. Level 3, FO1 *n* = 123.

Wetland size can influence community heterogeneity and floristic composition, particularly in developed landscapes. We explored within-size class variation among our assessment metrics using a subset of NHP/APA sites for which we had contiguous wetland polygon data, applying size bins developed for the sample frame: small (<12.1 ha [<30 ac], n = 53), medium (12.1-28.3 ha, n = 46), and large (28.3 ha [>70 ac], n = 53). In larger wetlands, wetlands comprised nearly half of the original AOI (46 ± 4%), a two-fold increase compare to medium (25 ± 3%) and small (21 ± 3%) size classes. By contrast, maximum AOI impervious surface scores were significantly higher for small (29 ± 4%) and medium (16 ± 4%) wetlands compared to larger wetlands (12 ± 3%; $F_{2,149} = 4.754$, p = 0.010). Elevation range ($F_{2,149} = 1.031$, p =0.359) and AOI size ($F_{2,149} = 1.457$, p = 0.236) did not differ among wetland size classes. Floristic quality scores more strongly reflect landscape condition than wetland size (Figure 10).

Greater canopy cover in the upland buffer was positively correlated with wetland quality across all levels of assessment (Figure 11A, D, and G) and the 50-m buffer scores correlated more strongly with our assessment metrics than either AOI metric. Wetlands in good condition had 30% more canopy cover in the adjacent upland buffer (84 ± 2%, n = 39) compared to those in fair/poor condition (49 ± 3%, n = 63; $F_{1,100} = 97.228$, p < 0.001). Thresholds based on high quality wetlands suggest good (minimally disturbed) and fair quality wetlands are associated with >69% and 30-69% canopy cover, respectively (Figure 11). This trend is particularly strong for emergent (EM: r_s = -0.766, p < 0.001) and deciduous shrub swamps (SS1: r_s = -0.760, p < 0.001), but weakens for deciduous forested wetlands (FO1: r_s = -0. 292, p = 0.099; FO4 and SS3 p > 0.10). Wetland stressor scores were 43% percent lower (better) in wetlands with minimally disturbed buffers (mean NYRAM = 26 ± 15.8, Canopy > 69% n = 44) compared to sites with lower canopy cover (mean NYRAM = 60.8 ± 18.0, n = 58; $F_{1,100} = 104.224$, p < 0.001). Relative cover of invasive plants was also lower when buffers had greater canopy cover (4% vs. 15 %; $F_{1,144} = 18.177$, p < 0.001).

Compared to all other Level 3 and Level 2 metrics, wetland integrity scores for deciduous forested wetlands were the only metric that correlated with buffer composition (FO1: r_s = -0.449, p = 0.006) – highlighting the metric's ability to capture subtitle shifts in wetland condition. Wetland integrity scores (Level 2.5) relative to buffer canopy cover followed a similar trend as shown in Figure 11G (n = 147, r_s = -0.747, p < 0.001). Comparing Level 1 metrics we did see a negative correlation between buffer canopy cover and LCA540 scores (r_s = -0.759, p < 0.001), which we would expect.

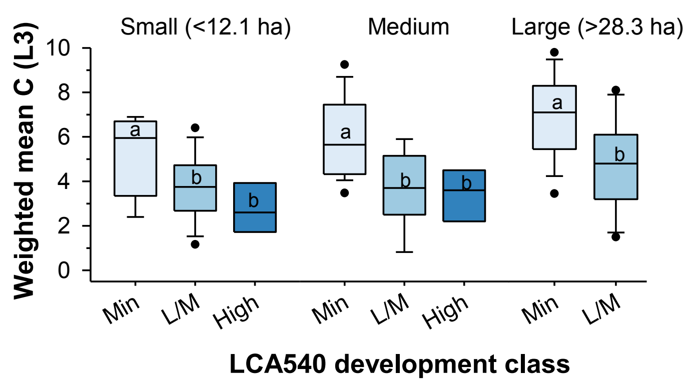

Figure 10: Landscape Condition Assessment (LCA540) bins include minimal development (LCA540<300), low/moderate development (300-1350), and high levels of developed (>1350). Differing letters indicate significant pairwise differences within a given size class (p < 0.05). Large wetlands: no sites had LCA540 scores >1350 in this subset of the data. Sample size per boxplot: $n \geq 8$.

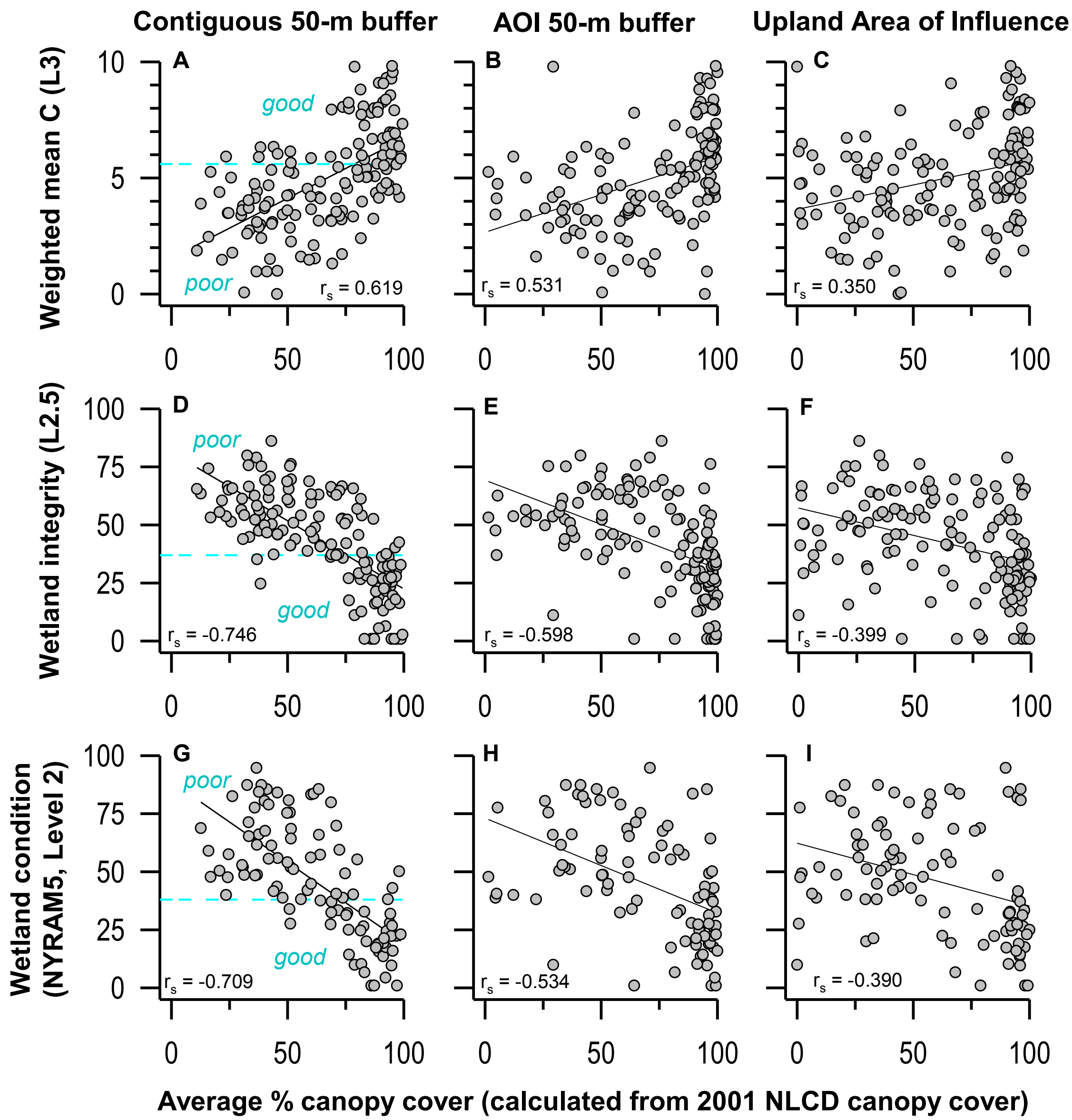

Figure 11: Comparison among the Level 1 adjacent upland metrics. Canopy cover in the 50-m buffer expressed the strongest correlations across all of our assessment levels. G) Only palustrine sites were used in this analysis. Dashed aqua line represents significant condition thresholds; black line represents line of best fit. Spearman's correlation coefficients are noted on each graph (all $p < 0.05$).

Historical legacies of anthropogenic disturbance

The Level 1 LCA model represents cumulative present-day anthropogenic stressors. Spatial proximity to stressors correlates to wetland condition; however, ecological integrity reflects temporal as well as spatial disturbances. As a coarse proxy we have used historical land cover data developed by USGS based on 1970-1985 aerial photography (Price et al. 2007). Historical land cover classes are broad, but do provide insight as to whether a site was dominated by human land use or a natural community. In "minimally" developed landscapes our wetland condition metric (NYRAM5) found sites identified as forest in the 1980s ($n = 32$) to have higher scores (worse condition) than those identified as wetlands in the 1980s ($n = 28$). Similarly, sites dominated by human land use in the past (classified as agricultural, urban, industrial, or residential) tend to have significantly lower current-day ecological integrity scores compared to those that were classified as natural cover types (Figure 13).

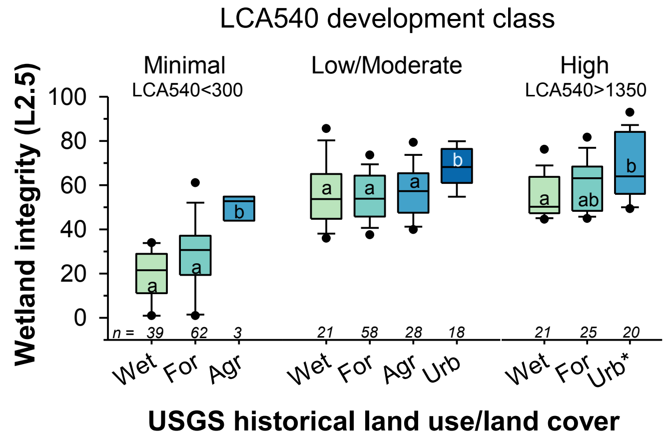

Figure 13: Sites with a history of historical land use tend to have lower integrity (high scores). Historical land cover classes modified after Price et al. (2007) includes natural wetland (wet), forested land (for), crops/pasture (agr), and urban/residential/industrial human land use (urb). Boxplot letters denote significant pair wise differences within a given development class ($p < 0.05$). Sample size (n) is noted along the x-axis.
*Reflects all human land uses.

Land use legacies are also likely reflected the proportion of canopy cover observed in the adjacent uplands. Emergent wetlands expressed the greatest change among historical LULC (Figure 12), but also have the potential to respond more quickly to changes in canopy cover. Separating out sites with natural land cover (n = 117) vs. human land use (n = 11), the former demonstrates a positive relationship between floristic quality and buffer canopy cover, a trend that is dampened by historical land use (Figure 12). These results highlight the importance of past land use on present-day ecological condition. They further underscore the importance of assessing present-day condition/stressors as well as potential land use legacies.

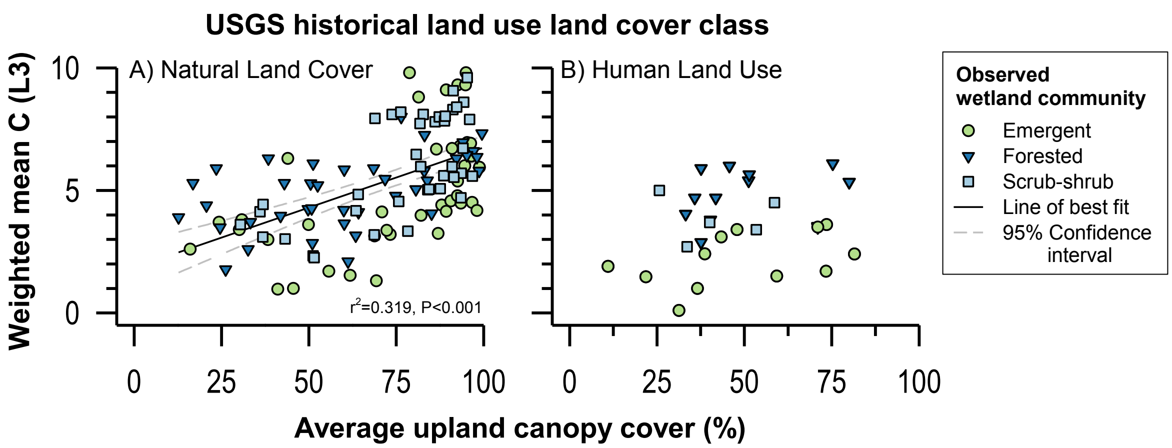

Figure 12: The extent of canopy development can reflect historical land use; to address this, we've separated sites with natural land cover (A) from those dominated by historical land use (B). A) Sites with natural land cover still tend to increase in floristic quality as canopy cover increases ($F_{1,116}$ = 54.347; $y = 1.852 + (0.0490 \times x)$). B) By contrast, in sites with historical human land use legacies, only emergent wetland communities suggest a slight positive correlation with upland canopy cover (n = 11, $r_s = 0.500$, $p = 0.109$). [Historical land use land cover groups modified after Price et al. 2007.]

CONCLUSIONS

Our results suggest wetland condition reflects not only the immediate upland area of influence, but also the cumulative effects of past and present stressors. Ecological integrity at a specific sample point in a wetland reflects overall stressors in the landscape and the condition of the upland buffer. Floristic quality exhibited a strong positive correlation with canopy cover in the surrounding uplands. We found wetlands in *poor* condition were most prevalent when canopy cover in the upland buffer was less than 30%.

Although we found significant correlations between our field buffer rapid assessment methods, the sample size was relatively small and comprised mostly on wetlands in poor or fair condition. Expanding the sample size to include more sites in excellent or good condition would likely provide stronger correlations with our wetland floristic quality metrics. Level 1 metrics such as canopy cover in the upland buffer appear to be a good proxy for UP-RAM, particularly in developed landscapes. We did see significant correlations between wetland floristic quality and UP-RAM, but we think more data are needed, particularly in excellent- and good-quality sites to ensure optimal calibration.

The digitized upland area of influence (AOI) is a novel tool for estimating the immediate drainage area upslope from a specific point. We saw significant correlations between wetland condition and LCA-AOI scores. Similar performance between LCA-AOI and LCA-540 suggest the latter, easier to calculate metric, accurately captures development stressors in the AOI. Unfortunately, localized Level 1 AOI-specific scores used in this project did not provide a clear stronger method for quantifying the impacts from site-specific activities in upland areas on wetland condition. However, the results reinforce the utility of our established Level 1 LCA540 metric, which is easier to generate than the AOI. We also found that increased canopy cover in the upland buffer of the AOI was positively correlated with floristic quality. These results suggest wetland condition is influenced by several factors including landscape condition (LCA) and the overall integrity of the upland buffer (e.g., natural buffer width and canopy cover).

Emergent herbaceous communities responded strongly to landscape stressors and poor buffer condition. Even sites suspected of having legacies of human land use tended to have lower floristic quality scores when canopy cover in the upland buffer fell below 30% (1.2 vs. 2.4). This difference, however, could be magnified by the nature of herbaceous communities where shifts in species composition can occur more rapidly compared to forested systems (apart from changes resulting from beaver or tree pests). Definitive shifts in species composition may therefore be easier/quicker to identify in non-forested wetlands. By contrast, as long as the tree canopy stays relatively intact, deciduous forested wetlands in particular may experience subtitle long-term shifts resulting from landscape stressors, dewatering, and fragmentation (edge effects). Moreover, because tree cover often dominates weighted c scores in forested wetlands, this subtitle shift in plant assemblage composition can be hard to pick up. Our new wetland integrity metric (Level 2.5), however, was able to capture shifts in the floristic composition of hardwood swamps. These results highlight the importance and utility of using multiple methods when assessing wetland condition and integrity.

Our novel and updated protocols developed during this project enhance our ability to assess wetland condition and integrity of wetlands across New York State. Our expanded urban and exurban coverage strengthened and reinforced the utility of our three-tiered assessment protocols. Recalibration of our New York Rapid Assessment Method (NYRAM5) for quantifying wetland condition has produced a more robust and intuitive scoring framework, which is now scaled from 1 (excellent) to 100 (very poor). Automating the onscreen assessment portion of NYRAM further increased usability by decreasing time-on-task and potential variation among observers. Preliminary thresholds developed for our three-tiered assessment metrics help provide context to users and can be used to inform management goals.

OUTREACH AND EVENTS

We took an inclusive approach early on in method development. Getting stakeholders involved early in this project was crucial for producing methods that met their needs and our project goals. Below is a list of presentations we gave, conferences we attended, and interactive workshops we held.

Conferences and Presentations

New York State Wetlands Forum (NYSWF). April, 2018. Watkins Glen, NY. Presenter: Dr. Laura Shappell. Title: A three-tiered approach to quantifying wetland condition in New York State.

NYSWF. April, 2017. Suffern, NY. Presenter: Dr. Laura Shappell. Title: Applying a three-tiered approach to assessing wetland condition on an urban to rural gradient.

The Joint Meeting of the New England Biological Assessment Wetlands Workgroup (NEBAWWG) and the Mid-Atlantic Wetlands Workgroup (MAWWG). November, 2016. New Jersey. Presenter: Dr. Laura Shappell. Title: A three-tiered approach to quantifying wetland condition in New York State.

NYSWF. April, 2016. Saratoga Spring, NY. Presenter: Dr. Laura Shappell. Title: A three-tiered approach to quantifying wetland condition in New York State.

NYS DEC Habitat Bureau Conference. March, 2016. Hamilton, NY. Presenter: Dr. Laura Shappell. Title: Wetland Assessment and a Novel Approach to Quantify Adjacent Area Impacts.

This presentation included an interactive breakout session where groups were given maps representing our sample frame. During within-group discussions and a concluding wrap up session, we discussed variables that would affect wetland condition at a site. Given the diversity of attendees' expertise, we gleaned valuable insight from the group, which was used in developing the buffer field protocols.

Training: NYRAM workshops and Level 3 survey methods training

Wetland assessment in New York State – a joint workshop hosted by New York Wetlands Forum. Co-organizers: Dr. Kevin Bliss (NYS DEC), Dr. Laura Shappell (NYNHP), Kim Farrell (USDA NRCS), and Dave MacDougall (CWD, private consultant). Syracuse, NY. October 13, 2016.

This full-day workshop had approximately 50 attendees and four presenters. Attendees' backgrounds included state, private, and academic/non-profit organizations.The morning included indoor presentation by all of the hosts, reviewing a range of assessment methods in NYS. Attendees were divided into groups for the afternoon, rotating through the various methodologies. Laura Shappell led groups through the NYRAM protocol as they walked through the wetland and adjacent upland at Beaver Lake Nature Center.

Workshop documents: http://www.wetlandsforum.org/resources.htm#workshop

Professor Mary Beth Kozlowski from Siena College and two of her students joined our staff-training day to learn our Level 3 vegetation survey protocols. June 2017, Peebles Island State Park, Waterford, NY.

Descemination of research

Laura Shappell developed a staff webpage where she has posted project descriptions, updated NYRAM documents, and the previous final report (Shappell et al. 2018). nynhp.org/shappell

LITERATURE CITED

Blom, C. W. P. M. and L. A. C. J. Voesenek. 1996. Flooding: the survival strategies of plants. Trends in Ecology & Evolution 11:290-295.

Bried, J. T., S. K. Jog, and J. W. Matthews. 2013. Floristic quality assessment signals human disturbance over natural variability in a wetland system. Ecological Indicators 34:260–267.

Bruland, G. L. and C. J. Richardson. 2005. Hydrologic, edaphic, and vegetative responses to microtopographic reestablishment in a restored wetland. Restoration Ecology 13:515-523.

Chamberlain, S. J., and R. P. Brooks. 2016. Testing a rapid Floristic Quality Index on headwater wetlands in central Pennsylvania, USA. Ecological Indicators 60:1142–1149.

Chapin, F. S., III, P. A. Matson and H. A. Mooney. 2002. Terrestrial water and energy balance. p. 71-96. *In* Principles of Terrestrial Ecosystem Ecology. 1st ed. Springer-Verlag, New York.

Chu, S., and B. Molano-Flores. 2013. Impacts of agricultural to urban land-use change on floristic quality assessment indicators in Northeastern Illinois wetlands. Urban Ecosystems 16:235–246.

Conte-Ecology, U.S. Geological Survey. 2015, November. The national hydrography dataset high resolution delineation version 2 (NHDHRDV2).

Cornell IRIS. 2018. Agricultural Districts, New York State. vector digital data, .

Cowardin, L. M., V. Carter, F. C. Golet, and E. T. LaRoe. 1979. Classification of wetlands and deepwater habitats of the United States. Office of Biological Services, Fish and Wildlife Service, U.S. Dept. of Interior, Washington, D.C.

Davis, M. A., J. P. Grime and K. Thompson. 2000. Fluctuating resources in plant communities: a general theory of invasibility. Journal of Ecology 88:528-534.

Edinger, G. J., T. G. Howard, and M. D. Schlesinger. 2016. Classification of Natural Areas Conservancy's Ecological Assessment Plots. New York Natural Heritage Program, Albany, NY.

Ehrenfeld, J. G. and J. P. Schneider. 1993. Responses of forested wetland vegetation to perturbations of water chemistry and hydrology. Wetlands 13:122-129.

Ehrenfeld, J. G., H. Bowman Cutway, R. Hamilton and E. Stander. 2003. Hydrologic description of forested wetlands in northeastern New Jersey, USA - an urban/suburban region. Wetlands 23:685-700.

Euliss, N. H., J. W. LaBaugh, L. H. Fredrickson, D. M. Mushet, M. K. Laubhan, G. A. Swanson, T. C. Winter, D. O. Rosenberry and R. D. Nelson. 2004. The wetland continuum: a conceptual framework for interpreting biological studies. Wetlands 24:448-458.

ESRI. 2014. ArcGIS Desktop: Release 10.3. Environmental Systems Research Institute, Redlands, CA.

Faber-Langendoen, D., J. Rocchio, S. Thomas, M. Kost, C. Hedge, B. Nichols, K. S. Walz, G. Kittel, S. Menard, J. Drake, and E. Muldavin. 2012. Assessment of Wetland Ecosystem Condition across Landscape Regions: A Multi-metric Approach. Part B: Ecological Integrity Assessment Protocols for Rapid Field Methods (L2). U.S. Environmental Protection Agency, Washington, DC.

Feldmann, A., and T. Howard. 2013. Landscape Condition Assessment (LCA2) for New York. New York Natural Heritage Program, Albany, NY.

Findlay, C. S. and J. Houlahan. 1997. Anthropogenic correlates of species richness in southeastern Ontario wetlands. Conservation Biology 11:1000-1009.

Genesee/Finger Lakes Regional Planning Council. 2004. The Genesee River Basin Action Strategy. Genesee/Finger Lakes Regional Planning Council, Rochester, NY.

Grabas, G. P. and D. Rokitnicki-Wojcik. 2015. Characterizing daily water-level fluctuation intensity and water quality relationships with plant communities in Lake Ontario coastal wetlands. Journal of Great Lakes Research 41:136-144.

Grime, J. P. 1977. Evidence for the existence of three primary strategies in plants and its relevance to ecological and evolutionary theory. The American Naturalist 111:1169-1194.

Groffman, P. M., D. J. Bain, L. E. Band, K. T. Belt, G. S. Brush, J. M. Grove, R. V. Pouyat, I. C. Yesilonis, and W. C. Zipperer. 2003. Down by the riverside: urban riparian ecology. Frontiers in Ecology and the Environment 1:315–321.

Homer, C. G., J. Dewitz, L. Yang, S. Jin, P. Danielson, G. Z. Xian, J. Coulston, N. Herold, J. Wickham, and K. Megown. 2015. Completion of the 2011 National Land Cover Database for the conterminous United States – Representing a decade of land cover change information. Photogrammetric Engineering and Remote Sensing 81:345354.

Houlahan, J. E., and C. S. Findlay. 2004. Estimating the "critical" distance at which adjacent land-use degrades wetland water and sediment quality. Landscape Ecology 19:677–690.

Houlahan, J. E., P. A. Keddy, K. Makkay, and C. S. Findlay. 2006. The effects of adjacent land use on wetland species richness and community composition. Wetlands 26:79–96.

IBM Corp. 2015. IBM SPSS Statistics for Windows. IBM Corp., Armonk, NY.

Jacobs, A. D. 2010. Delaware Rapid Assessment Procedure Version 6.0. Delaware Department of Natural Resources and Environmental Control, Dover, DE. 36 pages.

Jenks, G. F. 1967. The data model concept in statistical mapping. International Yearbook of Cartography 7:186–190.

Kozlowski, T. 2002. Physiological-ecological impacts of flooding on riparian forest ecosystems. Wetlands 22:550-561.

Lockwood, J. L., P. Cassey and T. Blackburn. 2005. The role of propagule pressure in explaining species invasions. Trends in Ecology & Evolution 20:223-228.

Magee, T. K. and M. E. Kentula. 2005. Response of wetland plant species to hydrologic conditions. Wetlands Ecology and Management 13:163-181.

Martin, P. H., C. D. Canham and P. L. Marks. 2009. Why forests appear resistant to exotic plant invasions: intentional introductions, stand dynamics, and the role of shade tolerance. Frontiers in Ecology and the Environment 7:142-149.

Matthews, J. W., P. A. Tessene, S. M. Wiesbrook, and B. W. Zercher. 2005. Effect of area and isolation on species richness and indices of Floristic Quality in Illinois, USA wetlands. Wetlands 25:607–615.

Middleton, B. A. 2003. Soil seed banks and the potential restoration of forested wetlands after farming. Journal of Applied Ecology 40:1025-1034.

Miller, S. J., and D. H. Wardrop. 2006. Adapting the floristic quality assessment index to indicate anthropogenic disturbance in central Pennsylvania wetlands. Ecological Indicators 6.

PA DEP. 2014. Pennsylvania Wetland Condition Level 2 Rapid Assessment. Pennsylvania Department of Environmental Protection, Harrisburg, PA. 37 pages.

Peet, R. K., T. R. Wentworth, and P. S. White. 1998. The North Carolina Vegetation Survey protocol: A flexible, multipurpose method for recording vegetation composition and structure. Castanea 63:262–274.

Pickett, S. T. A., M. L. Cadenasso, J. M. Grove, C. H. Nilon, R. V. Pouyat, W. C. Zipperer and R. Costanza. 2001. Urban ecological systems: linking terrestrial ecological, physical, and socioeconomic components of metropolitan areas. Annual Review of Ecology and Systematics 32:127-157.

Price, C. V., N. Nakagaki, K. J. Hitt, and R. M. Clawges. 2007. Enhanced Historical Land-Use and Land-Cover Data Sets of the U.S. Geological Survey: polygon format files. U.S. Geological Survey, Reston, VA.

Ring, R. M. 2016. Coefficients of conservatism values for a Flora Quality Assessment Index of the native vascular plants of New York. New York Natural Heritage Program, Albany, NY.

Schramm, J. and J. Ehrenfeld. 2010. Leaf litter and understory canopy shade limit the establishment, growth and reproduction of *Microstegium vimineum*. Biological Invasions 12:3195-3204.

Shappell, L. J., A. L. Feldmann, E. A. Spencer, and T. G. Howard. 2016. New York State wetland condition assessment, EPA Wetland Program Development Grant (CD-96294200) Final Report. New York Natural Heritage Program, Albany, NY. 60 pages.

Stevens, D. L., and A. R. Olsen. 2004. Spatially balanced sampling of natural resources. Journal of the American Statistical Association 99:262–278.

Stinson, K. A. and T. G. Seidler. 2014. Physiological constraints on the spread of *Alliaria petiolata* populations in Massachusetts. Ecosphere 5:art 96.

Swink, F., and G. Wilhelm. 1994. Plants of the Chicago region. Indiana Academy of Science, Indianapolis, IN.

Systat Software Inc. 2008. SigmaPlot. Systat Software, Inc., San Jose, CA.

Tarboton, D. 2016. Terrain Analysis Using Digital Elevation Models (TAUDEM).

Tiner, R. 2011. Nova Scotia Wetland Evaluation Technique. U.S. Fish and Wildlife Service.

Toogood, S. E. and C. B. Joyce. 2009. Effects of raised water levels on wet grassland plant communities. Applied Vegetation Science 12:283-294.

US Army Corps of Engineers. 2018. NWPL Home v3.3-f3 [Online]. Available: http://wetland-plants.usace.army.mil/nwpl_static/v33/home/home.html. [Accessed: 26-Jul-2018].

US EPA. 2016. National Wetland Condition Assessment 2016: Field operations manual. U.S. Environmental Protection Agency, Washington D.C.

U.S. Fish and Wildlife Service. 2015. National Wetlands Inventory [Online]. Available: http://www.fws.gov/wetlands.

van der Valk, A. G. 1981. Succession in wetlands: a Gleasonian approach. Ecology 62:688-696.

Werier, D. 2017. Catalogue of the Vascular Plants of New York State. Memoirs of the Torrey Botanical Society 27:1–542.

Zar, J. H. 1999. Biostatistical analysis. Prentice Hall, Upper Saddle River, NJ.

APPENDIX A: NYRAM FIELD MANUAL AND DATA SHEETS

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New York State Wetland Condition Assessment

Level 2 Rapid Assessment Method
NYRAM Version 5 (2018)

User's Manual and Data Sheets

Developed By New York Natural Heritage Program

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New York Natural Heritage Program

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NYRAM Field Manual

Project scope

Method development

The New York Rapid Assessment Method (NYRAM) provides users with a relatively quick procedure for assessing the quality and condition of New York State (NYS) wetlands. Methods presented here are part of a three-tiered sampling approach (Level 1, 2, 3); similar methods have been employed by federal and state agencies in an effort to develop environmental monitoring protocols (Faber-Langendoen et al. 2012, PA DEP 2014, Jacobs 2010). For Level 1, the New York Natural Heritage Program (NYNHP) developed a statewide Landscape Condition Assessment (LCA) model that cumulatively depicts key anthropogenic stressors across the NYS landscape at a 30 x 30-m resolution. Rapid assessment methods (RAM) developed for Level 2 classify and catalog anthropogenic stressors using basic quantitative air photo interpretation and qualitative field surveys. NYRAM field methods employ a stressor checklist that was modeled after established RAM procedures developed for Mid-Atlantic States (PA DEP 2014, Jacobs 2010). At the finest scale of measurement, Level 3 relevé sampling protocols modified from those developed by Peet et al. (1998) captured vegetation structure and floristic biodiversity. Level 1 and Level 3 data were used to refine and support the Level 2 RAM presented here.

NYRAM incorporates onscreen (Part A) and field (Part B) components that broadly assess hydrology, fragmentation, vegetation composition, and water quality. The field stressor checklist encompasses a broad range of potential stressors that may influence natural wetland structure (e.g., plant species composition) and function (e.g., ground water recharge, nutrient cycling), while providing flexibility for practitioners to document unique stressors present at their assessment site.

This rapid assessment method will continue to be refined as we expand our wetland assessment dataset. Updated NYRAM versions will be posted on the New York Natural Heritage website (www.nynhp.org). Please consider sharing your NYRAM data with NYNHP to help build our understanding of wetland condition in NYS.

Development of NYRAM

When developing this method, we aimed for it to be relatively quick, repeatable, and applicable to wetlands throughout NYS (Feldmann 2013, Feldmann and Spencer 2015). Most of the 54 survey sites used to calibrate NYRAM ver. 4.2 fell within the Lower Hudson River and Susquehanna River watersheds; a few additional points were located in the Adirondack Park. NYRAM scoring was recalibrated based on an expanded urban-rural dataset (n = 140). Following recalibration, NYRAM ver. 5 ("NYRAM5") scores correlate more strongly with floristic quality scores based on intensive vegetation surveys (Shappell and Howard 2018). The new scoring automates the onscreen assessment portion of NYRAM ("Part A"), but we've retained the original manual form, with updated scoring, as an option for users (NYRAM ver 4.5). Non-tidal palustrine wetlands were our target system so stressors unique to lacustrine, tidal, brackish, or estuarine environments are not addressed (e.g., tidal flow restrictions). Using NYRAM on non-target wetland systems is not recommended as appropriate stressors have not been identified and evaluated during the development of this protocol.

Sampling effort

Part A: The onscreen portion of this method assesses the 500 m Landscape Buffer around the target 40-m Sample Area (see figure below). Following recalibration of NYRAM5, users now have the option of automating this step in ArcGIS, using the "Zonal Statistics" tool to calculate the mean Landscape Condition Assessment score for a 540-m buffered area based on the center of your

Survey Area. More information about the rasterized LCA model and download information area available at nynhp.org/data. In NYRAM ver 4.5, this step may be completed using ArcGIS, Google Earth, or other air photo sources. Depending on landscape complexity and observer experience, manual completion of Part A may take 15-60 minutes. Tips for manually completing this portion of the assessment are outlined below.

Part B: The field portion of this method covers up to 6.15 ha (15.2 ac), including the Sample Area and surrounding 100-m radius Field Buffer that surrounds the Sample Area (i.e., 140-m out from the center point). Once at the Sample Area, a two-person team may complete the field stressor checklist in approximately 1 hour. However, sites that are difficult to traverse, such as shrub swamps or semipermanently flooded areas may take ≥1.5 hours to complete.

Overview of the NYRAM sampling design

This Level 2 rapid assessment method was designed to be suitable for a range of project needs from site assessment to establishing a reference baseline. Depending on project objectives, wetland site selection may be random, stratified random, or subjective. The Sample Area (SA) is the targeted area within a wetland that will be the focus of your NYRAM sampling. Standard sample designs focus around a 0.5 ha SA, but nonstandard layouts may vary in shape and range in size from 0.1 to 0.5 ha. The Landscape Buffer, a 540-m buffer around the center of the SA, is assessed in Part A of NYRAM ver. 4.5 through basic air photo interpretation. The field survey assesses stressors within the SA, and surrounding 100-m Field Buffer (Part B; Figure 14).

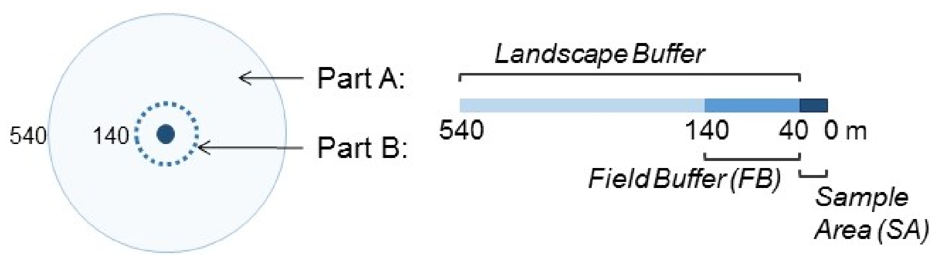

Figure 14: Schematic of the standard Level 2 rapid assessment survey design, which includes an onscreen evaluation of the Landscape Buffer (Part A), and a field survey assessing wetland quality (Part B). The standard SA is a 40-m radius plot 0.5 ha (1.24 ac), but non-standard SAs range in size (0.1-0.5 ha) and shape.

Site vetting and establishment

Sample Area

Prior to field work, try to establish an appropriate Sample Area (SA) via aerial or satellite imagery software such as ArcGIS, Google Earth (earth.google.com), Google Earth Pro (includes advanced functions, GIS file import: ([http://www.google.com/earth/download /gep/agree.html](http://www.google.com/earth/download/gep/agree.html)), or via online maps (e.g., Bing Maps: bing.com/maps/). Interactive mappers produced by the U.S. Environmental Protection Agency (EPA), U.S. Geologic Survey (USGS), U.S. Department of Agriculture (USDA) are also useful, as outlined below on page 35.

Additional mapped data such as topography, USGS SSURGO2 soils, or National Wetlands Inventory maps should be consulted in tandem with the imagery. Confirm that you are viewing the most up-to-date imagery available to you - site conditions and land use can change drastically over short periods. Work through the following steps to pre-screen SAs relative to your research objectives.

1) Depending on project goals, point placement may be determined randomly, on a target wetland assemblage class (*sensu* Cowardin et al. 1979), or subjectively. The SA will encompass this point, ideally with the point in the center of the SA. If the SA is *subjective*, points may be moved to any location yielding a SA that meets the minimum sampleable criteria outlined below (i.e., disregard the 60-m move maximum discussed below).

2) Remote assessment of potential SA

   Sample Area composition

   <u>≤10% of the *total* SA</u> may include water ≥1 m deep; standing water or soft substrates that are unsafe to sample effectively; or upland systems; and if applicable, ≤10% of a non-target wetland assemblage class. **If these criteria are not met**, try moving the point ≤60 m (e.g., Figure 15).

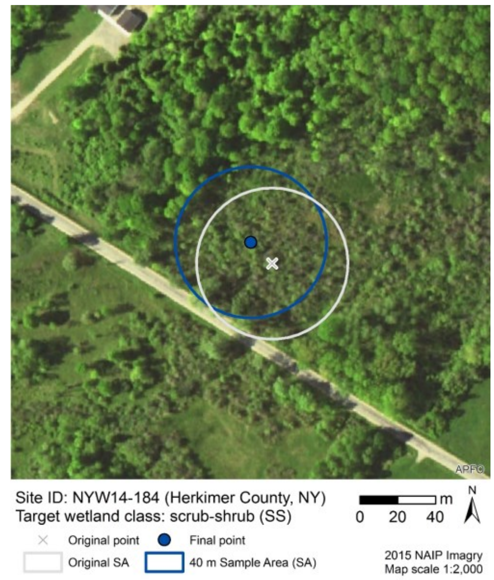

Figure 15: Sample Area around original random point included a road and some forested area (>10% non-target), so the point was moved ~15 m northwest.

   SA size & shape

   <u>Standard SA</u>: accommodates a 40-m radius plot 0.5 ha (5,025 m^2 ≈ 1.24 ac), while maintaining the above composition criteria.

   <u>Non-standard SA</u>: if a standard SA is unworkable (e.g., small wetlands, riparian systems), alternative SA shapes and sizes (0.5-0.1 ha ≈ 0.25-1.24 ac) may be employed.

   Example: Due to a railroad and non-target scrub-shrub vegetation, the example site in Figure 16 does **not** meet the standard SA criteria for size or as shape. Instead, a 20 m x 50-m rectangular non-standard SA was employed.

Figure 16: The original SA was <90% emergent, the target class for this survey, so a smaller nonstandard SA was established (0.1 ha).

   Accessibility

   <u>Ownership</u> – determine ownership using tax parcel or other government records. Private and public landowners/proprietors must grant you access to visit their property for each field-sampling event.

   <u>Physical obstructions</u> – sketch an access route to the target wetland. Determine if non-wadeable water bodies >1 m deep or another physical obstruction would prevent you from reaching and sampling the SA within a reasonable timeframe.

3) If the SA does not meet the criteria outlined above and you are using <u>random</u> point placement, try moving the point within 60 m of its *original* location. If moving the point does not address

the issue, try selecting another random point within the wetland polygon. [Still can't establish an SA? It may be time to move on to a different wetland.]

Digital resources for the field (Part B)

After the above criteria have been confirmed, save/print locator maps for each site. Include the 40-m SA (or non-standard SA polygon), as well as the 100-m radius Field Buffer (FB) that surrounds the SA (i.e., 140-m out from the center point). For example, the non-standard SA shown in Figure 16 would have a 100-m rectangular FB around the 20 m x 50 m SA (i.e., FB perimeter = 120 m x 150 m rectangle).

Additional helpful data to include with the map: site ID, target wetland boundary, topography, soils, tax parcel data, and site owner/manager contact information. If using a handheld digital device in the field, load the digital layers onto the device (e.g., point files, and SA polygon layers). Print the NYRAM 4.2 field datasheets or load an electronic version onto your field tablet. If completing Part A prior to the field survey (Part B), bringing a copy of the form with you to the field for orientation.

Part A: Onscreen assessment

This step can be conducted before or after the field assessment in Part B except when the SA is likely to be moved in the field. If the point will likely be moved, Part A should be completed *following* the field survey. Viewing the aerial photography in advance helps in identify potential stressors or ambiguous features that may be on the edge of the FB (e.g., an abandoned ditch), in difficult to access areas, or are otherwise likely to be overlooked in the field.

Materials & resources

Automated Part A (NYRAM Ver. 5) - Landscape Condition Assessment

Generate a 540-m buffer around the center of your survey area (point) in ArcGIS using the "buffer" tool. Using the rasterized LCA data layer (download from nynhp.org/data), use the "zonal statistics as table" tool to calculate the average (mean) LCA score within your target 540-m buffer (polygon). Your zonal statistics will be exported as a table – the average (mean) LCA value is what you're looking for, this is what we use for our landscape scale "Level 1" metric referred to as "LCA540". Use the following equation to transform your LCA540 score and calculate your NYRAM5 Part A score. *Note*: some stressors associated with land use history such as logging may not be captured by the LCA model and in such settings, it's best to crosscheck your automated score with a manual onscreen review.

$$\boldsymbol{NYRAM5\ Part\ A}: log_{10}(LCA540 + 1) \times 15$$

Manual Part A (NYRAM 4.5) - Aerial imagery

Use the most recent imagery that is available via ArcGIS, Google Earth, Bing Maps, or one of the interactive mappers listed below.

US EPA, "MyWATERS": http://watersgeo.epa.gov/mwm/
Relevant content: base maps (satellite imagery from Bing Maps, topography, street maps); water quality status/permitting; rivers and streams (National Hydrography Dataset, NHD), and wetland data (National Wetlands Inventory, NWI).

USGS National Map Viewer: http://viewer.nationalmap.gov/viewer/
Relevant content: base maps (satellite, orthoimagery, topography), elevation contours, NHD including flow direction, National Land Cover Database (NLCD), protected areas (status, type, owner/manager), and wetland data (NWI). All of the data layers accessible here may be exported and viewed in ArcGIS or Google Earth.

Additional spatial data for manual onscreen assessment (optional)

Wetland, hydrography, and soils

NWI data published by US Fish & Wildlife Service (USFWS) - Interactive mapper, GIS & Google Earth data downloads: http://www.fws.gov/wetlands/

EPA WATERS data, Google Earth download - Includes NHDPlus surface water features, water quality feature: http://www.epa.gov/waterdata/viewing-waters-data-using-google-earth

USGS National Hydrography Data: http://nhd.usgs.gov/data.html

USDA soils:

Interactive mapper: http://websoilsurvey.sc. egov.usda.gov/App/HomePage.htm
GIS data: https://gdg.sc.egov.usda.gov/ or via interactive downloader: http://www.arcgis.com/home/item.html?id=4dbfecc52f1442eeb368c435251591ec

Transportation & recreation: New York State (NYS) roads, railroad (active and abandoned), trails (hiking, horse, and snowmobile) trail layers.

NYS GIS clearing house (general data source): http://gis.ny.gov/gisdata

NYS Department of Environmental Conservation (NYSDEC) State Lands Interactive Mapper: http://www.dec.ny.gov/outdoor /45478.html

NYS Google Earth file formats (.kml): http://www.dec. ny.gov/pubs/42978.html

Snowmobile trails: Private entities have made statewide snowmobile trails publicly available (e.g., JIMAPCO, Inc. http://jimapco.com/maproom/snowmobile/nys/)

Methods for determining % LULC type

Delineate areas of interest

In ArcGIS, use the geoprocessing buffer tool to create a 540 m radius buffer around the center point (e.g., Figure 17).

In Google Earth *Pro* you should be able to draw in a circle with a defined radius (this program was released in 2015 so its functionality is evolving).

Overlay a standard grid - makes photo interpretation more efficient and repeatable

In ArcGIS, apply a measured grid overlay.

In *Layout View* of ArcGIS 10.3 go to View > Data Frame Properties > New Grid > Measured Grid > Intervals > 50 x 50 m). If viewing a 50 x 50 m grid, the Landscape Buffer contains approximately 364 full cells. Each cell is 2500 m^2 (0.62 ac). Tip: 4 cells = 1%. 18 cells = 5%.

To make a shapefile in *Data View* of ArcGIS 10.3 (shown in Figure 17), open the ArcToolbox > Cartography Tools > Data Driven Pages > Grid Index features. Use the 540-m buffer layer as your input, use 50 meters as your polygon width and height. [Note: depending on your computing power, this process may take 1+ hours to run if using >25 points.]

In Google Earth, you can display georeferenced grids that are distributed by private entities.

For example, the Earthpoint "UTM" grid (http://www. earthpoint .us/Grids.aspx), scales the grid relative to your viewing altitude. If using this tool, make sure to measure the cell size of your grid and adjust your calculations accordingly – methods discussed here are based on a 50 m x 50 m grid.

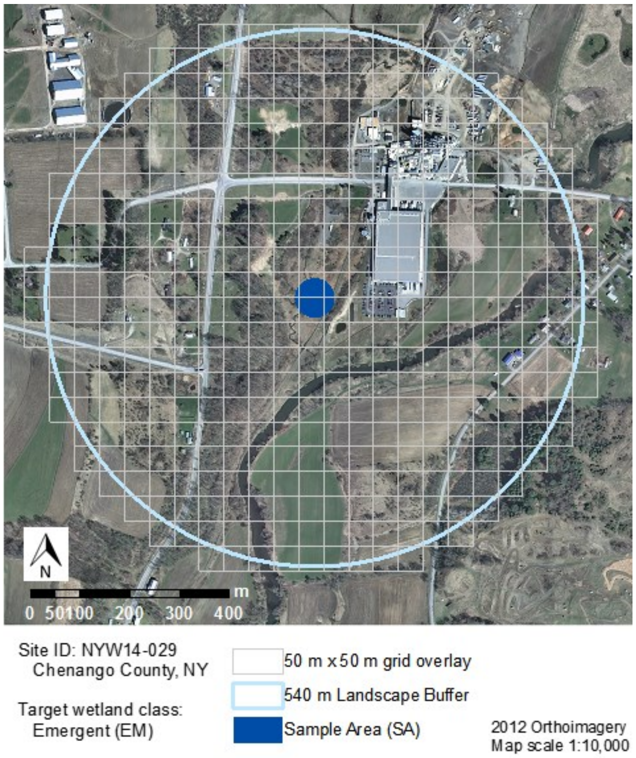

Figure 17A: Part A assesses the Landscape Buffer that extends 540 m from the *center* of the Sample Area. An overlay grid aids percent cover estimates of LULC types.

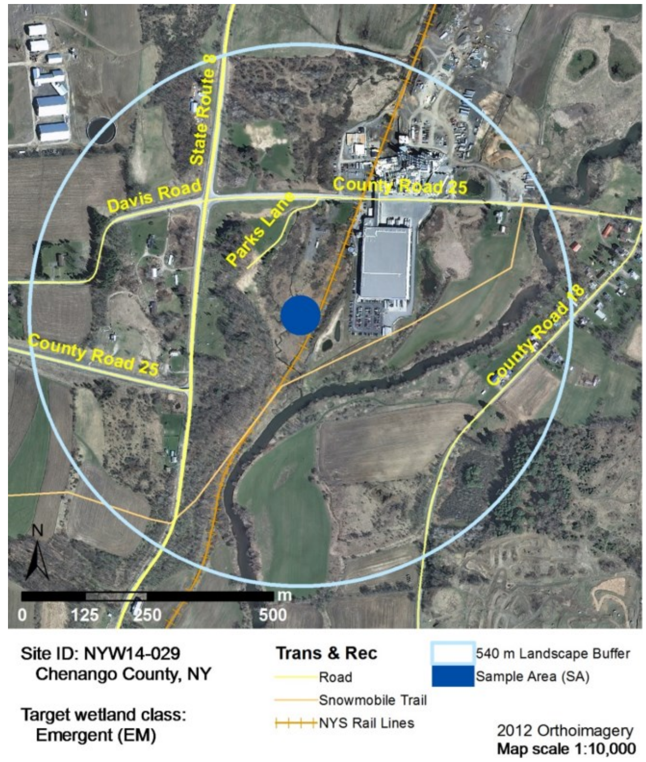

Figure 17B: Fragmenting feature tally example. This site includes three categories of features: 2-lane roads, railroad, and an unpaved trail.

Additional tips

Orthoimagery help identify "actively-" and "intensively-managed" agricultural land use types (i.e., hay or lawn vs. row crops). The former appears bright green early in the growing season (or red if infrared). In contrast, land used for intensive row crops appear as smooth or finely striated dull tan/brown/grey.

Worked example: Emergent marsh (Figure 17)

Part A: Land Use Land Cover (LULC)

Looking forward to LULC percent cover estimates in the field manual appendix, you will see four classes of anthropogenic LULC, plus a natural cover class.

Using Figure 17 (site ID NYW14-029), we will start with the "**Impervious Surface**" cover type, which is often easiest to identify due to its clearly defined boundaries. Approximately how many cells are filled with urban or built-up land (e.g., buildings, paved roads/parking lots, industrial, residential)? For partially filled cells, such as roads and house, visually aggregate features to produce the equivalent of a "filled" cell.

Repeat this process for the remaining types:

"**Intensely managed**" such as golf courses, sand or gravel mining, warm season row crops (e.g., corn, soy), and pervious land/ponds associated with confined feeding animal operations (e.g., upper left corner of Figure 17). In this example, warm season cropland appears finely striated with a tan/brown or grey color; this pattern is best seen in spring air photos.

"**Actively managed**" types include lawn, hay, or winter wheat (all appear green in 20), vineyards, golf courses, railroads, and timber harvesting.

"**Lightly managed**" such as inactive cropland/old fields, pasture (compared to "active" cropland, pastures often occur near barns/buildings and has a more mottled texture), pine plantations (usually planted in uniform blocks), orchards.

The remaining cells should be "**Natural"** forests, wetlands, shrubland, surface water (excluding agricultural ponds), and/or barren land. Assuming the previous categories were correct, subtract the sum of those tallies from 364 to obtain the number of "**Natural**" cells.

Minor variations among observers is expected, as shown in Table 6, but these differences are marginal once the weighted percent cover scores are calculated and the total LULC score is obtained (see page 30 for weights and calculation). Total LULC scores produced form Table 6 averaged 17.6 (± 1.2).

Part A: fragmentation

Five fragmenting features categories are assessed and tallied. These range in magnitude from 4-lane highways to unpaved roads and trails (e.g., hiking, snowmobile, horse). Additional intermediate categories include 2-lane roads, railroads (i.e., active, abandoned, rail-to-trail), and utility line Right of Way (ROW). Continuing with the same example site (Figure 5), the Landscape Buffer includes one (1) unpaved trail (snowmobile), one (1) railroad, and five (5) continuous named roads.

Table 6: Variation among three independent observations for Land Use Land Cover (LULC) at site NYW14-029. Values are present as mean tallies ± standard error (n = 3). Tallies were based on the 50 m x 50-m grid overlay; % LULC = # / 364 *100.

LULC type	cell tally (#)	LULC (%)
Impervious	44 ± 3	12 ± 1
Intense	39 ± 3	11 ± 1
Active	79 ± 10	22 ± 3
Light	37 ± 6	10 ± 2
Natural	164 ± 0	45 ± 0

Works cited

Cowardin, L. M., V. Carter, F. C. Golet and E. T. La Roe. 1979. Classification of wetlands and deepwater habitats in the United States. Rep. FWS/OBS-79/31. U.S. Fish and Wildlife Service, Washington, DC.

Faber-Langendoen, D., J. Rocchio, S. Thomas, M. Kost, C. Hedge, B. Nichols, K. Walz, G. Kittel, S. Menard, J. Drake, and E. Muldavin. 2012. Assessment of wetland ecosystem condition across landscape regions: A multi-metric approach. Part B. Ecological Integrity Assessment protocols for rapid field methods (L2). Report nr EPA/600/R-12/021bU.S. Environmental Protection Agency Office of Research and Development, Washington, DC.

Feldmann, A. L. 2013. Quality Assurance Project Plan (QAPP): Development of wetland assessment protocols in New York. Version 2. 26. New York Natural Heritage Program, SUNY-ESF Research Foundation, Albany, NY.

Feldmann, A. L. and T. Howard. 2013. Landscape Condition Assessment (LCA2) for New York. New York Natural Heritage Program, Albany, NY. <nynhp.org/shappell>

Feldmann, A. L., and E. A. Spencer. 2015. Draft EPA wetland workflow for plot set-up, sampling and scoring NYRAM 4.1. 6. New York Natural Heritage Program, Albany, NY.

Jacobs, A. D. 2010. Delaware Rapid Assessment Procedure Version 6.0. 36 pages. Delaware Department of Natural Resources and Environmental Control, Dover, DE.

PA DEP. 2014. Pennsylvania Wetland Condition Level 2 Rapid Assessment. Report nr 310-2137-002. 37 pages. Pennsylvania Department of Environmental Protection, Harrisburg, PA.

Peet, R. K., T. R. Wentworth, and P. S. White. 1998. A flexible, multipurpose method for recording vegetation composition and structure. Castanea 63:262-274.

Shappell, L. J., Feldmann, A. L., Spencer, E. A., and Timothy G. Howard. 2016. New York State Wetland Condition Assessment. EPA Wetland Program Development Grant. Final Report. New York Natural Heritage Program, Albany, NY.

Shappell, L. J., and T. G. Howard. 2018. Supporting actionable decision making for wetland permitting in New York from urban to rural environments. EPA Wetland Program Development Grant. Final Report. New York Natural Heritage Program, Albany, NY.

WETLAND CONDITION LEVEL 2 RAPID ASSESSMENT SCORING FORMS

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New York Rapid Assessment Method (Level 2) Field Worksheets

Developed by New York Natural Heritage Program
625 Broadway, 5th Floor, Albany, NY 12233-4757 (518) 402-8935 Fax (518) 402-8925 www.nynhp.org

Part A: Onscreen rapid assessment

Area of focus: The Landscape Buffer, a 540-m buffer around the center point.
Note: If the sample point will likely be moved in the field, complete this portion *after* the field survey.

Site description

Observer ______________________ Date of onscreen assessment ____________

Site name ______________________ Site code ______________________

Pub. date of the imagery: ______________________ Sample location was determined (*circle one*): *Randomly* *Subjectively*

Option 1: Use zonal statistics in ArcGIS, calculate the mean LCA score for a 540-m buffer around the center point ("LCA540" score), and then follow the calculation outlined below in Option 1.

Option 2: Complete the following LULC and fragmenting features tables.
Please note: Although score calculations are shown below, these may be completed after field survey or in Microsoft Excel. The % LULC column should sum to 100%, and the max Total LULC score is 40.

Land Use Land Cover (LULC)

Qualitatively assess the percent area occupied by each of the following land cover types.

GIS tip: in layout view, apply a 50 x 50 m grid to the data frame. Google Earth or GIS: use the measure polygon tool to measure type area.

	% LULC		*Type score*
Impervious surface *pavement, buildings, rock quarries*	________	*x 4 =*	________
Intensely managed *golf, row crops, sand/gravel mining*	________	*x 4 =*	________
Actively managed *lawn, timber, hay, ROW, grazing, unpaved road*	________	*x 3 =*	________
Lightly managed *old field, ditch, plantation, Stormwater pond*	________	*x 2 =*	________
Natural *forest, wetland, shrubland, water*	________	*x 0 =*	________

Sum type scores = ________ *÷ 10*

Total LULC score = ________

Fragmenting features

Tally the number of fragmenting features in each category found in Landscape Buffer.

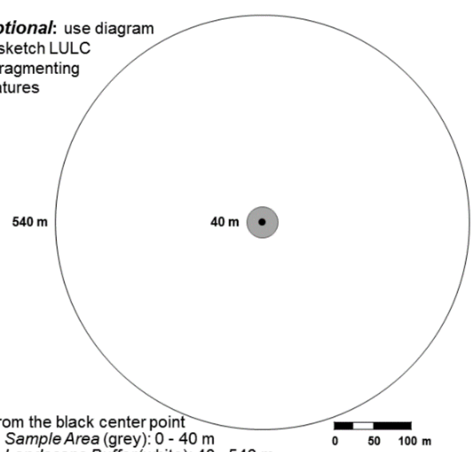
GIS tip: add New York State road, railroad, hiking & snowmobile trail layers

	Feature tally		*Feature score*
4-lane paved road *4-lanes or larger*	________	*x 6 =*	________
2-lane paved road	________	*x 4 =*	________
Railroad *Active or abandoned*	________	*x 4 =*	________
Utility line *Right-of-way (ROW)*	________	*x 2 =*	________
Unpaved road/trail *Grave/dirt road, hiking or snowmobile trail*	________	*x 1 =*	________
Other*:	________	*x =*	________

**Select an equivalent multiplier: 1, 2, or 4*

Total fragment score = ________
[sum feature scores or *maximum* score of 40]

Optional: use diagram to sketch LULC & fragmenting features



From the black center point
Sample Area (grey): 0 - 40 m
Landscape Buffer (white): 40 - 540 m

***Option 2** (manual)*
LULC + Frag scores *or* **max of 50 pts**: ________

***Option 1** (automated)*
$\text{Log}_{10}(\text{LCA540} + 1) \times 15$ ________

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Part B: Wetland stressor field worksheet

Area of focus: 40-m radius Sample Area (SA) & the surrounding 100-m Field Buffer (FB)

Observers ______________________________ Date ____________

County ____________________ Town ____________________

Site name ____________________ Site code ____________________

UTM or Lat/Long: ______________ / ______________ Field point in the GPS? Yes No

Wetland community description

Target NWI wetland class (≥ 90% of SA): EM SS FO1 FO4

Optional: NYNHP/ Nature-Serve/ other comm. class ____________

Optional: Landscape setting or Wetland origin (e.g., natural, created) ______________________________

Basic guidelines for establishing a Sample Area (SA) in the field

Refer to the methods manual for detailed guidelines and pre-field office activities. Note: <10% of SA should contain water >1 m deep. If applicable, randomly generated points are invalidated if moved >60 m.

Standard, 0.5 ha (5,025 m^2; 1.24 acres)

SA dimensions determined by (circle one): tape measure visual estimate

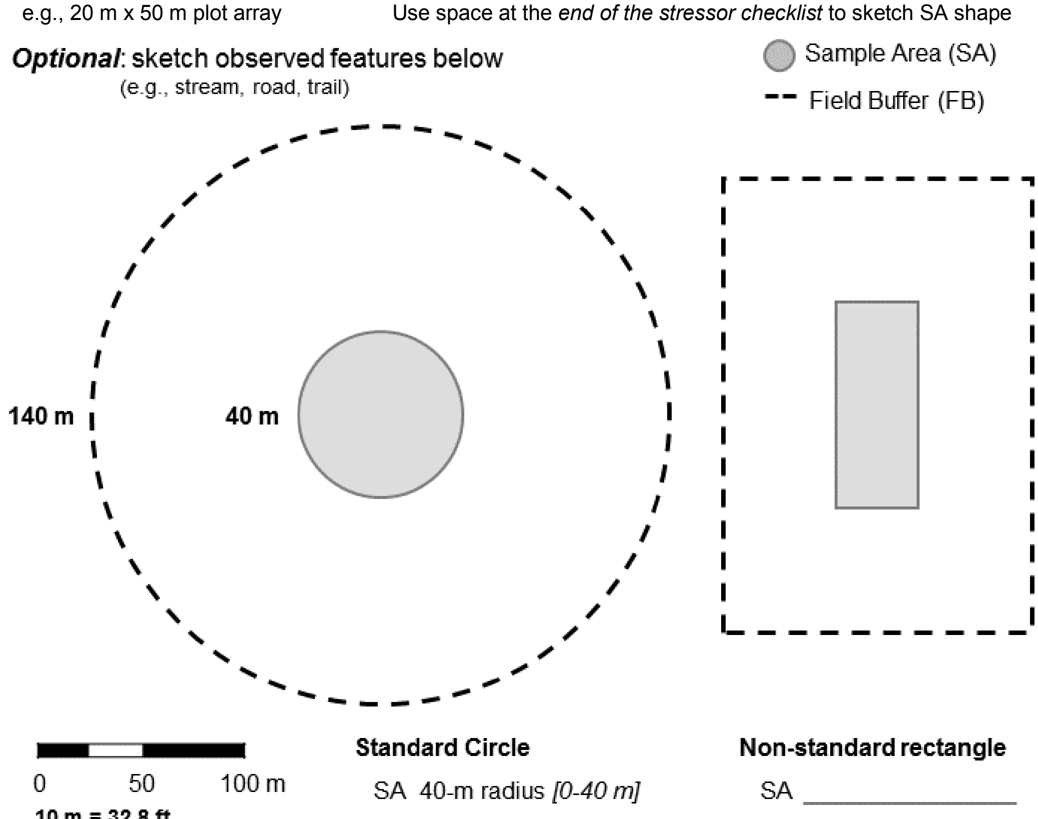
☐ CIRCLE - 40-m radius

Non-standard, 0.1-0.5 ha

☐ RECTANGLE e.g., 20 m x 50 m plot array

☐ OTHER Use space at the *end of the stressor checklist* to sketch SA shape

Optional: sketch observed features below (e.g., stream, road, trail)



Standard Circle

SA 40-m radius *[0-40 m]*

FB 100-m radius *[40-140 m]*

Non-standard rectangle

SA ____________

FB ____________

 Site code: _____________ Date: ___________

Wetland stressor checklist

Mark "X" in each applicable column if stressor is present in the Sample Area (SA), Field Buffer (FB), or absent (Abs) from both areas.

Tips: Keep an eye out for invasive species to include in the Invasive Richness Survey (pp. 7-8). Stressor sums at the bottom of each page are optional, but may be helpful when making the final checklist sum for each column.

VEGETATION ALTERATIONS

V1. Vegetation modification occurred within the past year, unless noted	SA	FB	Abs
Excessive wildlife herbivory *(e.g., deer, geese, insects)*			
Moderate/intense livestock grazing *(>25% bare soil)*			
Mowing *(low intensity lawn or hay)*			
Golf course or highly maintained turf *(NOT typical residential lawns)*			
Right-Of-Way: cleared *(brush cutting, chemical, etc. assoc. with powerlines & roads)*			
ROW, but no maintenance evident within past year			------
Logging within 2 years			
Annual agricultural row crops			
Plantation *(conversion from natural tree species, e.g., orchards, forestry)*			
V2. Invasive plant species abundance (see invasive richness list)			
Absent (circle one if applicable): SA FB Both	------	------	
Uncommon (Present, ≤ 20% cover) – List species in the invasive survey (see end)			------
Abundant (Present, > 20% cover) – List species in the invasive survey (see end)			------
V3. Other vegetation alterations *(e.g. woody debris removal)*			

HYDROPERIOD MODIFICATION

H1. General hydroperiod alterations	SA	FB	Abs
Ditching, tile draining, or other dewatering methods			
Stormwater inputs *(e.g., source pipe, impervious surface/roads/parking lot)*			
Water inflow reduced by upstream structure *(dam / weir / culvert; including perpendicular road, railroad beds)*			
Water outflow reduced due to impounding structure *(see above examples)*			
H2. Stream/riverine-specific modifiers			
Artificial levee *parallel* to stream *(including parallel road, railroad beds)*			
Channelized stream: straightened, hardened, or incised			
H3. Other indicators of hydro modification *(e.g. high temperature discharge, dead/dying standing trees)*			
Sum of stressor tallies for each column on this page:			

NYRAM 5 - Part B

Site code: ______________ Date: ____________

OTHER HYDRO/TOPOGRAPHIC MODIFICATIONS

T1. Development, filing, grading	SA	FB	Abs
Residential development: Low-moderate (≤2 houses/acre)	____	____	____
High (>2 houses /acre)	____	____	____
Commercial development *(e.g., buildings, factories, parking lots)*	____	____	____
Other filling/grading activity (not road-related; *e.g., exposed soils, dredge spoils*)	____	____	____
Landfill or illegal dump (*excessive garbage, trash*)	____	____	____
T2. Material removal			
Artificial pond, dredging (not ditch-related)	____	____	____
Mining/quarry (circle those present): sand gravel peat topsoil	____	____	____
T3. Roads, railroads, trails			
Hiking or biking trail (well-established)	____	____	____
Unpaved dirt/gravel road (established ATV, logging roads)	____	____	____
Railroad (circle those present): active abandoned rail-to-trail	____	____	____
Paved road: 2 lane	____	____	____
4 lane or larger	____	____	____
T4. Microtopography Soil surface variation <1 m in height (not pavement)			
Vehicle or equipment tracks: ATV, off-road motorcycles	____	____	____
Skidder or plow lines	____	____	____
Ruts in unpaved road (within poorly maintained *unpaved* roads)	____	____	____
Livestock tracks	____	____	____

SEDIMENT TRANSPORT

S1. Potential sediment stressors (within past year, unless noted)			
Active: construction (soil disturbance for development)	____	____	____
plowing (agricultural planting)	____	____	____
Forestry (circle if known): clear cut, even-aged management (within 2 years)	____	____	____
selective tree harvesting, salvage (within 1 year)	____	____	____
Livestock grazing (intensive, ground is > 50% bare)	____	____	____
Sediment deposits / plumes	____	____	____
Eroding banks / slopes	____	____	____
S2. Other evidence of sedimentation / movement (water consistently turbid, active mine, etc. – list if present)			
______________________	____	____	____
______________________	____	____	____
Sum of stressor tallies for each column on this page:	____	____	____

NYRAM 5 - Part B

Site code: ______________ Date: ____________

EUTROPHICATION

E1. Nutrient inputs	SA	FB	Abs
Direct discharge: agri. feedlots, manure spreading/pits, fish hatcheries	____	____	____
septic/sewage treatment plant	____	____	____
Adjacent to intensive annual row crops	____	____	____
Adjacent to intensive pasture grazing (>50% bare soil)	____	____	____
Dense/moderate algal mat formation	____	____	____
E2. Other evidence of contamination or toxicity (acidic drainage, fish kills, industrial point discharge, etc. – list if present)			
____________		____	____
____________		____	____
Sum of stressor tallies for each column on this page:	____	____	____

ADDITIONAL NOTES OR SKETCH OF NON-STANDARD LAYOUT

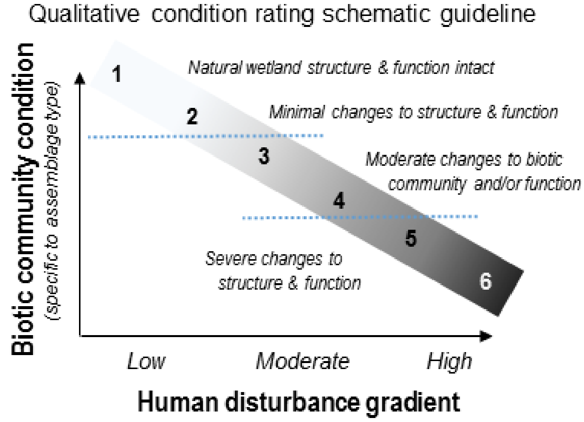
Qualitative condition rating

After completing the survey, describe overall site quality (SA + FB) as it relates to the level of human-mediated disturbance.

Least disturbed 1 2 3 4 5 6 *Highly disturbed*

Circle the number that best describes the site:

Qualitative condition rating schematic guideline



 Site code: ______________ Date: ____________

Invasive & nonnative species richness survey

Check or list all invasive and nonnative species present in the Survey Area (SA) and/or Field Buffer (FB). Note that the richness value only represents the number of *unique* species observed in both the SA and FB (i.e., *do not double* count a species).

Plants

Scientific name	Common name	USDA code	SA	FB
Acer platanoides	Norway maple	ACPL		
Agrostis gigantea	Redtop	AGGI2		
Ailanthus altissima	Tree-of-heaven	AIAL		
Alnus glutinosa	European alder	ALGL2		
Alliaria petiolata	Garlic mustard	ALPE4		
Aralia elata	Japanese angelica tree	AREL8		
Artemisia vulgaris	Mugwort	ARVU		
Berberis thunbergii	Japanese barberry	BETH		
Butomus umbellatus	Flowering rush	BUUM		
Celastrus orbiculatus	Oriental bittersweet	CEOR7		
Centaurea stoebe	Spotted knapweed	CEST8		
Cichorium intybus	Chicory	CIIN		
Cirsium arvense (syn. *C. setosum, C. incanum, Serratula arvensis*)	Canada thistle	CIAR4		
Cynanchum spp.	Swallowwort (black, pale or white)	CYNAN		
Daucus carota	Queen Anne's lace	DACA6		
Dioscorea oppositifolia	Chinese yam	DIOP		
Dioscorea polystachya	Chinese yam	N/A		
Elaeagnus umbellata	Autumn olive	ELUM		
Euonymus alatus	Burning bush/Winged euonymus	EUAL13		
Frangula alnus	Glossy/smooth buckthorn	FRAL4		
Galeopsis tetrahit	Hemp-nettle	GATE2		
Glechoma hederacea	Ground ivy	GLHE2		
Glyceria maxima	Reed manna grass	GLMA3		
Heracleum mantegazzianum	Giant hogweed	HEMA17		
Hydrocharis morsus-ranae	Common frogbit	HYMO6		
Hypericum perforatum	Common St. Johnswort	HYPE		
Iris pseudacorus	Yellow iris	IRPS		
Ligustrum vulgare	European privet	LIVU		
Lonicera japonica	Japanese honeysuckle	LOJA		
Lonicera spp.	Shrub honeysuckles (nonnative)	LONIC		
Lysimachia nummularia	Creeping Jenny, moneywort	LYNU		
Lythrum salicaria	Purple loosestrife	LYSA2		
Microstegium vimineum	Japanese stiltgrass	MIVI		
Murdannia keisak	Marsh dewflower	MUKE		
	Sum of unique species observed on this page			

 Site code: ____________ Date: ___________

Scientific name	Common name	USDA Code	SA	FB
Myosotis scorpioides	True forget-me-not	MYSC		
Myriophyllum spicatum	Eurasian water-milfoil	MYSP2		
Persicaria hydropiper (syn. *Polygonum hydropiper)*	Water-pepper smartweed	PEHY6 (POHY)		
Persicaria perfoliata	Mile a minute	POPE10		
Phalaris arundinacea	Reed canarygrass	PHAR3		
Phragmites australis	Common reed	PHAU7		
Poa compressa	Canada bluegrass	POCO		
Poa trivialis	Rough bluegrass	POTR2		
Prunus avium	Sweet cherry	PRAV		
Ranunculus ficaria	Lesser celandine	RAFI		
Reynoutria japonica (syn. *Polygonum cuspidatum*, *Fallopia japonica*)	Japanese knotweed	REJA2 (POCU6, FAJA2)		
Rhamnus cathartica	Common buckthorn	RHCA3		
Rosa multiflora	Multiflora rose	ROMU		
Rubus phoenicolasius	Wineberry	RUPH		
Solanum dulcamara	Climbing nightshade	SODU		
Trapa natans	Water chestnut	TRNA		
Trifolium repens	White clover	TRRE3		
Tussilago farfara	Coltsfoot	TUFA		
Typha x *glauca*	Hybrid cattail	TYGL		
Verbascum thapsus	Common mullein	VETH		
Veronica officinalis	Common speedwell	VEOF2		

Animals & pathogens

Adelges tsugae	Hemlock Wooly Adelgid		
Agrilus planipennis	Emerald Ash Borer		
Anaplophora glabripennis	Asian Longhorned Beetle		
Cipangopaludina spp *aquatic snails*	Invasive Aquatic Snails		
Dendroctonus frontalis	Southern Pine Beetle		
Halyomorpha halys	Brown Marmorated Stink Bug (BMSB)		
Orconectes rusticus	Rusty Crayfish		
Lymantria dispar	Gypsy Moth (caterpillar)		

Additional species observed, but not listed above

Sum of unique species observed on this page ______________

 Site code: ____________ Date: ___________

Part B *field data summary*

Summarize your data and enter values into the empty spaces below.

STRESSORS

Sum tallies in the Wetland Stressor Checklist (do *not* include invasive richness survey data here). Use the stress multiplier to calculate the Metric Score. Stressor score = sum of the metric scores.

		SA		FB		Absent
Stressor tally sum						
Stressor Multiplier (SM)	×	*8*	×	*4*	×	*0*
Metric Score	=	________	=	________	=	________
Stressor score		________				

INVASIVE PLANT COVER (%)

Where invasives are present, circle the number that corresponds to tallies indicated in section V2. Sum the values to obtain the invasive cover score. (Invasive score = zero if no invasive were observed in the SA or FB.)

Please note: All values below account for points earned when tallied in section V2 above. This scoring adjustment removes double-counting concerns for this metric, and in doing so, causes some values to be negative.

	SA	FB
Uncommon (≤ 20% absolute cover)	*-4*	*-2*
Abundant (>20% absolute cover)	*8*	*4*
Pervasive in SA (>75% relative cover)	*15*	---

Invasive cover score ________

INVASIVE & NONNATIVE PLANT SPECIES RICHNESS (#)

Count all <u>unique</u> plant, animal, & pathogen species observed in the SA & FB. If absent, write zero.

Invasive & nonnative richness ________

QUALITATIVE CONDITION RATING

Value generally describes the SA *and* the buffer, from least disturbed (1) to heavily disturbed (6) (see p. 6).

Condition rating ________

Part B cumulative score ________

[Part B is capped at a maximum of 70 points.
If Part B>70, use 70 when calculating your final score.

Stressors score + Invasives cover score + Invasive richness + Condition score.

NYRAM5 Score: ________

$$\left(\frac{Part\ A\ (\max 50\ pts) + Part\ B\ (\max 70\ pts)}{135}\right)\times 100$$

Scores range from a minimum of 1 to a maximum of 100.

Submit your NYRAM score to NYNHP's databank & see how your score stacks up: www.nynhp.org/shappell

Helpful Invasive Species References

Identification and General information

New York Invasive Species Information

www.nyis.info/

Website includes plants, animals and pathogens

Invasive Plants and their Native Lookalikes: an Identification Guide for the Mid-Atlantic

www.nybg.org/files/scientists/rnaczi/Mistaken_Identity_Final.pdf

Invasive Species ID Training Modules by Midwest Invasive Species Info. Network

www.misin.msu.edu/training/

Website includes plants, animals, and pathogens.

A Field Guide to Invasive Plants or Aquatic and Wetland Habitat for Michigan

http://mnfi.anr.msu.edu/invasive-species/AquaticsFieldGuide.pdf

Prohibited and Regulated Invasive Plants of New York State

www.dec.ny.gov/docs/lands_forests_pdf/isprohibitedplants2.pdf

USDA National Invasive Species Information Center – Identification Resources

www.invasivespeciesinfo.gov/resources/identify.shtml

Website includes plants, animals, and pathogens.

Invasive species mapping

iMapInvasives

www.imapinvasives.org/

Website includes plants, animals, and pathogens – serves as the central repository for existing locations of invasive species in New York State.

Features/tools:

Generate species lists by geographic, municipal, property, or jurisdictional boundaries.

Contribute data from *your* field observations.

Learn about invasive management methods.

Invasive Plant Atlas of New England (IPANE)

www.eddmaps.org/ipane/Species/

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APPENDIX B: UPLAND ADJACENT AREA RAPID ASSESSMENT FIELD FORMS

Adjacent areas upland structure & stressor field worksheet

Observers ______________________________ Date ____________

Site name ____________________ Site code ________ F-code ____________

County ____________________ City/Town ________________________

Basic Guidelines

Standard layout includes three regularly placed 10m x 10m plots starting at the biological wetland edge (≤50% FAC/FACW/OBL), on which the first buffer plot (BP) is centered (0m). Moving upland, the second and third plots should be placed 25m and 50m from the wetland edge, respectively; indicate how that measurement was made (meter tape, GPS, or paced). GPS points should be taken at each BP center, but if a plot center is inaccessible, indicate your reasoning in the Lat/Long space provided. Aspect (°): take the down-slope aspect within each plot (use mag. north). Slope (°): obtain a representative slope for the 10-m plot using a clinometer.

Habitat type: indicate whether the plot is Natural (**Nat'l**: e.g., unmanaged forest, shrubland, water); Lightly Managed (**LM**: e.g., old field, ditch, plantation, Stormwater pond); Actively Managed (**AM**: e.g., lawn, hay, ROW, grazing, timber, unpaved road); Intensely Managed (**IM**: e.g., golf, row crops, sand/gravel mining); Impervious Surface (**IS**: e.g., pavement, homes/buildings). If habitat types along the 50-m transect transitions from natural to human land use, take a GPS point at the boundary (e.g., forest edge & yard); no BP strata or stressor data need be collected at the boundary.

Table 1	Dist. from wet edge (m)	Method (Circle one)	Aspect (mag N)	Slope (degrees)	Point in GPS?	Latitude/UTM	Longitude/UTM	Habitat type (Circle one)
BP0		N/A			Yes No			Nat LM AM IM IS
BP25		Tape GPS Pace			Yes No			Nat LM AM IM IS
BP50		Tape GPS Pace			Yes No			Nat LM AM IM IS
Nat'l edge		Tape GPS Pace			Yes No			N/A

Strata Composition (Part A)

Circle all that apply: Canopy Type: D = Deciduous; E = Evergreen; B = Broad-leaf; N = Needle-leaf; A = Absent: No tree canopy. Estimate lichen on tree trunks (0-3m high) using four cover classes: 0; <1/3; 1/3 to 2/3; >2/3 of the trunk is covered in lichen.

Strata cover: Circle one cover class for each category: 0 = Absent; 1 = Sparse (<10%); 2 = Moderate (10-40%); 3 = Heavy (40-75%); 4 = Very heavy (>75%). For data validation, also give a raw estimate of strata cover (%). Trees are classified as individuals >5m high, while shrubs and saplings ("Shrub/Sap") are woody plants <5m high. Short vines are <0.5m high. Coarse Woody Debris (CWD) includes down wood >7.5 cm diameter.

Buffer Plot 0

Strata Category		%
Canopy Type	D E A	
Leaf Type	B N	
Arboreal lichen	0 1 2 3	%
Trees (>5m high) Big (DBH>0.3m)	0 1 2 3 4	
Little (DBH<0.3m)	0 1 2 3 4	
Shrub/Sap (<5m high) Tall (2-5m high)	0 1 2 3 4	
Medium (0.5-2m)	0 1 2 3 4	
Short (<0.5m)	0 1 2 3 4	
Short Vines	0 1 2 3 4	
Herbs/Forbs/Grams	0 1 2 3 4	
Lawn or Old Field (circle one)	0 1 2 3 4	
Ground Moss	0 1 2 3 4	
% invasive cover	0 1 2 3 4	
Bare ground	0 1 2 3 4	
Natural litter, duff (not yard waste)	0 1 2 3 4	
CWD (>7.5 cm D)	0 1 2 3 4	
Rocks	0 1 2 3 4	
Water	0 1 2 3 4	
Other* (describe)	0 1 2 3 4	

Buffer Plot 25

Strata Category		%
Canopy Type	D E A	
Leaf Type	B N	
Arboreal lichen	0 1 2 3	%
Trees (>5m high) Big (DBH>0.3m)	0 1 2 3 4	
Little (DBH<0.3m)	0 1 2 3 4	
Shrub/Sap (<5m high) Tall (2-5m high)	0 1 2 3 4	
Medium (0.5-2m)	0 1 2 3 4	
Short (<0.5m)	0 1 2 3 4	
Short Vines	0 1 2 3 4	
Herbs/Forbs/Grams	0 1 2 3 4	
Lawn or Old Field (circle one)	0 1 2 3 4	
Ground Moss	0 1 2 3 4	
% invasive cover	0 1 2 3 4	
Bare ground	0 1 2 3 4	
Natural litter, duff (not yard waste)	0 1 2 3 4	
CWD (>7.5 cm D)	0 1 2 3 4	
Rocks	0 1 2 3 4	
Water	0 1 2 3 4	
Other* (describe)	0 1 2 3 4	

Buffer Plot 50

Strata Category		%
Canopy Type	D E A	
Leaf Type	B N	
Arboreal lichen	0 1 2 3	%
Trees (>5m high) Big (DBH>0.3m)	0 1 2 3 4	
Little (DBH<0.3m)	0 1 2 3 4	
Shrub/Sap (<5m high) Tall (2-5m high)	0 1 2 3 4	
Medium (0.5-2m)	0 1 2 3 4	
Short (<0.5m)	0 1 2 3 4	
Short Vines	0 1 2 3 4	
Herbs/Forbs/Grams	0 1 2 3 4	
Lawn or Old Field (circle one)	0 1 2 3 4	
Ground Moss	0 1 2 3 4	
% invasive cover	0 1 2 3 4	
Bare ground	0 1 2 3 4	
Natural litter, duff (not yard waste)	0 1 2 3 4	
CWD (>7.5 cm D)	0 1 2 3 4	
Rocks	0 1 2 3 4	
Water	0 1 2 3 4	
Other* (describe)	0 1 2 3 4	

* Examples of "other" categories: Tall Vines (>5m high); Submerged Aquatic Vegetation (SAV); yard waste (clippings, leaves, etc.); trash.

Adjacent areas upland structure & stressor field worksheet

Stressor checklist (Part B). Use the checkboxes to indicate stressor “presence” within observed buffer plot(s). The “flag” column functions as a footnote when additional comments/notes pertain to a specific stressor.

Habitat/Vegetation stressors

Buffer plot #	0	25	50	Flag
Forest cutting (clear of selective)	☐	☐	☐	
Tree plantation	☐	☐	☐	
Tree canopy herbivory (insect)	☐	☐	☐	
Shrub/sapling layer browsed	☐	☐	☐	
Herbicide/pesticide use	☐	☐	☐	
Mowing/shrub cutting	☐	☐	☐	
Trails	☐	☐	☐	
Soil compaction (wild animal or human)	☐	☐	☐	
Off-road vehicle damage	☐	☐	☐	
Soil erosion/deposition (from wind, water, or overuse)	☐	☐	☐	
Other	☐	☐	☐	

Comments/Flags (V#):

Residential & Urban stressors

Buffer plot #	0	25	50	Flag
Road (paved or unpaved)	☐	☐	☐	
Power Line	☐	☐	☐	
Parking lot/pavement	☐	☐	☐	
Golf course	☐	☐	☐	
Lawn/park	☐	☐	☐	
Suburban residential	☐	☐	☐	
Urban/Multifamily	☐	☐	☐	
Landfill	☐	☐	☐	
Dumping	☐	☐	☐	
Trash	☐	☐	☐	
Other	☐	☐	☐	

Comments/Flags (R#):

Hydrology stressors

Buffer plot #	0	25	50	Flag
Ditches, Channelization	☐	☐	☐	
Dike/Dam/Road/RR bed (impede horizontal flow)	☐	☐	☐	
Water level control structure	☐	☐	☐	
Excavation, Dredging	☐	☐	☐	
Fill/Spoil banks	☐	☐	☐	
Freshly deposited sediment (unvegetated)	☐	☐	☐	
Soil loss/Root exposure	☐	☐	☐	
Wall/Riprap	☐	☐	☐	
Inlets, Outlets	☐	☐	☐	
Point Source/Pipe (effluent or stormwater)	☐	☐	☐	
Impervious surface input (sheetflow)	☐	☐	☐	

Comments/Flags (H#), Other:

Agricultural & Rural stressors

Buffer plot #	0	25	50	Flag
Rural residential	☐	☐	☐	
Pasture/Hay	☐	☐	☐	
Row crops - tilling	☐	☐	☐	
Orchard/Nursery	☐	☐	☐	

Buffer plot #	0	25	50	Flag
Fallow field (recent-resting row crop field)	☐	☐	☐	
Old field (old grass, shrubs, trees)	☐	☐	☐	
Irrigation	☐	☐	☐	
Drain tiling	☐	☐	☐	

Buffer plot #	0	25	50	Flag
Livestock or Domestic Animals	☐	☐	☐	
Confined Animal Feeding	☐	☐	☐	
Gravel Pit	☐	☐	☐	
Other	☐	☐	☐	

Comments/Flags (A#):

Invasive species. Write-in additional species as needed. See NYRAM form for full suggested species list.

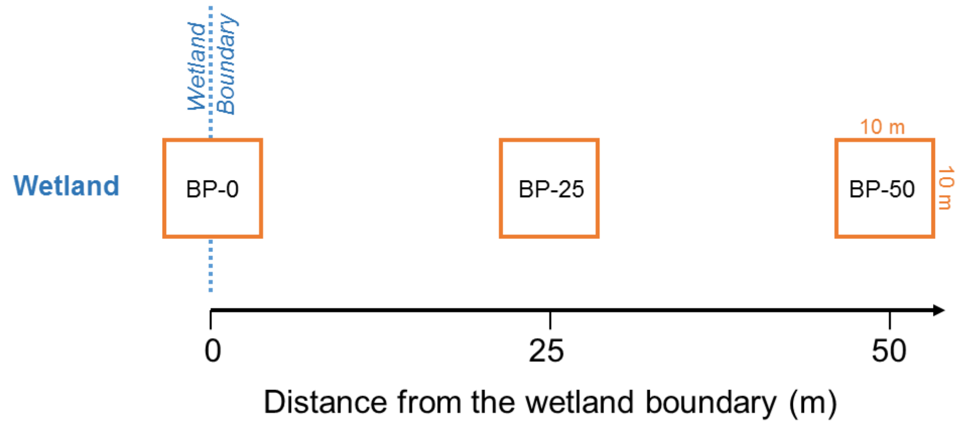
Buffer plot #	0	25	50	Flag
Agrilus planipennis (EAB)	☐	☐	☐	
Ailanthus altissima	☐	☐	☐	
Alliaria petiolata	☐	☐	☐	
Berberis thunbergii	☐	☐	☐	
Celastrus orbiculatus	☐	☐	☐	
Cichorium intybus	☐	☐	☐	
Cirsium spp.	☐	☐	☐	
Cynanchum spp.	☐	☐	☐	
Daucus carota	☐	☐	☐	
Elaeagnus spp. (*E. umbellata, E. angustifolia*)	☐	☐	☐	
Euonymus alatus	☐	☐	☐	
Frangula alnus	☐	☐	☐	
Glechoma hederacea	☐	☐	☐	

Buffer plot #	0	25	50	Flag
Hesperis matronalis	☐	☐	☐	
Hypericum perforatum	☐	☐	☐	
Ligustrum vulgare	☐	☐	☐	
Lonicera japonica	☐	☐	☐	
Lonicera spp. (shrub)	☐	☐	☐	
Lotus corniculatus	☐	☐	☐	
Lysimachia nummularia	☐	☐	☐	
Lythrum salicaria	☐	☐	☐	
Microstegium vimineum	☐	☐	☐	
Myosotis scorpioides	☐	☐	☐	
Nasturtium officinale	☐	☐	☐	
Phalaris arundinacea	☐	☐	☐	
Phragmites australis	☐	☐	☐	

Buffer plot #	0	25	50	Flag
Reynoutria japonica	☐	☐	☐	
Rhamnus cathartica	☐	☐	☐	
Rosa multiflora	☐	☐	☐	
Rubus phoenicolasius	☐	☐	☐	
Saponaria officinalis	☐	☐	☐	
Solanum dulcamara	☐	☐	☐	
Trifolium repens	☐	☐	☐	
Tussilago farfara	☐	☐	☐	
Verbascum thapsus	☐	☐	☐	
	☐	☐	☐	
	☐	☐	☐	
	☐	☐	☐	
	☐	☐	☐	

Comments/Flags(I#):

Schematic of a standard upland adjacent area plot layout:



Calculating the upland adjacent area rapid assessment score (UP-RAM)

Field RAM pre-score: Use the strata scoring tables on the following page to calculate plot scores for BP0 and BP25. Plot scores, along with the following variables populate equation 1 to produce the Field RAM pre-score.

$BP50_w$: The field RAM pre-score includes BP50 habitat type as a weighted score: Natural = 0; Lightly Managed (LM) = +0.5; Active Management (AM) = +0.9; and Impervious surface (IS) = +1.2.

$BUFF_w$: Based on your measured distance to natural edge, score as follows: ≤1 m wide = +4; ≤8 = +4; ≤15 m = +2; <100 m = +1; >100 m = 0.

INV_w: This is a constant based on the presence of more than one nonnative invasive plant species. If two or more invasive species were observed across either BP0 or BP25 add two (2) points.

Equation 3: Field RAM pre-score

$$Field\ RAM\ score = Abs(BP0\ score - BP25\ score) + BUFF_w + BP50_w + INV_w$$

UP-RAM final score

Using your site's digitized Area of Interest (AOI), use the zonal statistics tool in ArcGIS to calculate the maximum impervious surface score within the AOI polygon. Use that maximum score to assign weighting as follows (IS_{MAX}): <20 = 0; ≥20 = +2; ≥50 = +5; ≥50 = +8. Scoring threshold were modeled after National Wetland Condition Assessment 2011 reference wetland protocols.

Equation 4: UP-RAM final score

$$UP - RAM\ = IS_{MAX} +\ Field\ RAM\ score$$

Table 7: Use strata composition data to complete the following scoring tables. Points are assigned based on cover classes selected in Part B. Points are earned (+) or deducted (-) based on strata composition. Stressor and invasive species data collected in Part B should be tallied (counted) and entered in the field below. Habitat type weighting decreases with land use intensity and distance from the biological wetland boundary; refer to BP-specific weighting scores below.

BP0 strata scoring

Strata Category	Cover class criteria	(+)	CC criteria	(-)
Canopy	"absent"	+5	*NA*	---
Arboreal lichen (Cover class 2 = zero pts)	0 or 1	+1	3	-1
Big Trees	0- 2	+2	3 or 4	-2
Little Trees (Cover class 2 = zero pts)	0 or 1	+1	3-4	-2
Tall Shrub/Sap (Cover class 2 = zero pts)	0 or 1	+2	2-4	-1
Medium Shrub/Sap (Cover class 2 = zero pts)	0 or 1	+2	2-4	-1
Short Shrub/Sap (Cover class 2 = zero pts)	0 or 1	+2	2-4	-1
Bare ground (Cover class <3 = zero pts)	3 or 4	+1	--	--
Herbs/Forbs/Grams (Cover class 2 = zero pts)	0 or 1	+1	3 or 4	-1
Lawn or Old Field	0 or 1	+0	--	--
	2	+1	--	--
	3 or 4	+2	--	--
% invasive cover	0 or 1	+0	--	--
	2	+17	--	--
	3	+34	--	--
	4	+51	--	--
	Sum (+) ______		Sum (-) ______	

Additive strata score: BP0	
Total stressor tally: BP0	
Total invasive tally: BP0	
Habitat type score: BP0 (N=0; LM=2; AM=3; IM=4; IS=5)	
BP0 total plot score: [sum grey boxes]	

BP25 strata scoring

Strata Category	Cover class criteria	(+)	CC criteria	(-)
Canopy	"absent"	+5	*NA*	---
Arboreal lichen (Cover class 2 = zero pts)	0 or 1	+1	3	-1
Big Trees	0- 2	+2	3 or 4	-2
Little Trees (Cover class 2 = zero pts)	0 or 1	+1	3-4	-2
Tall Shrub/Sap (Cover class 2 = zero pts)	0 or 1	+2	2-4	-1
Medium Shrub/Sap (Cover class 2 = zero pts)	0 or 1	+2	2-4	-1
Short Shrub/Sap (Cover class 2 = zero pts)	0 or 1	+2	2-4	-1
Bare ground (Cover class <3 = zero pts)	3 or 4	+1	--	--
Herbs/Forbs/Grams (Cover class 2 = zero pts)	0 or 1	+1	3 or 4	-1
Lawn or Old Field	0 or 1	+0	--	--
	2	+1	--	--
	3 or 4	+2	--	--
% invasive cover	0 or 1	+0	--	--
	2	+17	--	--
	3	+34	--	--
	4	+51	--	--
	Sum (+) ______		Sum (-) ______	

Additive strata score: BP25	
Total stressor tally: BP25	
Total invasive tally: BP25	
Habitat type score: BP25 (LM=0.9; AM=1.3; IM=1.8; IS=2.2)	
BP25 total plot score: [sum grey boxes]	

APPENDIX C: ADDITIONAL DATA TABLES AND GRAPHS

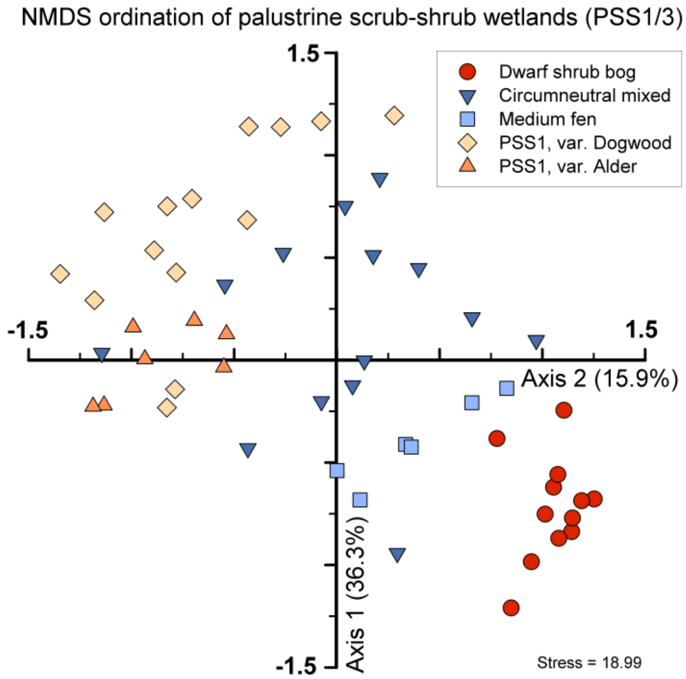
Table 8: Wetland floristic quality and condition scores by community. Data are present as mean ± standard error. Communities with fewer than three survey sites were not included in the table. Wetland class follows Cowardin et al. 1979: emergent marsh (EM); deciduous scrub-shrub (SS1); evergreen scrub-shrub (SS3); deciduous forested wetland (FO1); evergreen forested wetland (FO4). Data are divided among NHP* (NYNHP, APA, and NWCA) and New York City-base Natural Areas Conservancy (NAC), the latter did not use NYRAM.

Data source	Wetland class	Community name	n	Plant Richness	Weighted mean C	Mean C	Integrity RAM (Level 2.5)	NYRAM5 (Level 2)	LCA540 (Level 1)
NHP*	EM	Patterned peatland	3	25 ± 5	9.1 ± 0.1	8.4 ± 0.2	25.3 ± 3.2	22 ± 3	77 ± 33
	EM	Sedge meadow	20	31 ± 3	5.3 ± 0.3	5.0 ± 0.2	28.1 ± 3.2	38 ± 7	244 ± 84
	EM	Shallow emergent marsh	34	48 ± 3	3.3 ± 0.2	3.8 ± 0.1	50.5 ± 2.4	52 ± 5	565 ± 89
	EM	Invaded marsh	8	29 ± 4	1.1 ± 0.2	3.8 ± 0.2	64.9 ± 3.9	76 ± 10	761 ± 100
	EM/SS	Inland poor fen	8	26 ± 3	8.3 ± 0.6	7.5 ± 0.5	14.6 ± 3.8	17 ± 4	30 ± 14
	SS1	Circumneutral Neutral Mix**	15	36 ± 4	5.6 ± 0.3	5.4 ± 0.3	30.9 ± 4.0	16 ± 4	180 ± 63
	SS1	Medium fen	6	28 ± 5	7.4 ± 0.3	6.6 ± 0.2	17.8 ± 6.1	16 ± 8	93 ± 75
	SS1	SS var. Alnus**	7	49 ± 5	4.4 ± 0.2	4.2 ± 0.2	42.5 ± 3.5	43 ± 6	389 ± 130
	SS1	SS var. Cornus**	14	48 ± 3	3.6 ± 0.3	3.9 ± 0.2	55.1 ± 3.4	62 ± 6	801 ± 131
	SS3	Dwarf shrub bog	12	19 ± 1	8.3 ± 0.1	8.0 ± 0.2	19.6 ± 3.9	21 ± 4	137 ± 82
	FO1	Floodplain forest	15	49 ± 3	3.7 ± 0.3	3.6 ± 0.2	60.2 ± 2.7	69 ± 4	854 ± 130
	FO1	Red maple-hardwood swamp	11	54 ± 4	4.7 ± 0.1	4.3 ± 0.1	51.5 ± 2.8	49 ± 6	714 ± 168
	FO1	Silver maple-ash swamp	16	57 ± 4	4.9 ± 0.3	4.0 ± 0.2	54.6 ± 5.0	57 ± 5	808 ± 141
	FO4	Black spruce-tamarack bog	5	25 ± 3	7.5 ± 0.3	7.8 ± 0.2	13.6 ± 5.7	13 ± 6	36 ± 28
	FO4	Hemlock-hardwood swamp	10	55 ± 5	6.1 ± 0.1	5.6 ± 0.2	39.2 ± 2.3	36 ± 4	270 ± 81
	FO4	Northern white cedar swamp	7	67 ± 8	5.2 ± 0.4	5.2 ± 0.3	49.2 ± 8.9	45 ± 11	709 ± 170
	FO4	Spruce-fir swamp	5	29 ± 3	6.4 ± 0.3	6.8 ± 0.2	9.3 ± 6.2	10 ± 8	39 ± 39
NAC	FO1	Floodplain forest	7	3 ± 1.0	2.4 ± 0.4	20 ± 2	72 ± 7	N/A	1741 ± 155
	FO1	Floodplain forest variant: *Juglans/Carya/Quercus*	12	5 ± 0.3	3.4 ± 0.2	20 ± 3	70 ± 4	N/A	1363 ± 104
	FO1	Red maple-hardwood/blackgum swamp	61	5 ± 0.1	3.8 ± 0.1	22 ± 1	58 ± 1	N/A	1500 ± 52
	SS1	Shrub-swamp	3	4 ± 0.5	4.1 ± 1.0	13 ± 3	59 ± 8	N/A	1296 ± 143

**Preliminary shrub swamp variants were identified through statistical analyses outlined on the following page.

Scrub-shrub shrub wetland variants

We used ordination analysis, hierarchical cluster analysis, and indicator species analysis to identify three possible variants of the deciduous shrub swamp community.



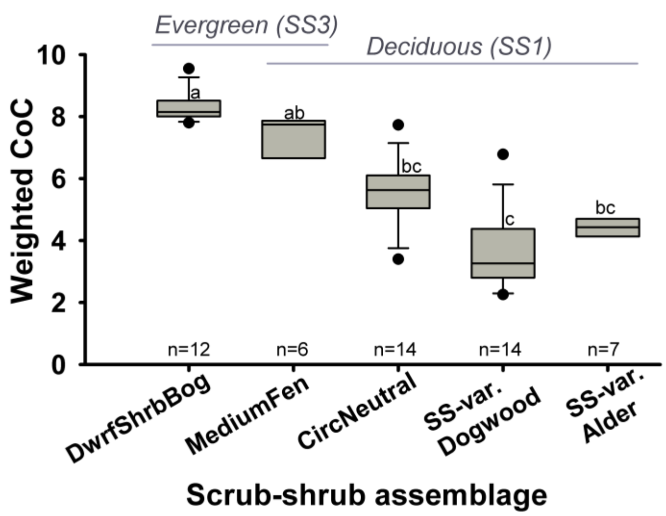


Figure 18: Top: Ordination analysis was used to identified potential variants within the deciduous shrub swamp community. Bottom: Variant communities differ significantly in their weighted mean C scores (p <0.005).

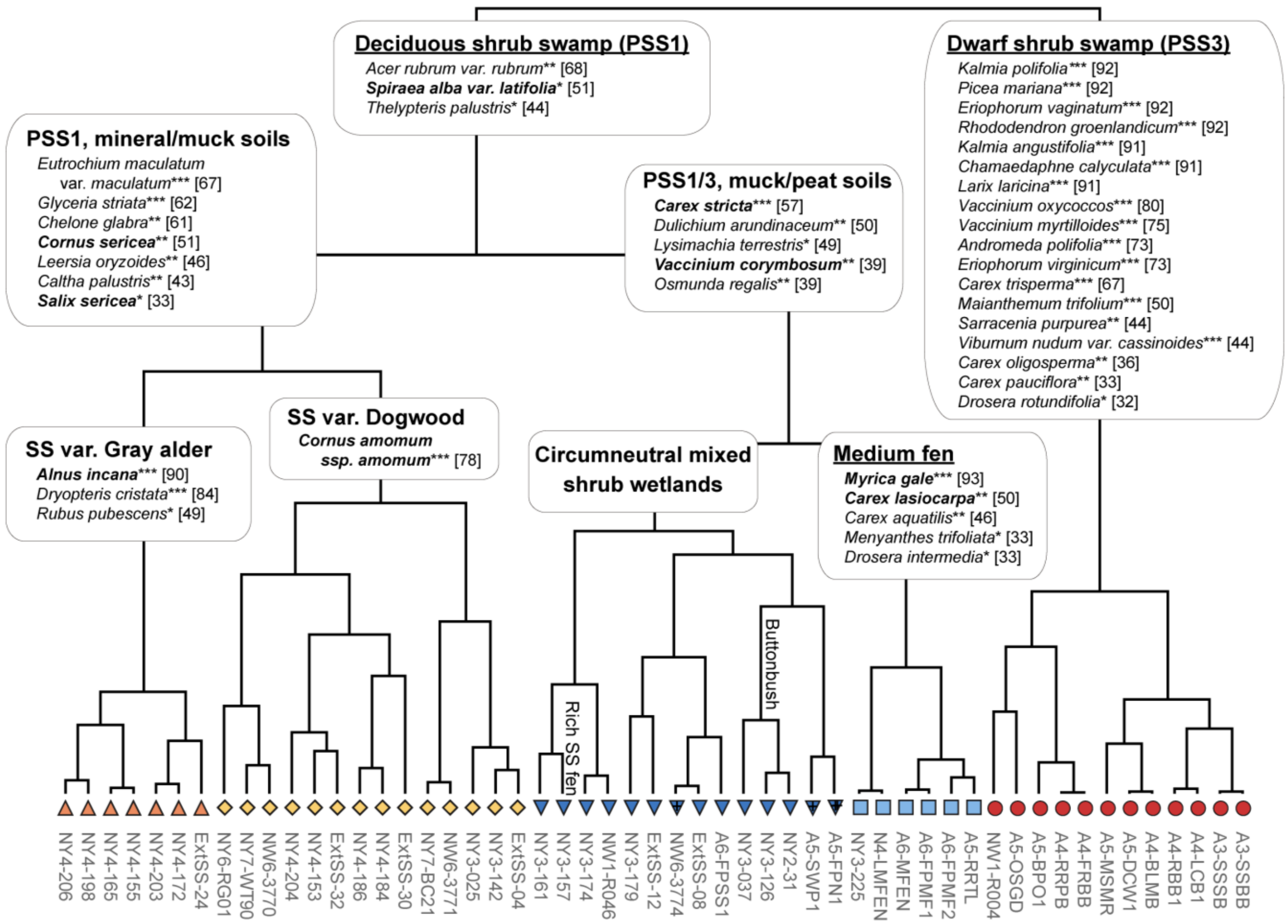


Figure 19: Hierarchical cluster analysis and indicator species analysis of shrub wetland communities and community variants within the NHP/APA dataset (PCORD ver. 5, McCune and Grace). Palustrine deciduous and evergreen scrub-shrub (PSS1 and PSS3, respectively) classification follows Cowardin et al. (1979). Underlined community names are currently recognized and described as NYS communities by Edinger et al. (2014); data analysis suggests four variants of deciduous shrub swamps. Dwarf shrub bogs served as the "out group" for the cluster analysis because they have a unique and specific plant assemblage. Here medium fens dominated by sweetgale (*Myrica gale*) were significantly different from the circumneutral mixed shrub wetland group, which includes non-*Myrica* dominated fens (blue triangles with black crosses), rich shrub fens, high-bush blueberry bogs, and assemblages dominated by buttonbush (*Cephalanthus occidentalis*). Two variants of deciduous shrub swamps were identified, one dominated by grey alder, the other by dogwood. Species' indicator value [IV] is noted in brackets with significance as follows: *** p<0.001; ** p<0.01; * p<0.05. Minimum indicator species requirements: IV score > 30; Species' coefficient of conservatism score > 3; p < 0.05; and relative frequency pre-IV score > 25 (occurred within at least a quart of sites). Species' placement within the hierarchy corresponds to where their IV score was the highest. Primary shrub and herbaceous indicator species for a given deciduous shrub swamp guild (PSS1) are highlighted by bold font. Two-way cluster analysis used Sorensen (Bray-Curtis) distance matrix and flexile beta linkage (-0.75); percent chaining for the displayed cluster analysis 1.96%.

APPENDIX D. SCRIPTS FOR CREATING AREA OF INFLUENCE POLYGONS FOR GIS ASSESSMENT

First script, "a_buffer_points.py"

```
# -*- coding: utf-8 -*-
"""
Created on Fri Oct 21 14:42:24 2016

@author: Tim Howard

This script begins with, as inputs:
    sampled wetland points

and then buffers each point a specified distance (1 or 1.5 km seems appropriate)
without merging the resulting polygons (important)

Assumptions:
    input point layer has a field named "site_ID" and these are unique
    site_ID values MUST NOT have hyphens "-". These are illegal in shapefile names
    (you can replace hyphens with underscore using field calculator in Arc,
    using the re python library and Python as parser: add "import re" in Codeblock,
then
    re.sub("-", "_", !theSiteIDFieldWithHyphens!)
    in main code field.)

If running a new set of points and you want to keep earlier runs, move all the
folders
in output/ to a new folder (except _workspace)

"""

#%%
# setup
import arcpy
from arcpy import env as ENV

ENV.workspace = "D:/EPA_AdjArea/CalcAdjArea/output/_wrkspace"
ENV.overwriteOutput = True

#%%
# start with the sample points, buffer them
POINT_LOC = "D:/EPA_AdjArea/CalcAdjArea/inputs"
POINT_LAYER = "all_points_4April2018.shp"
IN_POINTS = POINT_LOC + "/" + POINT_LAYER

BUFFERED_PTS = POINT_LOC + "/" + "AllPts_Buff1km.shp"
BUFF_DIST = "1000"
# do the buffer, don't merge the resulting polys
arcpy.Buffer_analysis(IN_POINTS, BUFFERED_PTS, BUFF_DIST, "FULL", "ROUND", "NONE")

#%%

#===============================================================================
# The previous call, Buffer_analysis, seems to create a situation in inPoints
# that messes up later attempts to use the same shapefile. Probably a bug. So this
# script needs to be stopped here and the next script run with a fresh console.
#===============================================================================
```

Second script, “b_calc_flow_dir.py”

```
# -*- coding: utf-8 -*-
"""
Created on Fri Oct 21 14:42:24 2016

@author: Tim Howard

This script begins with, as inputs:
    - sampled wetland points and buffered polygons (see prev script)
    - 10 m dem or other dem such as from lidar. Use 'mosaic to new raster' tool in
      arcgis toolbox to create a single raster from many tiles.
    - you can provide a dem that does not cover the full extent of the points. Those
      locations with no dem under them will be tossed.

It then extracts an area around each point and, through many steps, estimates the
    upland area contributing to that point (or a region around the point)

Assumptions:
    input point layer has a field named "site_ID" and these are unique

If running straight from previous script,
    restart the kernal with ctrl+. in console (control period).
"""

#%%
# setup
import os
import arcpy
from arcpy import env as ENV
import arcpy.sa as SA

ENV.workspace = "D:/EPA_AdjArea/CalcAdjArea/output/_wrkspace"
ENV.overwriteOutput = True
arcpy.CheckOutExtension("Spatial")
arcpy.ImportToolbox("C:/Program Files/TauDEM/TauDEM5Arc/TauDEM Tools.tbx", "TauDEM")

BASE_OUT_PATH = "D:/EPA_AdjArea/CalcAdjArea/output"

#%%
# get a list of siteIDs for all records, just to be sure for the next step
POINT_LOC = "D:/EPA_AdjArea/CalcAdjArea/inputs"
BUFFERED_PTS = POINT_LOC + "/" + "AllPts_Buff1km.shp"

cursor = arcpy.SearchCursor(BUFFERED_PTS)
idList = []
for row in cursor:
    siteval = row.getValue("site_ID")
    idList.append(siteval)

if len(idList) > len(set(idList)):
    print "site_ID VALUES ARE NOT UNIQUE!!"
else:
    print "Values in site_ID column are unique"

# check if there are hyphens in idList
if True in ["-" in x for x in idList]:
    print "HYPHEN in site names! Remove them before proceeding"
else:
    print "No hyphens found; continue"
```

```
del cursor, row

#%%
# extract a separate DEM raster for each buffered point. Call them 'disks'
#arcpy.MakeFeatureLayer_management(buffedPts, "lyr")
lyr = arcpy.mapping.Layer(BUFFERED_PTS)

IN_RAS = "D:/GIS_data/DEM/Masked_NED_Resampled_10m_DEM.tif"

OUT_PATH = BASE_OUT_PATH + "/a_disks_DEM"

if not os.path.exists(OUT_PATH):
    os.makedirs(OUT_PATH)

for site in idList:
    selStmt = "site_ID = '" + site + "'"
    arcpy.SelectLayerByAttribute_management(lyr, "NEW_SELECTION", selStmt)
    outname = OUT_PATH + "\\" + site + ".tif"
    extent = lyr.getSelectedExtent()
    XMIN = str(extent.XMin)
    YMIN = str(extent.YMin)
    XMAX = str(extent.XMax)
    YMAX = str(extent.YMax)
    ENV.extent = XMIN + " " + YMIN + " " + XMAX + " " + YMAX
    print "clipping " + site
    outExtractByMask = SA.ExtractByMask(IN_RAS, lyr)
    # if the result is all no data (e.g. no dem under the poly), don't save
    # careful: this keeps partial disks
    if arcpy.GetRasterProperties_management(outExtractByMask,
"ALLNODATA").getOutput(0) == '0':
        print " ... saving " + site
        outExtractByMask.save(outname)
    else:
        print " ... " + site + " dem is all null"

arcpy.SelectLayerByAttribute_management(lyr, "CLEAR_SELECTION")

del lyr, selStmt

#%%
# complete Pit Remove for each disk

IN_PATH = BASE_OUT_PATH + "/a_disks_DEM"
OUT_PATH = BASE_OUT_PATH + "/b_disks_pitsRemoved"

ENV.workspace = IN_PATH
RasList = arcpy.ListRasters("*", "TIF")

if not os.path.exists(OUT_PATH):
    os.makedirs(OUT_PATH)

for ras in RasList:
    lyrName = ras[:-4]
    outRas = OUT_PATH + "/" + lyrName + "_pr.tif"
    print "pit removal on " + lyrName
    arcpy.PitRemove_TauDEM(ras, "", "", 8, outRas)

#%%
# calculate flow direction (infinity) and slope for each disk

IN_PATH = BASE_OUT_PATH + "/b_disks_pitsRemoved"
```

```
OUT_PATH = BASE_OUT_PATH + "/c_disks_flowdir"
OUT_PATH2 = BASE_OUT_PATH + "/d_disks_slope"

ENV.workspace = IN_PATH
RasList = arcpy.ListRasters("*", "TIF")

if not os.path.exists(OUT_PATH):
    os.makedirs(OUT_PATH)
if not os.path.exists(OUT_PATH2):
    os.makedirs(OUT_PATH2)

for ras in RasList:
    lyrName = ras[:-7]
    OUT_RAS = OUT_PATH + "/" + lyrName + "_fd.tif"
    OUT_RAS2 = OUT_PATH2 + "/" + lyrName + "_sl.tif"
    print "flow direction on " + lyrName
    arcpy.DinfFlowDir_TauDEM(ras, 8, OUT_RAS, OUT_RAS2)
```

<u>Third script, “c_calc_contrib_areas.py”</u>

```
# -*- coding: utf-8 -*-
"""
Created on Fri Oct 21 14:42:24 2016

@author: Tim Howard

This script begins with, as inputs:
    sampled wetland points and buffered polygons (see prev script)
    a DEM
It then extracts an area around each point and, through many steps, estimates the
upland area contributing to that point (or a region around the point)

Assumptions:
    input point layer has a field named "site_ID" and these are unique

If running straight from previous script, restart the kernal with ctrl+. in console.

RESTART THE KERNEL BEFORE RUNNING THIS SCRIPT!!
"""

#%%
# setup
import os
import arcpy
from arcpy import env as ENV

ENV.workspace = "D:/EPA_AdjArea/CalcAdjArea/output/_wrkspace"
ENV.overwriteOutput = True
arcpy.CheckOutExtension("Spatial")
arcpy.ImportToolbox("C:/Program Files/TauDEM/TauDEM5Arc/TauDEM Tools.tbx", "TauDEM")

BASE_OUT_PATH = "D:/EPA_AdjArea/CalcAdjArea/output"

#%%
# get a list of siteIDs for all records; make sure they are unique
POINT_LOC = "D:/EPA_AdjArea/CalcAdjArea/inputs"
POINT_LAYER = "all_points_4April2018.shp"
IN_POINTS = POINT_LOC + "/" + POINT_LAYER

cursor = arcpy.SearchCursor(IN_POINTS)
```

```
idList = []
for row in cursor:
    siteval = row.getValue("site_ID")
    idList.append(siteval)

if len(idList) > len(set(idList)):
    print "site_ID VALUES ARE NOT UNIQUE!!"
else:
    print "values in site_ID column are unique"

del cursor, row

#%%
# split points into separate shapefiles as tauDEM can't seem to use selections
# only do points where we have raster disks

OUT_SHP = BASE_OUT_PATH + "/e_pts_pointShps"
RAS_PATH = BASE_OUT_PATH + "/a_disks_DEM"

if not os.path.exists(OUT_SHP):
    os.makedirs(OUT_SHP)

ENV.workspace = RAS_PATH
rasList = arcpy.ListRasters("*", "TIF")

ENV.workspace = OUT_SHP
arcpy.MakeFeatureLayer_management(IN_POINTS, "lyr2")

for siteFN in rasList:
    site = siteFN[:-4]
    selStmt = "site_ID = '" + site + "'"
    arcpy.SelectLayerByAttribute_management("lyr2", "NEW_SELECTION", selStmt)
    outFileN = OUT_SHP + "/" + site + "_pt.shp"
    arcpy.CopyFeatures_management("lyr2", outFileN)

arcpy.SelectLayerByAttribute_management("lyr2", "CLEAR_SELECTION")
#%%
# expand the reach of each point.
# buffer the points by 50 m

print "buffering points"

IN_PATH = BASE_OUT_PATH + "/e_pts_pointShps"
OUT_PATH = BASE_OUT_PATH + "/f_pts_buff_pols"

if not os.path.exists(OUT_PATH):
    os.makedirs(OUT_PATH)

ENV.workspace = IN_PATH
shpList = arcpy.ListFeatureClasses()

for shp in shpList:
    site = shp[:-7]
    buffDist = "50"
    outShp = OUT_PATH + "/" + site + "_bu.shp"
    arcpy.Buffer_analysis(shp, outShp, buffDist, "FULL", "ROUND", "NONE")


#%%
# use the original dem disk
# to make points for each cell within each polygon
```

```
IN_PATH = BASE_OUT_PATH + "/f_pts_buff_pols"
OUT_PATH = BASE_OUT_PATH + "/g_disks_buffPts"
RAS_PATH = BASE_OUT_PATH + "/a_disks_DEM"

if not os.path.exists(OUT_PATH):
    os.makedirs(OUT_PATH)

ENV.workspace = IN_PATH
shpList = arcpy.ListFeatureClasses()

print "small buffered point to raster:"

for shp in shpList:
    site = shp[:-7]
    shpFull = IN_PATH + "/" + shp
    rasFull = RAS_PATH + "/" + site + ".tif"
    print " ... " + site
    ENV.cellSize = rasFull
    ENV.snapRaster = rasFull
    ENV.extent = shpFull
    outRas = OUT_PATH + "/" + site + "_bp.tif"
    arcpy.PolygonToRaster_conversion(shpFull, "FID", outRas, "CELL_CENTER", "",
ENV.cellSize)

arcpy.ClearEnvironment("extent")

IN_PATH = BASE_OUT_PATH + "/g_disks_buffPts"
OUT_PATH = BASE_OUT_PATH + "/h_pts_in_buff"

if not os.path.exists(OUT_PATH):
    os.makedirs(OUT_PATH)

ENV.workspace = IN_PATH
rasList = arcpy.ListRasters("*", "TIF")

print "raster cells to points"

for ras in rasList:
    site = ras[:-7]
    rasFull = IN_PATH + "/" + ras
    outShp = OUT_PATH + "/" + site + "_bp.shp"
    print ".. " + site
    arcpy.RasterToPoint_conversion(rasFull, outShp, "VALUE")

#%%
# calculate contributing area for each disk and point
IN_PATH = BASE_OUT_PATH + "/c_disks_flowdir"
OUT_PATH = BASE_OUT_PATH + "/i_disks_contribArea"
IN_SHP = BASE_OUT_PATH + "/h_pts_in_buff"

print "calculating contributing area"

if not os.path.exists(OUT_PATH):
    os.makedirs(OUT_PATH)

ENV.workspace = IN_PATH
RasList = arcpy.ListRasters("*", "TIF")

ENV.workspace = IN_SHP
shpList = arcpy.ListFeatureClasses()
```

```
for shp in shpList:
    site = shp[:-7].lower()
    for ras in RasList:
        rname = ras[:-7].lower()
        #rname = ras[:-10].lower()
        #print rname
        if rname == site:
            #print "...match"
            flowDirGrid = IN_PATH + "/" + ras
            outContribArea = OUT_PATH + "/" + rname + "_ca.tif"
            inShap = IN_SHP + "/" + shp
            print ". " + site
            arcpy.AreaDinf_TauDEM(flowDirGrid, inShap, "", "false", 8,
outContribArea)
#%%
```

Fourth script, "d_make_contrib_area_poly.py"

```
# -*- coding: utf-8 -*-
"""
Created on Thu Oct 27 09:04:22 2016

@author: Tim Howard
"""
#%%
# setup
import os
import arcpy
from arcpy import env as ENV
from arcpy import sa as SA

ENV.workspace = "D:/EPA_AdjArea/CalcAdjArea/output/_wrkspace"
ENV.overwriteOutput = True
arcpy.CheckOutExtension("Spatial")

BASE_OUT_PATH = "D:/EPA_AdjArea/CalcAdjArea/output"

#%%
# first convert rasters to integer with all cells (! NoData cells) equal to 1

IN_PATH = BASE_OUT_PATH + "/i_disks_contribArea"
OUT_PATH = BASE_OUT_PATH + "/j_disks_contrib_int"

if not os.path.exists(OUT_PATH):
    os.makedirs(OUT_PATH)

print "cleaning up contrib area raster"

ENV.workspace = IN_PATH
RasList = arcpy.ListRasters("*", "TIF")

for ras in RasList:
    lyrName = ras[:-7]
    print lyrName
    inRas = IN_PATH + "/" + ras
    outRas = OUT_PATH + "/" + lyrName + "_ci.tif" #contributing area integer
    result = SA.Int((arcpy.Raster(inRas) * 0) + 1)
    result.save(outRas)

#%%
```

```
# now convert to poly

IN_PATH = BASE_OUT_PATH + "/j_disks_contrib_int"
OUT_PATH = BASE_OUT_PATH + "/k_pols_contribArea"

if not os.path.exists(OUT_PATH):
    os.makedirs(OUT_PATH)

print "converting to polygon"

ENV.workspace = IN_PATH
RasList = arcpy.ListRasters("*", "TIF")

for ras in RasList:
    lyrName = ras[:-7].replace("-", "_")
    print " .. " + ras
    inRas = IN_PATH + "/" + ras
    outPol = OUT_PATH + "/" + lyrName + "_ca.shp" #contributing area
    arcpy.RasterToPolygon_conversion(inRas, outPol, "NO_SIMPLIFY", "VALUE")


#%%
# to clip these polys down to size, we first need to make another set of
# circles to use as clippers

IN_PATH = BASE_OUT_PATH + "/e_pts_pointShps"
OUT_PATH = BASE_OUT_PATH + "/l_pts_buff_pols540"

if not os.path.exists(OUT_PATH):
    os.makedirs(OUT_PATH)

print "clipping polys down to size"

ENV.workspace = IN_PATH
shpList = arcpy.ListFeatureClasses()

for shp in shpList:
    site = shp[:-7]
    buffDist = "540"
    outShp = OUT_PATH + "/" + site + "_bu.shp"
    arcpy.Buffer_analysis(shp, outShp, buffDist, "FULL", "ROUND", "NONE")

IN_PATH = BASE_OUT_PATH + "/k_pols_contribArea"
CLIP_PATH = BASE_OUT_PATH + "/l_pts_buff_pols540"
OUT_PATH = BASE_OUT_PATH + "/m_clip_contribArea"

if not os.path.exists(OUT_PATH):
    os.makedirs(OUT_PATH)

ENV.workspace = IN_PATH
shpList = arcpy.ListFeatureClasses()

for shp in shpList:
    site = shp[:-7]
    print site
    inShp = IN_PATH + "/" + shp
    clpShp = CLIP_PATH + "/" + site.upper() + "_bu.shp"
    outShp = OUT_PATH + "/" + site + "_cr.shp" #contributing area restricted
    arcpy.Clip_analysis(inShp, clpShp, outShp)

#%%
```

```
# merge all the polys into one GDB

IN_PATH = BASE_OUT_PATH + "/m_clip_contribArea"
OUT_PATH = BASE_OUT_PATH + "/n_merge_up"
OUT_GDB = "clip_contribArea_FCs.gdb"
OUT_FC = OUT_PATH + "/" + OUT_GDB + "/contributingAreas"

if not os.path.exists(OUT_PATH):
    os.makedirs(OUT_PATH)

print "merge up to a single feature class"

ENV.workspace = IN_PATH
shpList = arcpy.ListFeatureClasses()

# first add a site_ID field to all of them
for shp in shpList:
    site = shp[:-7]
    arcpy.AddField_management(shp, "site_ID", "TEXT")
    cur = arcpy.UpdateCursor(shp)
    print "adding to attribute table for " + shp
    for row in cur:
        row.setValue("site_ID", site)
        cur.updateRow(row)

arcpy.CreateFileGDB_management(OUT_PATH, OUT_GDB)

arcpy.Merge_management(shpList, OUT_FC)
```