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Floristics of the Abrams Creek Wetlands, a Calcareous Fen Complex in Winchester City and Frederick County, Virginia

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ABSTRACT The 24-ha Abrams Creek Wetlands (Winchester City and Frederick County, Virginia) is an array of fen, swamp, and disturbed transitional ecosystems underlain by limestone and dolostone bedrock. Soils of the area are generally characterized by exceptionally high levels of calcium (>10,000 ppm). Floristic data were collected through monthly surveys during the 2012–14 growing seasons and plot sampling in representative locations. We documented 296 vascular plant species during the inventory period; eight species found previously were not relocated. The 304 total species comprised 206 genera in 78 families. Of these, 55 species were graminoids (27 grasses, 21 sedges, 7 rushes). Obligate or facultative wetland species comprised 43% of the list. The 216 native species represented 71% of the total and included 20 listed as rare in Virginia. Plot data revealed that native species represented 72–99% of the total vegetative cover in the communities sampled. Floristic quality of the 12 constituent sites was consistently high, with Floristic Quality Assessment Index (FQAI) scores between 30 and 44; the property as a whole scored an exceptional FQAI of 67. Constricted and fragmented by suburban and rural development, the Abrams Creek Wetlands nonetheless supports distinctive ecological assemblages that are characterized by native wetland calciphiles, many of which are rare statewide.

Key words: Calcareous, floristic quality, marsh, Shenandoah Valley, wetland.

INTRODUCTION Long known to naturalists as a regional birding “hot spot” (Majorov 2012, Smith pers. comm. 2016), the botanical distinctiveness of the Abrams Creek Wetlands (Figure 1) was first recognized by Thomas Wieboldt, who made several visits beginning in 1980 (Wieboldt pers. comm. 2014). His discoveries in various wetlands of the area included seven vascular plant species that were new state records at the time. Fleming (unpublished) identified 18 state-rare plant species and reported on their distribution within the wetlands complex described by Wieboldt. By 1997, the Virginia Natural Heritage Program (VNHP) recognized two state rare natural communities at

the site: a “prairie fen” and a “calcareous spring marsh/muck fen,” which followed the first statewide community classification system published 4 yr later (Fleming et al. 2001).

Bousquet and his undergraduate students in Shenandoah University’s Environmental Studies Program began investigating, in collaboration with Fleming, the wetland communities associated with Abrams Creek in 1998 (Bousquet et al. 1999, Stevens et al. 2012). Their studies included calcareous wetlands contiguous with those that had been examined by Wieboldt, Fleming, and others. These studies, spanning 1.7 km along Abrams Creek, increased the extent of known wetlands to 24 ha (Figure 2). When the City of Winchester accepted developers’ donations of 10 ha as open space in 2002–03, the various fens, swamps and transitional zones became known collectively as the Abrams Creek Wetlands

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Figure 1. Abrams Creek Wetlands, adjacent land uses, and physiographic setting looking west across the Shenandoah Valley to the Allegheny Mountains. Boundary between Frederick County (left) and Winchester City (right) follows the railroad tracks. Headwaters of Abrams Creek are on Round Hill. Photo by Shaun Galang, Cedarmeade Studios.

(Davis 2003; Mangino 2003a, 2003b; Gomes 2014).

These aforementioned investigations formed the foundation for the present study. We intended to produce a complete floristic inventory of the Abrams Creek Wetlands, describe its natural communities, and discuss the factors potentially responsible for its species composition and temporal dynamics. In addition to more fully documenting the ecological communities and flora of this fen complex, our findings will allow comparison with other wetlands in the Shenandoah Valley and elsewhere, particularly in adjacent portions of the Great Appalachian Valley that are also underlain by calcareous bedrock. In addition, floristic changes resulting from natural succession, invasive species, preserve management, and nearby developments can be measured.

STUDY AREA Situated in northwestern Virginia's Shenandoah Valley, the Abrams Creek Wetlands extend for 1.7 km beside the upper reaches of Abrams Creek, a valley stream

located entirely within Frederick County and the independent city of Winchester. At the Clarke County line, Abrams Creek empties into Opequon Creek, which continues northeastward to the Potomac River near Martinsburg, West Virginia. The wetlands straddle the boundary between Frederick County and Winchester. Approximately 14.5 ha lie in Frederick County whereas 9.7 ha are in Winchester (Figure 2).

The Abrams Creek Wetlands lie within the folded and faulted terrain of the Ridge and Valley physiographic province of the Appalachian Highlands (Fenneman 1938, Hunt 1974). Much of the drainage in this carbonate-rock region, part of the Great Valley karst, is underground. Bedding planes and the area's numerous faults and joints exert a substantial influence on subsurface hydrology, creating fractured-rock aquifers, as well as conduits for groundwater movement (Harlow et al. 2005). Two geologic units occur in the study area. The Elbrook Formation consists of thin beds of limestone, shale, and dolostone, and the Conococheague Formation consists primarily of medium-bedded

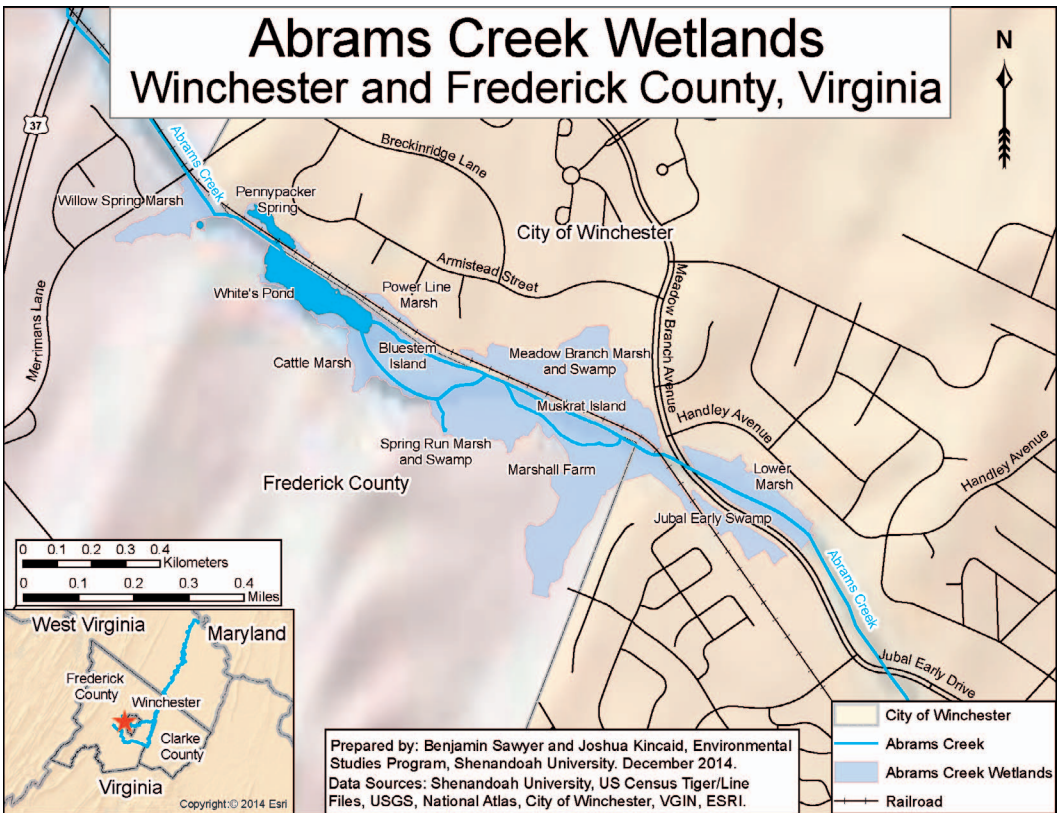


Figure 2. Location, hydrologic setting, and study sites of the Abrams Creek Wetlands.

limestone with interlayered dolostone and sandstone (Butts and Edmundson 1966, Orndorff et al. 2003). Groundwater, which provides all of the base flow to Abrams Creek and other area streams (Harlow et al. 2005, Doctor et al. 2008), emerges in the Abrams Creek Wetlands as springs and seeps. The study site's largest spring, Pennypacker Spring (also called Robinson's Spring or Merriman's Spring), is an artesian welling at the base of a 15-m-high hill. Historical records provide an estimated flow of 1,500 m³/d (Yager et al. 2013). Typical of groundwater, surface temperatures vary less than nearby streams. Between June and October, the spring varied by 6°C as opposed to 18°C in the nearby upstream portions of Abrams Creek (Bousquet et al. 1999).

The study site is situated within the 100-yr floodplain of Abrams Creek and is subject to occasional inundation. Although there is a 5% to 50% chance that a given portion of the property will flood in a given year, flooding is infrequent

under normal weather conditions and usually persists for only 2 to 7 d (Holmes and Wagner 1987). The level riparian terrain, surrounding hills, and occasional impervious sandstone strata beside Abrams Creek create conditions favorable to the formation of perched water tables and wetlands.

Soils are mapped as Fluvaquentic Hapludolls of the Massanetta series (Holmes and Wagner 1987), a deep, alluvial, silt loam formed by material weathered from limestone or shale. This soil is typically slightly alkaline and contains about 5% small, secondary lime concretions. Although not included as a hydric soil in the National Hydric Soils List (USDA, NRCS 2015), "wetlands and flooding are the main limitations to use of this soil for community development" (Holmes and Wagner 1987). Soils in test pits dug as part of this study displayed mottling in the A and B horizons, except in the transition zones to bordering uplands, providing strong evidence for the prevalence of hydric soil conditions in the study area.

Providing fertile soil, numerous springs and waterways, and valley corridor geography, the Abrams Creek watershed and Shenandoah Valley region attracted human settlement for a considerable time prior to European contact (Gardner 1986). Although no Native American settlements are documented in or adjacent to the study site itself, remains of encampments at Shawnee Springs, a tributary that runs through downtown Winchester, demonstrate that the Shawnee were active in the watershed prior to European contact (Geier et al. 1993). The Winchester-Frederick County area was one of the first localities west of the Blue Ridge Mountains to be colonized by European settlers. Three farmsteads encompassing the Abrams Creek Wetlands, with sturdy homes that remain today, date from the late 1700s to the 1840s (Kalbian 1999). Wheat, cattle, corn, and sheep were raised (Varle 1809 cited in Kalbian 1999; Raitz 2010), with much of the grain ground at gristmills along Abrams Creek (Kalbian 1999). In 1917, the Winchester & Western Railroad constructed a spur directly through the study area to connect with sandstone quarries in western Frederick County (O'Connor 2006). This line continues to operate.

Adjacent land uses today reflect a city-county contrast. Immediately to the north and east in Winchester are residential and small-scale commercial developments, most of which were built between 1984 and 2005. Frederick County's hayfields and pastures lie to the south. However, a 1,390-unit residential development is planned for 146 ha of this agricultural land, with an arterial road that will cross the wetlands of Marshall Farm and Jubal Early Swamp (Dorolek 2007, Krystal 2007a). A 54-unit housing tract and an 18-hole golf course were built on Frederick County farmland to the west of Willow Spring in about 2003, and an additional golf course opened nearby in 2015.

In addition to disturbances from urbanization, several transportation and utility corridors transect the Abrams Creek Wetlands. The Winchester & Western Railroad tracks and a city sewer line slice through the site, and a gas line crosses portions of Meadow Branch Marsh and Lower Marsh. An electric power transmission corridor runs east-west, and another extends north-south. In 2003, developers of adjacent residential and commercial properties completed a 1.5 km asphalt-paved recreational pathway, a segment

of the Winchester Green Circle, through and next to the wetlands.

Efforts of Shenandoah University's environmental studies students and faculty to promote the Abrams Creek Wetlands through a printed report (Bousquet et al. 1999), public field trips, and meetings with Winchester officials helped to prompt residential developers to donate 10 ha (24.7 ac) of the wetlands and portions of surrounding uplands to the city as open space. The Winchester City Council dedicated this property as the Abrams Creek Wetlands Preserve—the city's first formally protected natural area—in October 2013 (Davis 2003, Mangino 2003b). A management committee appointed by city officials recommended that recreational development be confined to the existing Winchester Green Circle walkway (Figure 2) and a gravel path through the northeastern corner of Lower Marsh. The group also noted with concern the advance of native trees, especially *Platanus occidentalis*, into the Preserve's marshes. This successional change, discussed further below, threatens the site's rare ecological communities and vascular plants (ACWP Management Committee 2007).

Although no portions of the site in Frederick County have been similarly set aside, owners of wetland and adjacent upland tracts in the county have offered buffer zones to help reduce the impacts of future roads and residential developments on Abrams Creek and adjoining wetlands. The pace of anthropogenic disturbance has accelerated over the past three decades. With new residential construction and a major road extension slated for the area in 2018, plus ongoing vegetation changes shaped by natural processes and human influences, the documentation of the flora and habitats of Abrams Creek Wetlands is not only timely but urgent.

METHODS

Vegetation Analysis and Site Characterization

Quantitative analyses of vegetation and site characterization were accomplished in 2010 and 2012 by the relevé method (Westhoff and Maarel 1978, Peet et al. 1998) as adapted by the Virginia Natural Heritage Program (Fleming et al. 2017). We chose seven sites within the study area to provide a diversity of habitats for examination. In each of these sites, researchers established a single plot (i.e., a relevé) for detailed study in a location selected to represent

the most typical expression of vegetation, microtopography, moisture conditions, and other ecological characteristics. Transition zones between community types were avoided. Where shrubs or herbaceous plants dominated, we used standard relevé sizes of 100 m². Relevés of 400 m² were laid out where woody vegetation dominated to capture the diversity of trees present. Square or circular plots were used in larger communities, but the researchers set up rectangular plots in elongated communities to conform to these locations' geometry.

Physical data collected in each relevé included plot location, surface substrate, topographic position, landform type, slope shape, bedrock, soil moisture regime, soil drainage class, hydrological regime, and evidence of disturbance. At the edge of each plot, we dug a hole approximately 50 cm deep to examine soil characteristics. Soil samples from the A horizon were sent to Brookside Laboratories, Inc., New Bremen, Ohio. This facility conducted analyses for pH, estimated nitrogen release (N), phosphorus (P), soluble sulfur (S), exchangeable cations (calcium [Ca], magnesium [Mg], potassium [K], and sodium [Na] in ppm), extractable micronutrients (boron [B], iron [Fe], manganese [Mn], copper [Cu], zinc [Zn], and aluminum [Al], in ppm), total cation exchange capacity (CEC; meq/100 g), percent total base saturation (TBS), and percent organic matter (% OM). Extractions were carried out using the Mehlich III method (Mehlich 1984), and percent organic matter was determined by loss on ignition.

Researchers described vegetation strata by physiognomy and density, the latter by percent cover. Diameter at breast height (dbh) for woody stems ≥ 2.5 cm dbh was measured. Within each vegetation layer, we assigned the percent cover of each vascular plant species present to a cover class (e.g., 1–2%, 5–10%, 25–50%). Additional species occurring within the habitat type and close to, but outside of, the relevé's boundaries were recorded as peripherals. These peripheral species were added to the property's master species list but not included in quantitative analyses of habitat characteristics. The resulting data were used to develop an initial species list, determine dominant species in each habitat, and characterize habitats.

Floristic Inventory, Collection, and Preservation

We conducted the floristic inventory in 2012–14. To help assure that all portions of the Abrams

Creek Wetlands were examined on a regular basis, the property was divided into 12 survey areas using habitat transitions, railroad tracks, fences, and roads as boundaries (Figure 2). The researchers visited each location at least monthly during the March 15–October 15 growing season.

Primary taxonomic references were Weakley et al. (2012) and Virginia Botanical Associates (2017); supplementary resources included Strausbaugh and Core (1977), Gleason and Cronquist (1991), and Holmgren (1998). Nomenclature followed that of Weakley et al. (2012). Voucher specimens of each vascular plant species were collected, pressed, mounted, and labeled. Specimens were deposited in the Ted R. Bradley Herbarium, George Mason University (GMUF). Comparison with historical collection records revealed that eight previously documented species were not relocated during the present study. We included these species in the annotated species list (Appendix).

The resulting vascular plant list was examined for noteworthy species occurrences (i.e., state-rare or state watch-listed species) and county or state records (Townsend 2016). Each species was further characterized by its habitat(s) within the study site, as native or introduced (Townsend 2016), by wetland indicator status, and by coefficient of conservatism. Wetland indicator status followed Lichvar et al. (2014). Coefficient of conservatism is discussed below.

Floristic Quality and Coefficient of Conservatism

Assessments of floristic quality permit the evaluation and comparison of wetlands by their ecological integrity and species richness. A site's floristic quality is calculated from the sensitivity to disturbance and fidelity to habitat type of each native vascular plant species present (Wilhelm and Ladd 1988, Virginia Department of Environmental Quality, Office of Wetlands and Water Protection 2015). Those characteristics are reflected in the coefficient of conservatism, or C-value, which is scaled from 1 to 10. The C-value is established a priori for each native species by a review panel of regional wetland botanists. The sum of the C-values is divided by the square root of the number of native species found to produce the site's floristic quality assessment index (FQAI) score. As an ecological measure, the FQAI is derived from index of biotic integrity (IBI) approaches that are com-

Table 1. Vascular plants of the Abrams Creek Wetlands.

| | Families | Genera | Species (native, introduced) | % of Total (native, introduced) |
|---------------|----------|--------|------------------------------|---------------------------------|
| Pteridophytes | 4 | 4 | 5 (5,0) | 1.6 (1.6, 0) |
| Gymnosperms | 2 | 2 | 2 (2,0) | 0.7 (0.7, 0) |
| Angiosperms | 72 | 200 | 297 (209,88) | 97.7 (68.8,28.9) |
| Graminoids | | 25 | 55 (44,11) | 18.1 (14.5,3.6) |
| Cyperaceae | | 6 | 27 (27,0) | 8.9 (8.9,0) |
| Juncaceae | | 1 | 7 (7,0) | 2.3 (2.3,0) |
| Poaceae | | 18 | 21 (10,11) | 6.9 (3.3,3.6) |
| Asteraceae | | 30 | 44 (32,12) | 14.5 (10.5,3.9) |
| Lamiaceae | | 13 | 18 (12,6) | 5.9 (3.9,2.0) |
| Rosaceae | | 9 | 13 (6,7) | 4.3 (2.0,2.3) |
| Total | 78 | 206 | 304 (216, 88) | (71.1, 28.9) |

monly employed to assess streams' water quality by their assemblages of fish, macroinvertebrates, or periphyton (Barbour et al. 1999, Mack 2004).

Floristic quality can be calculated from species lists that are generated through quadrats, line transects, or floristic surveys. Comparisons are more robust when data are obtained by the same means over similar time scales (Andreas et al. 2004). For this analysis, we recorded all species that were present in each of the 12 Abrams Creek Wetlands sites from mid-June through mid-August. C-values were obtained from the list provided by Virginia Department of Environmental Quality, Office of Wetlands and Water Protection (2015) supplemented by Mid-Atlantic Wetland Workgroup (2014) and Andreas et al. (2004).

RESULTS

Soils

Based on samples collected from five vegetation plots within the site, soils of the area were characterized by high pH (mean = 7.6), extraordinarily high levels of exchangeable calcium (mean = 19,605 ppm), high magnesium (mean = 330 ppm), and relatively low iron, manganese, and aluminum. Percent organic matter varied from 3.5% in well-drained soils to 32.5% in deep muck soils. Depth of A horizon is somewhat variable but averages approximately 23 cm over deep B horizons. These soil chemistry and depth data indicate high fertility and optimal growing conditions for plants adapted to mesic and wetland habitats.

Species Composition

We documented a total of 304 vascular plant species (Table 1 and Appendix). During 3 yr of field surveying, 296 species were found; eight additional species were represented as herbari-

um specimens but not seen in this study (*Callitriche stagnalis*, Wieboldt 3675, VPI [Massey Herbarium, Virginia Polytechnic Institute]; *Carex interior*, Wieboldt 3665, VPI; *Carex utriculata*, Fleming 8002, GMUF; *Cyperus bipartitus*, Fleming 5945, GMUF; *Cyperus flavescens*, Fleming 5954, GMUF; *Hydrocotyle ranunculoides*, Fleming 5940, GMUF; *Juncus scirpoides* var. *compositus*, Wieboldt 3826, VPI; *Scleria verticillata*, Fleming 5952, GMUF).

Native species constituted 216 (71.1%) of the total, whereas 88 introduced species constituted 28.9% of the total. In regard to wetland indicator status (Lichvar et al. 2014), 67 species (22.0%) were obligate wetland taxa (OBL), 64 species (21.1%) were facultative wetland (FACW), 39 species (12.8%) were facultative (FAC), 81 species (26.6%) were facultative upland (FACU), 48 species (15.8%) were upland (UPL), and 5 species (1.6%) were undesignated.

Plant Habitats and Communities

A summary of the major habitats of the Abrams Creek Wetlands appears below. These are arranged from wettest to driest, which approximates a disturbance gradient from least disturbed to most disturbed. Where possible, a cross-reference to the Virginia Natural Heritage Program's classification of natural communities (Fleming and Patterson 2017) and the United States National Vegetation Classification (USNVC 2016) is provided in the descriptions.

1. *Aquatic and semiaquatic wetlands (AS)*. This community occupies lotic to slightly lentic habitats dominated by floating, submersed, and emergent hydromorphic vegetation. Habitats are permanently flooded with water up to 2 m deep, and include White's Pond, the channel of Abrams Creek, backwater sloughs of



Figure 3. Muck fen (MF) habitat type on the edges of Muskrat Island (foreground) and Marshall Farm (background). Dominated by mixed graminoids; *Eutrochium maculatum* var. *maculatum* in foreground. Photo by Gary Fleming.



Figure 4. Calcareous wet prairie (CW) habitat type at Meadow Branch Marsh. Dominated by *Scirpus pungens*; *Symphyotrichum praealtum* var. *angustior* flowering in foreground. Note invasion by *Platanus occidentalis*, *Cornus amomum*, and other native woody species in background. Photo by Gary Fleming.

Abrams Creek, and the deepest outflow of Pennypacker Spring. Diagnostic indicator species include *Bidens laevis*, *Lemna minor*, *Nuphar advena*, *Potamogeton foliosus*, *Potamogeton illinoensis*, and *Sparganium americanum*. State-rare species restricted to this habitat include *Lemna trisulca* (G5S1) and *Sparganium emersum* (G5S1). *Chara* sp. dominates much of the substrate of Pennypacker Spring and White's Pond. The introduced species *Myriophyllum aquaticum* is an aggressive invader at Pennypacker Spring. The vegetation of these habitats represents the Floodplain Pool/Pond and Semi-permanent Impoundment ecological groups of the Virginia state vegetation classification (Fleming and Patterson 2017). Much of the vegetation of the natural (nonimpounded) sloughs and channels equates to the *Nuphar advena*–*Nymphaea odorata* Aquatic Vegetation association (CEGL002386; G4G5SU) of the USNVC (Faber-Langendoen 2001).

2. *Calcareous muck fens (MF)*. The habitats of this community feature deep, unstable, muck soils and seasonal to semipermanent flooding by calcareous groundwater discharging from large springs and seeps. The vegetation often develops in low swales, including the margins of Pennypacker Spring, Spring Run Marsh, the eastern portion of Marshall Farm, several small spring runs, and portions of Meadow Branch Marsh and Cattle Marsh (Figure 3). Diagnostic indicator species include *Alisma subcordatum*, *Carex comosa*, *Carex pellita*, *Carex stricta*, *Persicaria amphibia*, *Schoeno-*

plectus tabernaemontani, and *Sparganium eurycarpum*. State-rare species strongly associated with this habitat are *Carex lasiocarpa* var. *americana* (G5T5S1), *Carex prairea* (G5S1), and *Juncus brachycephalus* (G5S2). At Abrams Creek Wetlands, disturbed muck fens are commonly invaded by *Phalaris arundinacea* and *Typha latifolia*. The vegetation of these habitats represents the Calcareous Fens and Spring Marshes ecological group of the Virginia state vegetation classification (Fleming and Patterson 2017). It generally equates to the *Peltandra virginica*–*Polygonum amphibium* var. *emersum*–*Carex stricta*–*Impatiens capensis* Marsh association (CEGL006244) of the USNVC (Fleming 2005). This association is ranked globally imperiled (G1) by the NatureServe/Natural Heritage network.

3. *Calcareous wet prairies and meadows (CW)*. The habitats of this community are seasonally to permanently saturated by calcareous groundwater, but rarely have more than a few centimeters of standing water during wet periods. Soils are relatively firm and characterized by high pH and very high calcium levels. Vegetation is generally open and nonweedy, with native species dominant. Examples include major portions ($\geq 50\%$) of Bluestem Island, Meadow Branch Marsh, Marshall Farm, Muskrat Island, and Jubal Early Swamp (western portion); and smaller portions ($< 50\%$) of Cattle Marsh, Power Line Marsh, and Lower Marsh (Figure 4). This category encompasses consid-

erable microtopographic, hydrological, and floristic diversity that is often expressed in a zonal pattern at a given locality. Diagnostic species favoring the drier end of the gradient are *Andropogon gerardii*, *Pycnanthemum virginianum*, and *Sorghastrum nutans*, whereas wetter sites support *Glyceria striata*, *Mimulus ringens*, *Pilea fontana*, and *Schoenoplectus pungens*. Indicators adaptable to most site conditions include *Carex tetanica*, *Cirsium muticum*, *Juncus dudleyi*, *Packeria aurea*, *Pycnanthemum tenuifolium*, *Symphyotrichum novae-angliae*, and *Verbena hastata*. Several state-rare species are widespread, diagnostic components of wet prairies at Abrams Creek Wetlands, including *Eutrochium maculatum* var. *maculatum* (G5T5S1), *Juncus nodosus* (G5S1), *Scutellaria galericulata* (G5S1), and *Symphyotrichum praealtum* var. *angustior* (G5T4S1). These habitats are commonly invaded by *Schedonorus arundinaceus* following heavy grazing; and by *Fraxinus pennsylvanica*, *Platanus occidentalis*, *Populus deltoides*, and other woody plants of the Bottomland Forest (see below) in the process of natural succession. The vegetation of these habitats also represents the Calcareous Fens and Spring Marshes ecological group of the Virginia state vegetation classification (Fleming and Patterson 2017). It imperfectly equates to the *Carex tetanica*–*Carex prairea*–*Eleocharis erythropoda*–*Lysimachia quadriflora* Fen association (CEGL006170) of the USNVC (Fleming 2004). This association is ranked globally imperiled (G1Q) by the Nature-Serve/Natural Heritage network; the “Q” in the rank indicates some question about the type’s taxonomy.

4. *Bottomland forests (BF)*. This category comprises seasonally or temporarily flooded habitats with > 50% cover of trees. Examples include wooded portions of Spring Run, Meadow Branch Swamp, and Jubal Early Swamp, as well as wooded banks along portions of Abrams Creek, especially at Bluestem Island and Lower Marsh. Soil conditions are highly variable, ranging from seasonally flooded to well-drained. The most common woody indicators of this habitat are the trees *Acer saccharinum*, *Fraxinus pennsylvanica*, *Platanus occidentalis*, and *Populus deltoides*, along with the shrubs *Cornus amomum* and *Lindera benzoin*, which can be very dense in places. The herb layer in Bottom-

land Forests is generally patchy, sparse, or absent and contains both wetland and upland species, depending on site conditions. All sites of this habitat support young successional forest regenerating on formerly cleared or otherwise heavily disturbed agricultural land. Some patches of considerably larger trees (40 cm to >50 cm dbh) are present in interior portions of Meadow Branch Swamp and Jubal Early Swamp. These forests represent disturbed stands of the Piedmont/Mountain Floodplain Forests and Swamps ecological group of the Virginia state vegetation classification (Fleming and Patterson 2017). The vegetation equates to an early-successional variant of the *Acer saccharinum*–*Acer negundo*/Ageratina altissima–Laportea canadensis–(*Elymus virginicus*) Floodplain Forest association (CEGL006217; G4S4) of the USNVC (Fleming and Patterson 2006).

5. *Disturbed weedy marshes (DM)*. This habitat type essentially represents a variant of Calcareous Wet Prairies and Meadows disturbed by heavy recent or ongoing grazing and containing a large proportion of weedy, introduced species. It is recognized separately because it is floristically distinct and occurs fairly extensively in the Abrams Creek wetlands. The presence of this habitat type demonstrates the threat of change through internal disturbances (vs. adjacent external disturbances, see below) that facilitate the entry of invasive (usually introduced), often FACU species. Examples include major (>50%) portions of the Willow Spring Run area, Cattle Marsh, Power Line Marsh, and Lower Marsh. Widespread, often abundant, habitat type indicators that can exploit interior disturbances include *Carduus acanthoides* ssp. *acanthoides*, *Dipsacum fullonum*, *Mentha spicata*, *Persicaria longiseta*, *Poa pratensis* ssp. *pratensis*, *Schedonorus arundinaceus*, and *Solanum dulcamara*. Weedy natives such as *Impatiens capensis*, *Solanum carolinense* var. *carolinense*, *Solidago canadensis* var. *canadensis*, and *Symphyotrichum lateriflorum* can be common. Natives of the Calcareous Wet Prairies and Meadows are typically present, although usually with lower species diversity and cover than in undisturbed habitats.

6. *Disturbed weedy wetland-to-upland transition zones (DT)*. This habitat type generally includes extensive narrow ecotones where wetlands border the Winchester Green

Table 2. Comparison of Abrams Creek Wetlands community types based on numbers and percent cover of native vs. introduced species in constituent sites.^a

| Community (Habitat) Type | Species Richness (in relevé) | Richness (% of total no.) | | Dominance (% of total cover) | |
|--|------------------------------|---------------------------|--------------|------------------------------|--------------|
| | | Native % | Introduced % | Native % | Introduced % |
| Calcareous Muck Fens (MF) | | | | | |
| Marshall Farm | 44 | 88.4 | 11.6 | 98.7 | 1.3 |
| Jubal Early Swamp | 45 | 84.1 | 15.9 | 86.2 | 13.8 |
| Calcareous Wet Prairies and Meadows (CW) | | | | | |
| Bluestem Island | 34 | 91.2 | 8.8 | 83.8 | 16.2 |
| Meadow Branch Marsh | 42 | 88.1 | 11.9 | 98.6 | 1.4 |
| Bottomland Forests (BF) | | | | | |
| Meadow Branch Swamp | 27 | 84.6 | 15.4 | 99.0 | 1.0 |
| Disturbed Margins (DM) | | | | | |
| Cattle Marsh | 41 | 75.6 | 24.4 | 72.3 | 27.7 |
| Power Line Marsh | 37 | 78.4 | 21.6 | 77.0 | 23.0 |

^aBased on relevé data collected in 2010 and 2012.

Circle pathway, the Winchester & Western Railroad tracks, Jubal Early Drive, and adjacent residential, agricultural, and commercial developments. These disturbed marginal zones provide avenues for invasion of weedy species from the typically much altered and developed uplands, reflecting the threat of change through adjacent external disturbances. They tend to be dominated by invasive introduced species, with weedy native species usually intermixed. Characteristic indicators include *Asclepias syriaca*, *Daucus carota*, *Elaeagnus umbellata*, *Lonicera japonica*, *Lonicera morrowi*, *Rosa multiflora*, and many others. Some of the invaders appear to be relatively recent arrivals that are increasing rapidly in the area (e.g., *Rhamnus davurica*) or represent taxa of high invasive potential (e.g., *Perilla frutescens*, *Prunus subhirtella*, *Solanum sarrachoides*, and *Tripidium ravennae*) that are currently scarce in the study area. Also included in this category are less widespread, forested transition zones bordering Cattle Marsh and Jubal Early Swamp. For the most part, these forested areas are weedy and disturbed, but not as pervasively as the open transitions from marshes to uplands.

Richness, Dominance, and Native vs. Introduced Species

Native species predominated in the floristic survey, as described above under species composition. They accounted for 71.1% (216) of the 304 vascular plant species found. The relevé method provides additional insight because it involves the collection of vegetation data on a cover-class (dominance) basis for each species

found in the area sampled. Consequently, our relevé data (Table 2) permit the comparison of community (habitat) types by cover class as well as by species richness. As in the discussion of habitat types above, Table 2 is organized from wettest to driest, which approximates a gradient from the least disturbed to the most disturbed sites.

All seven relevé sites (Table 2) show a higher richness of native species (75.6% to 91.2%) than does the Abrams Creek Wetlands property as a whole (71.1%). Dominance calculations reveal that introduced species comprise only a tiny constituent of the vegetation cover of three locations: Meadow Branch Swamp (1.0%), Marshall Farm (1.3%), and Meadow Branch Marsh (1.4%). In two more locations, introduced species constitute less than one-fifth of the vegetation cover: Jubal Early Swamp (13.8%) and Bluestem Island (16.2%). Not surprisingly, the communities with the most disturbance are also the most dominated by introduced species.

Rare Taxa

20 species ranked by the Virginia Natural Heritage Program (NHP) as rare (S1 or S2) in the state were found (Table 3). Within the state, two of these taxa are known in Virginia only from the study site: *Carex atherodes* and *Scutellaria galericulata*. The first species is confined to one small area of approximately 100 m². It had disappeared from Abrams Creek Wetlands for more than two decades following disturbance by adjacent residential construction, but was rediscovered during the present study. In contrast, the second taxon is remarkably

Table 3. Ecological characteristics, geographic distribution, and conservation status of Virginia rare vascular plant taxa (Townsend 2016) at the Abrams Creek Wetlands.

| Taxon | Abundance ^a | Habitat ^b | Geographic Distribution ^c | Global Rank | State Rank |
|---|------------------------|----------------------|--------------------------------------|-------------|------------|
| <i>Carex atherodes</i> Spreng. | 1 | CW | N | G5 | S1 |
| <i>Carex lasiocarpa</i> Ehrh. var. <i>americana</i> | 2 | MF | N | G5T5 | S1 |
| <i>Carex interior</i> Bailey | h | CW | N | G5 | S1 |
| <i>Carex prairea</i> Dewey ex Wood | 1 | MF | N | G5 | S1 |
| <i>Carex utriculata</i> Boott | h | MF | N | G5 | S1 |
| <i>Equisetum fluviatile</i> L. | 2 | MF, CW | N | G5 | S1 |
| <i>Eutrochium maculatum</i> (L.) E.E. Lamont var. <i>maculatum</i> | 4 | CW | N | G5T5 | S1 |
| <i>Juncus balticus</i> Willd. var. <i>littoralis</i> | 1 | CW | N | G5T5 | S1 |
| <i>Juncus brachycephalus</i> (Engelm.) Buch. | 1 | MF | N | G5 | S2 |
| <i>Juncus nodosus</i> L. | 3 | CW | N | G5 | S1 |
| <i>Juncus torreyi</i> Coville | 2 | CW | W | G5 | S2 |
| <i>Lemna trisulca</i> L. | 2 | AS | N | G5 | S1 |
| <i>Liparis loeselii</i> (L.) L.C. Rich. | 1 | BF | N | G5 | S2 |
| <i>Lysimachia hybrida</i> Michx. | 1 | BF | W | G5 | S2 |
| <i>Scleria verticillata</i> Muhl. ex Willd. | h | CW | E | G5 | S1 |
| <i>Scutellaria galericulata</i> L. | 3 | CW | N | G5 | S1 |
| <i>Sparganium emersum</i> Rehmman | 1 | AS | N | G5 | S1 |
| <i>Spiranthes lucida</i> (H.H. Eaton) Ames | 1 | CW | N | G5 | S1 |
| <i>Stachys arenicola</i> Britton | 1 | CW | W | G4? | S1 |
| <i>Symphotrichum praealtum</i> (Poiret) G.L. Nesom var. <i>angustior</i> (Wieg.) G.L. Nesom | 4 | CW | N | G5T4 | S1 |

^aRelative abundance ratings from 1 (rare) to 4 (common), and h (historical record). Further details in Appendix.

^bHabitat types: AS = aquatic and semiaquatic wetlands; BF = bottomland forests; CW = calcareous wet prairies and meadows; DM = disturbed weedy marshes; DT = disturbed weedy wetland-to-upland transition zones; MF = calcareous muck fens.

^cGeographic distribution: E = eastern North America; W = midwestern or western North America; N = northern or northeastern North America, or widespread in northern and western North America; see Table 5 for more detailed criteria.

abundant in calcareous wetland (CW) habitats of the site; these locations have continuously saturated soils but are covered by small amounts of standing water during wet periods only. Five additional rare species of Abrams Creek Wetlands—*Carex lasiocarpa* var. *americana*, *Carex utriculata*, *Equisetum fluviatile*, *Juncus balticus* var. *littoralis*, and *Symphotrichum praealtum* var. *angustior*—are each currently known from just one other site in Virginia.

We were unable to relocate three rare species that were documented previously: *Carex interior* (Wieboldt 3665, VPI), *C. utriculata* (Fleming 8002, GMUF), and *Scleria verticillata* (Fleming 5952, GMUF). Although residential construction obliterated one of the two stations for *Scleria verticillata* at the site, natural succession might be responsible for the disappearance of the second station. Succession might also be the cause of the local extirpation of *Carex interior* and *C. utriculata* because both are fen species that likely require substantial sunlight. Only one population of *C. utriculata* remains extant in Virginia (Clarke County, Fleming 8094, GMUF).

Nineteen of the 20 state-rare species documented in the Abrams Creek wetlands have global ranges centered well to the north and west of Virginia. At least half of them are typical constituents of wet prairies in the upper Midwest whereas others are widespread in wetlands of northern and boreal North America. Several of these rare species (e.g., *Carex atherodes*, *Carex lasiocarpa* var. *americana*, *Carex prairea*, *Juncus balticus* var. *littoralis*, *Stachys arenicola*) are significantly disjunct from their main ranges (Kartesz 2015).

Floristic Quality

Floristic quality, as reflected in FQAI scores and depicted in Table 4, ranged between 30 and 44 for the property's 12 constituent sites. Based on US Fish and Wildlife Service criteria (USFWS 2016), three sites reached the high quality rank (scores between 20 and 35). The remaining nine sites attained the highest quality "natural area" rank (scores greater than 35). FQAI scores for all 12 sites exceeded 20, the threshold for classification as high quality aquatic resources. Consid-

Table 4. Comparison of sites within Abrams Creek Wetlands based on floristic quality^a (FQAI) and state-rare species.^b

| Sites | Floristic Quality (FQAI score) ^c | State-Rare Species | Community Types (see Table 3 footnote c) |
|--------------------------------------|---|--------------------|--|
| White's Pond and Willow Spring Marsh | 44 | 7 | DM, AS |
| Marshall Farm | 43 | 9 | MF, CW |
| Pennypacker Spring | 43 | 6 | CW, MF, AS |
| Muskrat Island | 42 | 6 | CW, MF |
| Spring Run Marsh and Swamp | 42 | 6 | CW, BF, MF, DM |
| Cattle Marsh | 41 | 5 | DM, CW, DT, MF |
| Lower Marsh | 40 | 5 | DM, CW |
| Bluestem Island | 38 | 9 | CW, DM, BF |
| Meadow Branch Marsh | 38 | 6 | CW, MF |
| Jubal Early Swamp | 31 | 1 | MF, BF, DT |
| Power Line Marsh | 30 | 4 | DM, CW |
| Meadow Branch Swamp | 30 | 1 | BF |
| Abrams Creek Wetlands (entire site) | 67 | 20 | all |

^aFloristic Quality Assessment Index (FQAI) is based on summer surveys.

^bRare species listings are derived from the full 2014–16 floristic inventory, without historical records.

^cScores ≤ 19 = low vegetative quality; 20–35 = high vegetative quality; above 35 = “natural area” quality. Wetlands with FQAI > 20 are considered high-quality aquatic resources (USFWS 2016).

ered as a whole, the Abrams Creek Wetlands reached an exceptional FQAI of 67.

DISCUSSION

Origins and Biogeographic Affiliations of the Flora

Because site-specific paleoecological studies are lacking, the nature of presettlement vegetation in the Abrams Creek area is uncertain. However, the presence of so many regionally rare, light-demanding wetland plants of northern biogeographic affiliation (Table 3) suggests that open wetlands similar to those at the site today were present prior to the arrival of European colonists. The general patterns of vegetation development from the late Wisconsin glacial maximum about 18,000 yr ago through the Holocene are well known in Virginia from the pollen records at multiple sites (Fleming 2012). Until about 12,500 yr ago, a complex of northern pine-spruce woodland or taiga, boreal forests, and alpine tundra vegetation occupied the Virginia mountains (Delcourt and Delcourt 1986). Evidence from several sites suggests that severe climatic conditions and repeated freeze-thaw cycles accelerated mass wasting and erosional processes in the Appalachians, helping to maintain bogs, ponds, and other open wetlands on the valley floors (Delcourt and Delcourt 1988). As the glaciers retreated, colluvial and alluvial processes increased in the early Holocene, depositing extensive sediments and peat along

streams. As the vegetation gradually changed from boreal forests to forests of oak, chestnut, and pine, open wetlands continued to develop in many of the stream valleys. Palynological studies at two sites in montane Virginia valleys—in Augusta and Smyth counties, approximately 150 km and 400 km southwest of Abrams Creek, respectively—have confirmed the continuous presence of such wetlands for at least 15,000 yr (Ray et al. 1967, Craig 1969).

The contemporary Virginia distributions of northern and boreal plants occurring in populations peripheral to or disjunct from their main ranges are typically interpreted as relicts of wider distributions during the colder, late Wisconsin and early Holocene periods (Fleming 2012). Many of these species have persisted in high-elevation habitats where cold microclimates prevail. But a subset of them, including those of the Abrams Creek Wetlands (Table 3), remained in low-elevation wetlands where hydrological and edaphic factors appear to have favored their persistence. Given the exceptional assemblage at the study site of northern species, many of them known from just one or a few sites in Virginia, it seems reasonable to assume that at least some have been present in the region for many millennia, their ranges shifting and becoming increasingly restricted to locally suitable niche habitats through climatic warming in the Holocene. Among the quantifiable environmental variables at the study site that might have

Table 5. Biogeography of native species of the Abrams Creek Wetlands and comparison with that of the overall Virginia (VA) flora.

| Biogeographic Group | No. of Species in Study Area | Percentage of Study Area Native Flora | Percentage of Total VA Native Flora |
|-----------------------------------|------------------------------|---------------------------------------|-------------------------------------|
| Eastern USA ^a | 134 | 62.0 | 25.8 |
| Northern/Boreal ^b | 61 | 28.3 | 22.8 |
| Southern ^c | 13 | 6.0 | 39.7 |
| Western ^d | 8 | 3.7 | 6.0 |
| Narrowly Appalachian ^e | 0 | 0.0 | 5.7 |
| Totals | 216 | 100 | 100 |

^aWidespread or evenly distributed in eastern or continental USA.

^bRange centered in northeastern North America, or widespread in northern North America, or widespread across northern and western North America.

^cRange centered in southeastern USA or widespread in southern North America.

^dRange centered west of Appalachians in upper/lower Midwest or Interior Low Plateau/Ozarks, or widespread in central or western USA.

^eSouthern or Central Appalachian endemics.

contributed to favorable habitats are (1) low groundwater temperature in the site's numerous springs and seeps, and (2) exceptionally high calcium levels in both groundwater and the prevalent alluvial silt loams.

Ten of the Abrams Creek Wetlands' noteworthy plants are common constituents of wet prairies of the upper Midwest (*Carex interior*, *Carex prairiea*, *Equisetum fluviatile*, *Eutrochium maculatum* var. *maculatum*, *Juncus balticus* var. *littoralis*, *Juncus brachycephalus*, *Juncus torreyi*, *Lysimachia hybrida*, *Spiranthes lucida*, and *Stachys arenicola*), and three species have general biogeographic affiliation with the western USA (Table 3). It is possible that some of these species might have reached the Central Appalachians during the Hypsithermal Interval, a warmer and drier period of several millennia during the Middle Holocene. The Hypsithermal saw the Midwestern prairie peninsula reach its greatest eastern extent, as well as the eastward migration of now-isolated prairie species (DeSelm and Murdock 1993, Thorne 1993, Laughlin 2004).

During the middle and late Holocene, native American fires and periodic megaherbivore grazing also might have contributed to the maintenance of open wetlands at the study site. Fire was a critical tool of Native Americans for land clearing, range management, hunting, and agriculture (Pyne 1982, Van Lear and Waldrop 1989, Mann 2005). In their attempt to reconstruct the colonial landscape of Frederick County through land survey records, Mitchell, et al. (2001) discount the potential influence of megaherbivores (deer, beaver, elk, wood bison) on reducing woody species enough to maintain

extensive prairie meadows in the Shenandoah Valley region. However, it can be argued that the springs and rich graminoid forage along Abrams Creek and other drainages might have been particularly attractive to wood bison, elk, and deer. In her review of early land surveys in the area, Southgate (pers. comm. 2017) noted that Frederick County surveyors used the terms "marsh" and "meadow" interchangeably to describe open land along valley creeks. Surveyor Robert Brooke reported crossing such a meadow, apparently at the study site, while preparing a deed in 1734 that was subsequently registered to Isaac Perkins (Rice 2009).

By the time of early European settlement, the current native flora in the Abrams Creek wetlands was probably in place, consisting of species of temperate climates that had migrated northward following the glacial retreat and more cold-tolerant northern species that had persisted through the climatic changes (Table 5).

Our analysis demonstrates that the percentages of widespread eastern species and northern species is considerably higher at Abrams Creek than those for the overall Virginia flora, whereas the percentage of southern species is much lower. This species composition might be explained by the location of the study area in the northwestern corner of Virginia, as well as by the restrictive environmental conditions of the site's wetland habitats.

Ecological Dynamics of Contemporary Species Composition

The Shenandoah Valley of Virginia, in which settlement began in the 1700s, is one of the

state's most productive agricultural regions (Kalbian 1999, Raitz 2010). Until recently, much of the land around Winchester supported large acreages of farms, orchards, fields, and small, scattered woodlots. Impacts over the last three centuries have included extensive land clearing, livestock grazing, crop cultivation, and repeated cutting of forests that were not destroyed. A railroad was constructed along Abrams Creek through the study area in 1917 (O'Connor 2006). During the past several decades, suburban development has steadily encroached on the study area and will likely continue unabated in the future (Krystal 2007a, 2007b; Janney 2016). Ditching, draining, and filling of wetlands was rampant during these land development activities, and palustrine wetlands today cover only 0.1% of the Virginia Ridge and Valley (USGS 1997).

The influence of these postsettlement human disturbances on the study area is amply demonstrated by the large component of introduced species, now totaling nearly 30% of the flora. Such species are most numerous in the disturbed wetland-to-upland transition zone, early successional bottomland forests, and weedy marshes with a long history of extensive cattle grazing. The preponderance of introduced, weedy species is clearly reduced in more remote marshes that were not as heavily grazed, and in the wetter habitats, where longer and deeper flooding is a mitigating factor (Table 2). Ironically, some human disturbances at the site, such as the railroad right-of-way, possible historical fires from coal-fired railroad engines, the construction of power lines, and tree cutting, might have extended the persistence of open wetlands and their constituent rare plants through the post-settlement era.

Although the present study was primarily floristic in scope, the results suggest that several interacting environmental gradients might be the primary influences controlling species composition in the current flora.

1. *Geologic substrate and soil chemistry.*

The site is underlain by dolostone and limestone, which weather to highly calcareous soils. Calcium levels in samples collected from relevé plots range from 9,979 ppm to 25,065 ppm, which rank among the highest calcium content recorded from more than 4,700 plots sampled statewide by the Virginia Natural Heritage Program (DCR-

DNH [Department of Conservation and Recreation, Division of Natural Heritage], unpubl. data). These exceptional levels might also be influenced by calcium precipitating out of the abundant, cold groundwater emerging from alkaline springs and seeps. The Abrams Creek Wetlands flora consists of obligate calciphiles, species which generally prefer base-rich soils, and species adaptable to a wide range of soil chemistries. Acidophiles are entirely absent from the flora.

2. *Hydrological regime and soil moisture.* The flora consists wholly of wetland and mesophytic species, with the assemblages present in specific habitats strongly influenced by hydrology and soil moisture. Weedy introduced species, as well as native woody invaders, have the highest frequency and cover in the drier end of the moisture gradient, whereas the more deeply flooded stream channels, sloughs, depressions, and spring outflows nearly exclude such species. The plant communities of the area are distinctly different in marshes that are seasonally flooded vs. those that are merely saturated (see Plant Habitats and Communities above).

3. *Exclusion of fire and other natural disturbance regimes.* Although it is a matter of conjecture, fires and megaherbivore grazing might have been significant disturbances assisting in maintaining open wetlands during the presettlement era. As these influences were eliminated postsettlement, land clearing, livestock grazing, railroad fires, and other anthropogenic disturbances likely served a similar function. Bartgis and Lang (1984) report that both fires and grazing have influenced calcareous wetlands in nearby Berkeley and Jefferson counties, West Virginia. With the demise of agriculture and the change in land use to suburban and residential development, woody succession of fens and marshes has become an increasing issue, especially in the drier end of the hydrological gradient. Successional elements include not only native trees and shrubs such as *Acer saccharinum*, *Cornus amomum*, and *Platanus occidentalis*, but a suite of invasive exotics that includes *Elaeagnus umbellata*, *Lonicera morrowi*, and *Rhamnus davurica*.

4. *Ongoing disturbances in and adjacent to the site.* The lawns, stormwater

Table 6. Location, ownership, and state-rare vascular plant species of the 18 calcareous wetlands in Virginia documented by the Virginia Natural Heritage Program (Department of Conservation and Recreation–Department of Natural Heritage [DCR-DNH] unpubl. data).

| Calcareous Wetland Site | County | Owner | No. of Rare Plants |
|--------------------------|------------|--|--------------------|
| Abrams Creek Wetlands | Frederick | City of Winchester, and private | 20 |
| Barns Chapel Swamp | Washington | The Nature Conservancy | 10 |
| Bolar Draft | Bath | Virginia Department of Game and Inland Fisheries | 4 |
| Cowbane Wet Prairie | Augusta | Virginia Department of Conservation and Recreation | 8 |
| Dismal Creek | Giles | George Washington and Jefferson National Forest | 8 |
| Folly Mills Fen | Augusta | private (Natural Area Preserve easement) | 13 |
| Fork Hollow Seep | Russell | private | 2 |
| Gaylord Calcareous Marsh | Clarke | private | 5 |
| Hotchkiss Meadow | Bath | private | 6 |
| Litz | Washington | private | 3 |
| Magnolia Swamp | Augusta | private | 6 |
| Montgomery Marl Meadow | Montgomery | private | 7 |
| Peters Mill Run | Shenandoah | George Washington and Jefferson National Forest | 3 |
| South River Marsh | Augusta | private | 1 |
| South River Preserve | Augusta | The Nature Conservancy | 12 |
| South River Wet Meadow | Augusta | private | 12 |
| Sweet Spring Hollow | Montgomery | private | 5 |
| Toms Creek Marshes | Montgomery | Town of Blacksburg | 3 |

outfalls, and roads associated with ongoing suburban development adjacent to the study area provide vectors for the continued establishment and spread of invasive introduced plants. Cattle grazing that continues in part of the site, as well as visitors who walk the trail through the wetlands in the city-owned preservation area, can also spread the propagules of various weeds.

Significance and Preservation of the Site

The Abrams Creek Wetlands site is only partly protected at present (Krystal 2007b, Gomes 2014). Much more work needs to be done to ensure that its globally rare natural communities and populations of state-rare plants remain viable. This site has a larger number of rare plants than any other Virginia calcareous wetland site (Table 6). It is noteworthy for containing two species not known elsewhere in Virginia, and five additional species known from just one other site. Despite the presence of invasive species, the floristic quality of the overall site ranks high. Even if additional formal protection is achieved, intensive stewardship and management will be required to keep woody succession and invasive weeds at bay.

Open calcareous wetlands are now very rare in the Virginia Ridge and Valley physiographic province. In more than 25 yr of inventory, the Virginia Natural Heritage Program has docu-

mented just 17 sites other than Abrams Creek supporting this class of wetland (Table 6). Of these, two (Cowbane Prairie and Folly Mills Fen) have been protected as State Natural Area Preserves, two (South River and Barns Chapel Swamp) have been protected by The Nature Conservancy, and two (Dismal Creek and Peters Mill Run) are protected in National Forest Special Biological Areas. Two of the remaining sites are on public lands with no formal protection, and the other nine are on private land and entirely unprotected. Like Abrams Creek, most are small fragments of remnant wetland surrounded by a matrix of agricultural or suburban land. Some have suffered irreparable damage from recent ditching and draining. In Jefferson County, West Virginia, only about 30 km northeast of Abrams Creek Wetlands, The Nature Conservancy has protected another calcareous wetland complex, Altona Marsh (Bartgis and Lang 1984).

Even though small, isolated, and altered, the calcareous wetlands of the Ridge and Valley Province remain vital clues to the original nature of stream-valley wetlands in montane Virginia. The urgency to conserve these fragmented but biologically rich sites is high. All of them support populations of rare plants that have been well inventoried, and all contain at least one globally rare natural community. However, a comparison of the vegetation, overall floristics, ecological

quality, and diversity of the few intact sites awaits future study.

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APPENDIX Annotated list of vascular plant species of the Abrams Creek Wetlands. This list of 304 vouchered vascular plant species comprises 206 genera in 78 families. Taxa appear alphabetically by family, genus, and species under the major plant groups (pteridophytes, gymnosperms, angiosperms); n = native, i = introduced. Family circumscriptions, nomenclature, and native/introduced status follow Weakley et al. (2012)

Habitat types: AS = aquatic and semiaquatic wetlands; BF = bottomland forests; CW = calcareous wet prairies, calcareous fens, and calcareous wet meadows; DM = disturbed weedy marshes; DT = disturbed weedy wetland-to-upland transition zones; MF = calcareous muck fens.

Relative abundance: 4 = common (relatively large numbers in suitable habitats throughout, often dominant); 3 = frequent (moderate numbers in suitable habitats, sometimes dominant); 2 = infrequent (sporadic in suitable habitats, sometimes numerous); 1 = rare (few individuals or only one or two colonies); h = historical record (abundance unrated, and taxon not documented at the site in the last 20 yr or more); nr = not rated.

Wetland indicator status ratings are from Lichvar et al. (2014); Floristic Quality Assessment Index (FQAI) coefficients of conservatism (CC) are from Virginia Department of Environmental Quality (2014); supplemented by Mid-Atlantic Wetland Workgroup (2014) and Andreas et al. (2004): 0 (highest range of ecological tolerance, greatest variety of habitats) to 10 (highest fidelity to narrowest range of habitats); * = introduced, therefore unrated.

Collection numbers are those of the Environmental Studies Program, Shenandoah University, Winchester, Virginia unless otherwise denoted

(F = Gary P. Fleming, W = Thomas F. Wieboldt). Names of individuals present on collecting trips appear on the herbarium specimen labels. All taxa are vouchered. Specimens collected by Shenandoah University and Fleming are deposited in the Ted R. Bradley Herbarium (GMUF), George Mason University, Fairfax, Virginia. Specimens collected by Wieboldt are deposited in the Massey Herbarium (VPI), Virginia Polytechnic Institute, Blacksburg, Virginia. The notation "cr" following the collection number indicates a county record at the time of the collection (Virginia Botanical Associates 2017).

PTERIDOPHYTES

EQUISETACEAE

Equisetum arvense L.: n, DM DT CW, 3; FAC, CC3; 14-019
Equisetum fluviatile L.: n, MF CW, 2; OBL, CC8; 13-057

ONOCLEACEAE

Onoclea sensibilis L. var. *sensibilis*: n, BF CW, 1; FACW, CC4; 13-300

OPHIOGLOSSACEAE

Botrypus virginianus (L.) Holub: n, BF, 2; FACU, CC5; 13-283

THELYPTERIDACEAE

Thelypteris palustris Schott var. *pubescens* (Lawson) Fernald: n, CW, 3; FACW, CC7; 13-396

GYMNOSPERMS

CUPRESSACEAE

Juniperus virginiana L. var. *virginiana*: n, CW, 3; FACU, CC3; 13-202

PINACEAE

Pinus strobus L.: n, CW, 1; FACU, CC5; 14-001

ANGIOSPERMS

ADOXACEAE

Sambucus canadensis L.: n, BF, 1; UPL, CC4; 13-090
Viburnum opulus L. var. *opulus*: i, BF, 2; FACW, CC*; 13-065
Viburnum prunifolium L.: n, BF, 2; FACU, CC5; 13-063

ALISMATACEAE

Alisma subcordata Raf.: n, MF AS, 3; OBL, CC6; 13-292
Sagittaria latifolia Willd.: n, AS MF, 3; OBL, CC6; 13-318

AMARYLLIDACEAE

Allium vineale L.: i, DT, 1; FACU, CC*; 13-245

ANACARDIACEAE

Rhus glabra L.: n, DT, 1; UPL, CC3; 13-350
Toxicodendron radicans (L.) Kuntze var. *radicans*: n, BF DM DT, 3; FAC, CC2; 14-122

APIACEAE

Cicuta maculata L. var. *maculata*: n, CW, 2; OBL, CC6; 13-142
Daucus carota L.: i, DM DT, 2; UPL, CC*; 13-247
Pastinaca sativa L.: i, DT, 1; UPL, CC*; 13-136
Sanicula odorata (Raf.) K.M. Pryer & L.R. Phillippe: n, BF, 1; FACU, CC7; 13-279cr
Sium suave Walter: n, BF, 3; OBL, CC6; 14-118
Torilis japonica (Houtt.) A.P. de Canolle: i, DT, 1; UPL, CC*; 13-234cr

APOCYNACEAE

Apocynum cannabinum L.: n, CW, 2; FACU, CC2; 13-364
Asclepias incarnata L. var. *incarnata*: n, CW, 3; OBL, CC5; 13-334cr
Asclepias syriaca L.: n, DT, 1; FACU, CC3; 13-213
Vinca major L.: i, DT, 1; UPL, CC*; 14-009cr

AQUIFOLIACEAE

Ilex verticillata (L.) A. Gray: n, BF, 2; FACW, CC7; 13-370

ARACEAE

Arisaema triphyllum ssp. *triphyllum* (L.) Schott: n, BF, 1; FACW, CC6; 14-025
Lemna minor L.: n, AS, 2; OBL, CC6; 14-104
Lemna trisulca L.: n, AS, 2; OBL, CC8; 14-094
Spirodela polyrrhiza (L.) Schleid.: n, AS, 2; OBL, CC5; 14-098
Wolffia columbiana H. Karst.: n, AS, 1; OBL, CC4; 14-100

ARALIACEAE

Hydrocotyle ranunculoides L. f.: n, AS, h; OBL, CC6; F5940

ASPARAGACEAE

Asparagus officinalis L.: i, DM, 1; FACU, CC*; 13-378

ASTERACEAE

Achillea millefolium L.: n, DT, 2; FACU, CC0; 13-229
Ambrosia artemisiifolia L.: n, DT, 2; FACU, CC1; 13-455
Ambrosia trifida L.: n, DT, 1; FAC, CC3; 13-483
Arctium minus Bernh.: i, DT, 2; FACU, CC*; 13-437
Bidens aristosa Britton: n, MF, 2; FACW, CC2; 13-538
Bidens frondosa L.: n, BF CW, 2; FACW, CC2; 13-494
Bidens laevis (L.) Britton, Sterns & Poggenb.: n, AS, 3; OBL, CC5; 13-478
Carduus acanthoides L. ssp. *acanthoides*: i, DM DT, 3; UPL, CC*; 13-196

- Centaurea nigrescens* Willd.: i, DT DM, 1; UPL, CC*; 13-511
- Centaurea stoebe* L. ssp. *micranthos* (S.G. Gmel. ex Gugler) Hayek: i, DT DM, 1; UPL, CC*; 13-357
- Cichorium intybus* L.: i, DM DT, 1; FACU, CC*; 14-116
- Cirsium arvense* (L.) Scop.: i, DT, 1; FACU, CC*; 13-192
- Cirsium muticum* Michx.: n, CW, 3; OBL, CC8; 13-156
- Cirsium vulgare* (Savi) Ten.: i, DT, 1; FACU, CC*; 13-400
- Conoclinium coelestinum* (L.) DC.: n, CW DM, 2; FAC, CC4; 13-464
- Conyza canadensis* (L.) Cronquist var. *canadensis*: n, DM DT, 2; UPL, CC1; 13-406
- Erechtites hieraciifolius* (L.) Raf. ex DC.: n, DM DT, 2; FACU, CC2; 14-124
- Erigeron annuus* (L.) Pers.: n, DT, 2; FACU, CC2; 13-176
- Erigeron philadelphicus* L. var. *philadelphicus*: n, DM DT, 3; FACU, CC3; 14-062
- Erigeron strigosus* Muhl. ex Willd. var. *strigosus*: n, DT, 2; FACU, CC1; 13-092
- Eupatorium altissimum* L.: n, DT, 1; UPL, CC1; 13-526
- Eupatorium perfoliatum* L.: n, CW DM, 3; FACW, CC6; 13-441
- Eutrochium maculatum* (L.) E.E. Lamont var. *maculatum*: n, CW, 4; FACW, CC8; 13-361
- Helenium autumnale* L.: n, CW, 2; FACW, CC4; 13-492
- Helianthus giganteus* L.: n, CW, 2; FACW, CC6; 13-522cr
- Heliopsis helianthoides* (L.) Sweet var. *helianthoides*: n, DT, 1; FACU, CC5; 13-215
- Lactuca serriola* L.: i, DT DM, 2; FAC, CC*; 13-239
- Leucanthemum vulgare* Lam.: i, DT, 1; UPL, CC*; 13-166
- Packera aurea* (L.) A. & D. Love: n, CW, 3; FACW, CC6; 13-016
- Rudbeckia triloba* L. var. *triloba*: n, DT, 2; FACU, CC5; 13-359
- Silphium asteriscus* L. var. *trifoliatum* (L.) Clevenger: n, DT, 1; UPL, CC5; 13-304
- Solidago altissima* L.: n, CW DM, 3; FACU, CC3; 13-514
- Solidago canadensis* L. var. *canadensis*: n, CW DM, 4; FACU, CC3; 13-548cr
- Solidago gigantea* Ait.: n, CW, 2; FACW, CC4; 14-126
- Sonchus asper* (L.) Hill: i, DT, 1; UPL, CC*; 12-205
- Symphotrichum lateriflorum* (L.) A. & D. Love: n, DM DT, 3; FACW, CC6; 13-531
- Symphotrichum novae-angliae* (L.) G.L. Nesom: n, CW, 3; FACW, CC5; 13-552
- Symphotrichum pilosum* (Willd.) G.L. Nesom var. *pilosum*: n, DT DM, 2; FAC, CC1; 13-558
- Symphotrichum praealtum* (Poir.) G.L. Nesom var. *angustior* (Wieg.) G.L. Nesom: n, CW, 4; FACW, CC6; 13-554
- Taraxacum officinale* G.H. Weber ex F.H. Wigg.: i, DT, 2; FACU, CC*; 13-550
- Tussilago farfara* L.: i, DT, 1; FACU, CC*; 14-023
- Verbesina alternifolia* (L.) Britton ex Kearney: n, DM DT, 2; FAC, CC3; 13-482
- Vernonia noveboracensis* (L.) Michx.: n, CW DM, 4; FACW, CC6; 13-402
- Xanthium strumarium* L.: n, DT DM, 2; FAC, CC1; 14-114

BALSAMINACEAE

Impatiens capensis Meerb.: n, DM CW, 4; FACW, CC4; 13-444

BERBERIDACEAE

Berberis thunbergii DC.: i, DT, 2; FACU, CC*; 13-306

Podophyllum peltatum L.: n, BF, 2; FACU, CC6; 14-027

BORAGINACEAE

Hackelia virginiana (L.) I.M. Johnst.: n, DT, 2; FACU, CC3; 13-261

Mertensia virginica (L.) Pers. ex Link: n, BF, 1; FACW, CC7; 14-030

BRASSICACEAE

Alliaria petiolata (M. Bieb.) Cavara & Grande: i, DM DT, 1; FACU, CC*; 13-150

Barbarea vulgaris R. Brown: i, DM, 2; FACU, CC*; 13-043

Cardamine bulbosa (Schreb. ex Muhl.) Britton, Sterns & Poggenb.: n, MF, 2; OBL, CC7; 14-013

Cardamine concatenata (Michx.) O. Schwarz: n, BF, 1; FACU, CC6; 14-003

Cardamine hirsuta L.: i, DT, 2; FACU, CC*; 14-005

Cardamine pensylvanica Muhl. ex Willd.: n, BF, 1; OBL, CC5; 13-067

Hesperis matronalis L.: i, DT, 1; FACU, CC*; 13-368

Nasturtium officinale R. Brown: i, MF, 1; OBL, CC*; 13-116

CAMPANULACEAE

Campanula aparinoides Pursh var. *aparinoides*: n, CW MF, 3; OBL, CC7; 13-237

Lobelia inflata L.: n, DM, 2; FACU, CC2; 13-431

Lobelia siphilitica L. var. *siphilitica*: n, CW DM, 3; FACW, CC4; 13-404

CANNABACEAE

Celtis occidentalis L.: n, BF, 2; FACU, CC3; 13-366

CAPRIFOLIACEAE

Dipsacus fullonum L.: i, DM DT, 2; FACU, CC*; 13-392

Lonicera japonica Thunb.: i, DT DM CW, 4; FAC, CC*; 13-061

Lonicera maackii (Rupr.) Maxim.: i, BF DT, 3; UPL, CC*; 13-314cr

Lonicera morrowii A. Gray: i, DM DT CW, 3; FACU, CC*; 13-132

CARYOPHYLLACEAE

Stellaria media (L.) Vill.: i, DT, 1; UPL, CC*; 14-021

CELASTRACEAE

- Celastrus orbiculatus* Thunb.: i, BF, 2; FACU, CC*; 13-286cr
Euonymus alatus (Thunb.) Siebold: i, BF, 1; UPL, CC*; 13-509cr

CONVOLVULACEAE

- Calystegia sepium* (L.) R. Brown: n, DM CW, 2; FAC, CC1; 14-080
Cuscuta gronovii Willd. ex J.A. Schult.: n, CW DM, 2; UPL, CC3; 13-388
Ipomoea hederacea Jacq.: n, DT, 1; FACU, CC0; 13-470

CORNACEAE

- Cornus amomum* Mill.: n, CW BF, 4; FACW, CC4; 13-094

CYPERACEAE

- Carex aggregata* Mack.: n, CW DM, 1; UPL, CC4; 13-082cr
Carex atherodes Spreng.: n, CW, 1; OBL, CC9; 13-073
Carex comosa Boott: n, MF AS, 3; OBL, CC7; 13-243
Carex frankii Kunth: n, CW DM, 3; OBL, CC4; 13-108
Carex granularis Muhl. ex Willd.: n, CW DM, 3; FACW, CC6; 14-042
Carex hystericina Muhl. ex Willd.: n, CW MF, 2; OBL, CC7; 13-028
Carex interior Bailey: n, CW, h; OBL, CC8; W3665
Carex lasiocarpa Ehrh. var. *americana* Fernald: n, MF, 2; OBL, CC8; 05-101
Carex molesta Mack. ex Bright: n, DM, 1; FAC, CC5; 13-120
Carex pellita Muhl.: n, MF, 2; OBL, CC8; 13-024
Carex prairea Dewey ex Wood: n, MF, 1; FACW, CC10; 13-080
Carex stipata Muhl. ex Willd. var. *stipata*: n, CW, 2; OBL, CC4; 13-014
Carex stricta Lam.: n, MF, 4; OBL, CC6; 13-018
Carex suberecta (Olney) Britton: n, CW, 2; OBL, CC9; 13-008
Carex tetanica Schkuhr: n, CW, 2; FACW, CC7; 13-001
Carex utriculata Boott: n, MF, h; OBL, CC7; F8002
Carex vulpinoidea Michx.: n, CW DM, 3; OBL, CC3; 13-253
Cyperus bipartitus Torr.: n, MF, h; FACW, CC4; F5945
Cyperus esculentus L. var. *leptostachyus* Böckler: n, CW DM, 2; FACW, CC2; 13-249
Cyperus flavescens L.: n, CW, h; OBL, CC3; F5954
Cyperus strigosus L.: n, CW, 2; FACW, CC3; 13-251
Eleocharis erythropoda Steudel: n, MF CW, 3; OBL, CC6; 13-114
Schoenoplectus pungens (Vahl) Palla var. *pungens*: n, CW MF, 4; OBL, CC5; 13-020
Schoenoplectus tabernaemontani (C.C. Gmelin) Palla: n, MF, 3; OBL, CC5; 13-030
Scirpus atrovirens Willd.: n, CW MF, 3; OBL, CC5; 13-140

- Scirpus pendulus* Muhl.: n, CW MF, 2; OBL, CC6; 13-070
Scleria verticillata Muhl. ex Willd.: n, CW, h; OBL, CC9; F5952

EBENACEAE

- Diospyros virginiana* L.: n, CW DT, 2; FAC, CC5; 13-217

ELEAGNACEAE

- Elaeagnus umbellata* Thunb.: i, DM DT, 3; UPL, CC*; 13-332

EUPHORBIACEAE

- Acalypha rhomboidea* Raf.: n, DM, 2; FACU, CC2; 13-468

FABACEAE

- Amphicarpaea bracteata* (L.) Fernald: n, CW, 2; FAC, CC4; 13-462
Cercis canadensis L. var. *canadensis*: n, BF DT, 1; FACU, CC6; 14-032
Desmodium perplexum B.G. Schub.: n, DT DM, 2; UPL, CC4; 13-460
Gleditsia triacanthos L.: n, DM, 2; FAC, CC3; 13-435
Lespedeza cuneata (Dumont-Cours.) G. Don: i, DT, 1; FACU, CC*; 13-542
Melilotus albus Medik.: i, DT, 1; UPL, CC*; 13-231
Robinia pseudoacacia L.: n, DT, 1; FACU, CC2; 13-275
Securigera varia (L.) Lassen: i, DT, 1; UPL, CC*; 13-174
Trifolium campestre Schreb.: i, DT, 1; UPL, CC*; 14-060
Trifolium pratense L.: i, DT, 2; FACU, CC*; 13-138
Trifolium repens L.: i, DT, 1; FACU, CC*; 14-067

FAGACEAE

- Quercus palustris* Muench.: n, BF DM, 2; FACW, CC7; 13-451cr

GERANIACEAE

- Geranium carolinianum* L.: n, DT, 1; UPL, CC1; 13-096
Geranium maculatum L.: n, BF, 1; FACU, CC7; 14-036

HALORAGACEAE

- Myriophyllum aquaticum* (Vell. Conc.) Verdc.: i, AS, 3; OBL, CC*; 14-082

HYPERICACEAE

- Hypericum perforatum* L.: i, DM, 1; FAC, CC*; 13-340
Hypericum punctatum Lam.: n, CW, 1; FAC, CC3; 13-296

IRIDACEAE

- Iris pseudacorus* L.: i, BF DM MF, 2; OBL, CC*; 13-035
Iris versicolor L.: n, CW, 1; OBL, CC8; 13-076cr
Sisyrinchium angustifolium Mill.: n, CW, 2; FACW, CC4; 13-037

JUGLANDACEAE

- Juglans nigra* L.: n, BF, 2; FACU, CC5; 14-046

JUNCACEAE

- Juncus balticus* Willd. var. *littoralis* Englem.: n, CW, 1; OBL, CC6; 14-092
Juncus brachycephalus (Engelm.) Buch.: n, MF, 1; OBL, CC10; 13-490
Juncus dudleyi Wieg.: n, CW, 4; FACW, CC7; 13-022
Juncus effusus L.: n, CW MF, 1; FACW, CC3; 13-324
Juncus nodosus L.: n, CW, 3; OBL, CC4; 13-235
Juncus scirpoides Lam. var. *compositus* Harper: n, CW, h; FACW, CC6; W3826
Juncus torreyi Coville: n, CW, 2; FACW, CC1; 13-233

LAMIACEAE

- Clinopodium vulgare* L.: n, CW DM BF, 2; UPL, CC1; 13-382
Lamium purpureum L.: i, DT, 1; UPL, CC*; 14-007
Leonurus cardiaca L.: i, DT, 1; UPL, CC*; 13-118
Lycopus americanus Muhl. ex W. Barton: n, CW, 2; OBL, CC4; 13-421
Lycopus uniflorus Michx.: n, CW, DM, 3; OBL, CC7; 13-419
Mentha canadensis L.: n, CW, 1; UPL, CC4; 13-328
Mentha piperita L.: i, CW DM, 2; FACW, CC*; 12-203cr
Mentha spicata L.: i, DM, 3; FACW, CC*; 13-425
Monarda fistulosa L. var. *fistulosa*: n, CW DM, 1; UPL, CC0; 13-372
Nepeta cataria L.: i, DM DT, 2; FACU, CC*; 13-130
Perilla frutescens (L.) Britton: i, DT, 1; FACU, CC*; 14-088
Prunella vulgaris L.: n, DT DM, 2; FACU, CC2; 13-227
Pycnanthemum tenuifolium Schrader: n, CW, 2; FACW, CC5; 13-374
Pycnanthemum virginianum (L.) T. Durand & B.D. Jacks. ex B.L. Rob. & Fernald: n, CW, 3; FAC, CC8; 13-336
Scutellaria galericulata L.: n, CW, 3; OBL, CC9; 13-257
Scutellaria lateriflora L.: n, DT DM, 2; FACW, CC6; 13-410
Stachys arenicola Britton: n, CW, 1; FACW, CC6; 13-384
Teucrium canadense L.: n, CW, 2; , FACW, CC4; 13-259

LAURACEAE

- Lindera benzoin* (L.) Blume: n, BF CW, 4; FAC, CC6; 13-158

MAGNOLIACEAE

- Liriodendron tulipifera* L.: n, BF, 2; FACU, CC4; 14-052

MENISPERMACEAE

- Menispermum canadense* L.: n, BF, 2; FACU, CC5; 13-051

MORACEAE

- Morus alba* L.: i, DT, 2; UPL, CC*; 13-146

NYMPHAEACEAE

- Nuphar advena* (Ait.) R. Brown ex Ait. f.: n, AS MF, 3; OBL, CC7; 13-255

OLEACEAE

- Fraxinus americana* L.: n, BF, 2; FACU, CC7; 13-453
Fraxinus pennsylvanica Marshall: n, BF CW, 3; FACW, CC6; 13-223
Ligustrum obtusifolium Seabold ex Zucc. var. *suave* (Kitag.) H. Hara: i, DT BF, 2; UPL, CC*; 13-288cr

ONAGRACEAE

- Circaea canadensis* (L.) Hill ssp. *canadensis*: n, BF DT, 1; FACU, CC3; 13-160
Epilobium coloratum Biehler: n, CW, 1; FACW, CC5; 13-408
Ludwigia palustris (L.) Elliott: n, MF DM, 2; OBL, CC2; 13-540
Oenothera biennis L.: n, DM, 2; FACU, CC2; 13-398
Oenothera gaura W.L. Wagner & Hoch: n, CW DT, 1; FACU, CC1; 13-416

ORCHIDACEAE

- Aplectrum hyemale* (Muhl. ex Willd.) Torr.: n, BF, 1; UPL, CC7; 14-048
Liparis loeselii (L.) L.C. Rich.: n, BF, 1; FACW, CC7; 14-069
Spiranthes cernua (L.) L.C. Rich.: n, CW, 1; FACW, CC7; 13-507
Spiranthes lucida (H.H. Eaton) Ames: n, CW, 1; FACW, CC10; 13-069

OROBANCHACEAE

- Agalinis purpurea* (L.) Pennell: n, CW, 2; FACW, CC5; 13-505

OXALIDACEAE

- Oxalis stricta* L.: n, BF, 1; FACU, CC2; 13-429

PENTHORACEAE

- Penthorum sedoides* L.: n, MF, 2; OBL, CC3; 13-267

PHRYMACEAE

- Mimulus ringens* L. var. *ringens*: n, CW, 2; OBL, CC5; 13-308

PHYTOLACCACEAE

- Phytolacca americana* L. var. *americana*: n, DT, 2; FACU, CC1; 13-211

PLANTAGINACEAE

- Callitriche stagnalis* Scop.: i, AS, h; OBL, CC*; W3675
Chelone glabra L.: n, CW MF, 1; OBL, CC6; 13-476
Linaria vulgaris Mill.: i, DT, 1; UPL, CC*; 13-427
Penstemon digitalis Nutt. ex Sims: n, CW, 2; FAC, CC5; 13-168cr
Penstemon hirsutus (L.) Willd.: n, DT, 1; UPL, CC6; 13-072
Penstemon laevigatus Ait.: n, CW, 2; FACU, CC4; 13-088
Plantago lanceolata L.: i, DT, 1; UPL, CC*; 13-180

- Plantago rugelii* Decne.: n, DT DM, 2; FACU, CC1; 13-466
Veronica anagallis-aquatica L.: n, CW MF, 2; OBL, CC6; 13-102
Veronica arvensis L.: i, DT, 1; UPL, CC*; 14-011
Veronicastrum virginicum (L.) Farw.: n, CW, 1; FACU, CC7; 13-326cr

PLATANACEAE

- Platanus occidentalis* L.: n, BF CW, 4; FACW, CC5; 14-074

POACEAE

- Agrostis stolonifera* L.: i, AS, 3; FACW, CC*; 13-084
Andropogon gerardii Vitman: n, CW, 2; FAC, CC7; 13-380
Arthraxon hispidus (Thunb.) Makino var. *hispidus*: i, DT DM, 2; FAC, CC*; 13-520
Bromus sterilis L.: i, DT, 1; UPL, CC*; 13-152
Dactylis glomerata L.: i, DT, 1; FACU, CC*; 13-059
Dichantheium leucothrix (Nash) Freckmann: n, CW, 2; FACW, CC2; 13-501cr
Echinochloa crus-galli (L.) Beauv. var. *crus-galli*: i, DT, 1; FAC, CC*; 13-390
Glyceria striata (Lam.) A.S. Hitchc. var. *striata*: n, CW, 2; OBL, CC5; 13-010
Leersia oryzoides (L.) Sw.: n, CW MF, 2; OBL, CC4; 13-472
Microstegium vimineum (Trin.) A. Camus: i, DM DT, 2; FAC, CC*; 13-516cr
Panicum dichotomiflorum Michx. var. *dichotomiflorum*: n, CW, 1; FACW, CC2; 13-496
Panicum flexile (Gattinger) Scribn.: n, DT, 2; FACU, CC5; 13-534
Panicum gattingeri Nash: n, DM, 2; FAC, CC1; 13-443cr
Phalaris arundinacea L.: n, MF, 4; FACW, CC1; 13-041
Poa pratensis L. ssp. *pratensis*: i, DM CW, 3; FACU, CC*; 13-026
Poa trivialis L.: i, CW, 2; FACW, CC*; 13-086
Schedonorus arundinaceus (Schreb.) Dumort.: i, DM DT CW, 4; FACU, CC*; 14-054
Setaria pumila (Poir.) Roemer & Schult.: i, DM, 2; FAC, CC*; 13-433
Sorghastrum nutans (L.) Nash: n, CW DT, 3; FACU, CC6; 13-503
Sphenopholis obtusata (Michx.) Scrib.: n, CW, 2; FAC, CC3; 13-078cr
Tripidium ravennae (L.) Scholz: i, DT, 1; UPL, CC*; 13-524cr

POLYGONACEAE

- Persicaria amphibia* (L.) S.F. Gray: n, MF, 3; OBL, CC6; 13-188
Persicaria extremiorientalis (Vorosh.) Tzvelev.: i, DT, 1; nr, CC*; 13-485cr
Persicaria longiseta (Bruijn) Kitag.: i, DM, 3; FAC, CC*; 13-200

- Persicaria punctata* (Elliott) Small: n, DM CW, 3; OBL, CC4; 13-394
Rumex crispus L. ssp. *crispus*: i, DM CW, 2; FAC, CC*; 13-106

POTAMOGETONACEAE

- Potamogeton foliosus* Raf. var. *foliosus*: n, AS, 3; OBL, CC5; 13-414
Potamogeton illinoensis Morong: n, AS, 2; OBL, CC6; 13-474

PRIMULACEAE

- Lysimachia ciliata* L.: n, BF, 1; FACW, CC5; 13-273
Lysimachia hybrida Michx.: n, BF, 1; OBL, CC8; 13-330
Samolus parviflorus Raf.: n, CW, 2; OBL, CC5; 13-047

RANUNCULACEAE

- Clematis virginiana* L.: n, CW DM, 1; FAC, CC4; 14-070
Delphinium exaltatum Ait.: n, CW, 1; UPL, CC7; 13-376
Ranunculus bulbosus L.: i, DT, 1; UPL, CC*; 14-044
Ranunculus hispidus Michx.: n, BF, 1; FAC, CC6; 14-078
Ranunculus scleratus L. var. *scleratus*: n, MF, 2; OBL, CC4; 13-045
Thalictrum pubescens Pursh: n, CW, 2; FACW, CC7; 13-294
Thalictrum thalictroides (L.) A.J. Eames & B. Boivin: n, BF, 1; FACU, CC6; 14-034

RHAMNACEAE

- Frangula alnus* Mill.: i, DM BF, 1; FAC, CC*; 13-198cr
Rhamnus davurica Pall.: i, BF DT, 2; nr, CC*; 14-065cr
Rhamnus lanceolata Pursh var. *lanceolata*: n, BF, 2; FAC, CC9; 14-064

ROSACEAE

- Agrimonia parviflora* Ait.: n, CW DM, 2; FACW, CC4; 13-499
Crataegus phaenopyrum Borkh.: n, BF, 1; FAC, CC4; 14-120cr
Geum canadense Jacq.: n, BF, 2; FACU, CC5; 13-134
Malus baccata (L.) Borkh.: i, BF, 1; UPL, CC*; 13-386
Potentilla indica (Andrews) T. Wolf: i, DT, 2; FACU, CC*; 13-055
Potentilla norvegica L.: n, DT, 1; FACU, CC3; 13-126
Prunus subhirtella Miq.: i, DT, 1; nr, CC*; 14-090cr
Pyrus calleryana Decne.: i, BF DT, 2; nr, CC*; 14-050cr
Rosa carolina L.: n, CW, 1; FACU, CC6; 13-225
Rosa multiflora Thunb. ex Murray: i, DT BF, 3; FACU, CC*; 13-033
Rubus discolor Weihe & Nees: i, DT, 1; UPL, CC*; 13-164cr
Rubus occidentalis L.: n, DT, 1; UPL, CC2; 14-084
Rubus phoenicolasius Maxim.: i, DT, 2; FACU, CC*; 13-207

RUBIACEAE

- Cephalanthus occidentalis* L.: n, BF MF, 1; OBL, CC6; 13-290

Galium aparine L.: n, DM, 2; FACU, CC2; 13-098

Galium obtusum Bigelow: n, BF, 2; FACW, CC5; 13-039

Galium triflorum Michx.: n, BF CW, 2; FACU, CC5; 13-298

Galium verum L.: i, DM, 1; UPL, CC*; 13-178

RUSCACEAE

Maianthemum racemosum (L.) Link ssp. *racemosum*: n, BF, 1; FACU, CC6; 13-277

RUTACEAE

Phellodendron amurense Rupr.: i, DT, 1; nr, CC*; 13-209cr

SALICACEAE

Populus deltoides W. Bartram ex Marshall var. *deltoides*: n, BF CW, 3; FAC, CC5; 13-345

Salix babylonica L.: i, CW, 2; FACW, CC*; 13-190

Salix eriocephala Michx.: n, CW, 2; FACW, CC5; 13-219cr

Salix nigra Marshall: n, CW BF, 3; OBL, CC3; 13-003

SAPINDACEAE

Acer negundo L. var. *negundo*: n, BF, 3; FAC, CC4; 14-076

Acer rubrum L.: n, BF, 1; FAC, CC2; 13-355

Acer saccharinum L.: n, BF, 2; FACW, CC5; 14-015

SCROPHULARIACEAE

Verbascum blattaria L.: i, DT, 2; UPL, CC*; 13-124

Verbascum thapsus L.: i, DT, 1; FACU, CC*; 13-347

SIMAROUBACEAE

Ailanthus altissima (Mill.) Swingle: i, DT, 2; FACU, CC*; 14-056

SOLANACEAE

Physalis longifolia Nutt. var. *subglabrata* (Mack. & Bush) Cronquist: n, DT, 1; UPL, CC1; 12-204

Solanum carolinense L. var. *carolinense*: n, DM DT, 2; FACU, CC2; 13-128

Solanum dulcamara L.: i, CW DM DT, 2; FAC, CC*; 13-172

Solanum sarrachoides Sendtn.: i, DT, 1; UPL, CC*; 13-532

TYPHACEAE

Sparganium americanum Nutt.: n, AS, 2; OBL, CC6; 13-322

Sparganium emersum Rehm.: n, AS, 1; OBL, CC8; 13-338

Sparganium eurycarpum Engelm. ex A Gray: n, MF AS, 4; OBL, CC6; 13-204

Typha latifolia L.: n, MF CW, 3; OBL, CC2; 13-154

ULMACEAE

Ulmus americana L.: n, BF CW, 2; FACW, CC6; 13-458

URTICACEAE

Boehmeria cylindrica (L.) Sw.: n, CW MF, 4; FACW, CC4; 13-162

Pilea fontana (Lunnell) Rydb.: n, CW, 3; FACW, CC8; 13-446

VERBENACEAE

Verbena hastata L.: n, CW, 3; FACW, CC4; 13-310

Verbena urticifolia L.: n, BF DT, 2; FAC, CC3; 13-263

VIOLACEAE

Viola cucullata Ait.: n, CW, 2; FACW, CC6; 13-032

VITACEAE

Parthenocissus quinquefolia (L.) Planch.: n, BF, 3; FACU, CC4; 14-072

Vitis riparia Michx.: n, BF, 1; FACW, CC5; 14-058

Vitis vulpina L.: n, BF, 3; FAC, CC4; 13-342

XANTHORRHOEACEAE

Hemerocallis fulva (L.) L.: i, DT, 1; FACU, CC*; 13-184