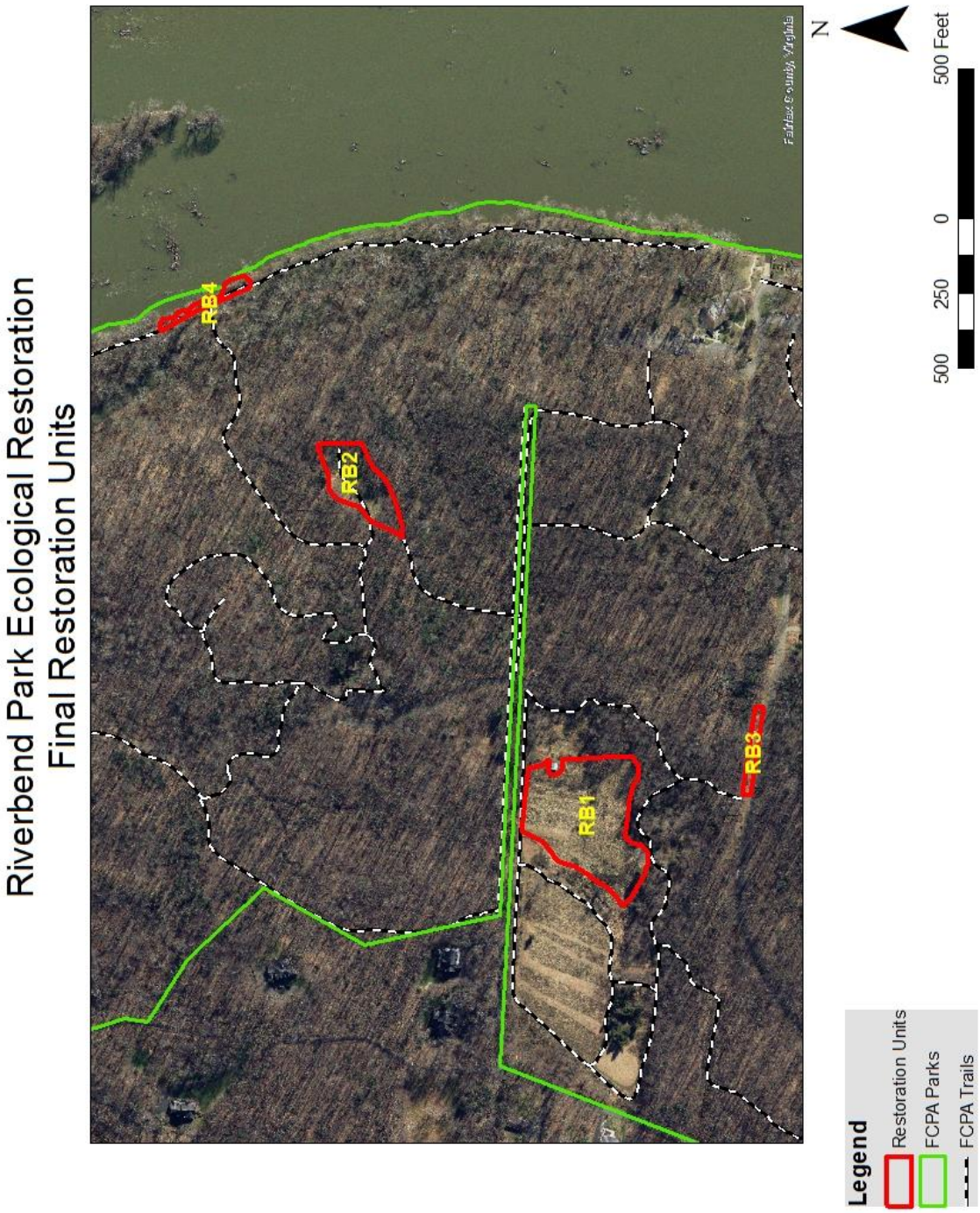
Final Progress Report

Riverbend Park Ecological Restoration

Overview

A Helping Our Land Heal (HOLH) project was implemented at Riverbend Park (RB) from 2018 to 2020 with the two goals of establishing native plant dominated grassland ecosystems in three separate locations; and stabilizing a stretch of riverbank along the Potomac River. In partnership with Riverbend Park staff, Fairfax County Park Authority (FCPA)'s Natural Resource Branch (NRB) managed the project as part of the agency's ecological restoration program. The project complied with the Riverbend Park Master Plan Revision (2013). The project contributed to achieving actions 16 through 19 in the FCPA natural resource management plan (NRMP). The Northern Virginia Soil and Water Conservation District (NRCS) regulated water quality and erosion and sediment controls for the project through creation of a Conservation Plan and a Nutrient Management Plan and monitoring of restoration activities. The objectives of the planned restoration were to restore and/or enhance ecological attributes as defined by the Society for Ecological Restoration (SER) and restore natural communities appropriate to each restoration unit's site conditions. Planned treatment would cover 4.5 acres, of which 4.25 acres were meadow and 0.25 acres were forested riverbank.

Project Map


Riverbend Park Ecological Restoration
Final Restoration Units
RB1
RB2
RB3
RB4
N
500 250 0 500 Feet
Legend
Restoration Units
FCPA Parks
FCPA Trails

Timeframe

Through a competitive process, funding was awarded from Fairfax County's Environmental Improvement Program in May, 2018. Upon notice of funding, an in-house restoration plan was created as a framework for project implementation. Management units were delineated for three meadow restoration sites (RB1, RB2, RB3) and one riverbank forest planting (RB4). Project implementation began in July 2018 and was completed in December 2020. Ongoing maintenance will be required for all restoration areas to maintain habitat quality.

Defining the Problem

Unit RB1 prior to restoration treatments (2018). This meadow was dominated by non-native orchard grass (*Dactylis glomerata*) and two weedy native species: deer-tongue grass (*Dichanthelium clandestinum*) and wingstem (*Verbesina alternifolia*).

Invasive species and low native plant biodiversity were the primary problems in meadow restoration units prior to project implementation. Each meadow restoration unit has a different site history and set of degrading pressures. Primary degrading pressures include an extended history of agriculture, past construction and soil grading, invasive species pressure, and white-tailed deer over abundance. Historical aerial

photography shows that the largest restoration unit (RB1) has been in herbaceous vegetation, presumably pasture, since at least 1937. Prior to project implementation, RB1 was dominated by non-native pasture grasses (such as?). Restoration unit 2 (RB2) contained a home site from 1937 through 1976, and the surrounding land was used for agriculture until at least 1960. RB2 was more recently disturbed when a telecommunications tower was installed, and the site sees light vehicle traffic for routine tower maintenance. Prior to project implementation, RB2 was a near-monoculture of invasive mugwort (*Artemesia vulgaris*). Restoration unit 3 (RB3) is located on a roadcut bank beside what is now the main entrance to the park's visitor center. The road was constructed around 1960 and RB3 appears to have been routinely cleared/mowed until project implementation. Prior to project implementation, RB3 was dominated by invasive species such as wineberry (*Rubus phoenicolasius*) and Japanese stiltgrass (*microstegium vimineum*).

Unit RB2 was heavily invaded by mugwort (*Artemisia vulgaris*) prior to restoration treatments (2018). Mugwort is tall, rhizomatous, and allelopathic. The only native species that grew alongside mugwort was wingstem (*Verbesina alternifolia*).

Restoration unit 4 (RB4) was located along a forested riverbank on the Potomac River. The primary issues affecting this unit were riverbank erosion, invasive plant encroachment, and lack of native overstory trees. RB4 is directly adjacent to a floodplain back swamp know as Black Pond. Black Pond provides habitat for a variety of vernal pool obligates, and riverbank erosion threatens to destroy this habitat. Erosion from

flood events along the Potomac River has been particularly damaging within RB4, and a flood in 2018 washed away several hundred square feet of the bank. Prior to project implementation, RB4 was dominated by bush honeysuckle (*Lonicera mackii*).

The Society for Ecological Restoration (SER) developed a recovery scale to characterize the results of ecological restoration projects in their publication, International Standards for the Practice of Ecological Restoration (2016). The scale measures 6 key attributes relative to a set of reference community conditions. Although all attributes are relevant to ecological health, not all attributes can be addressed by small-scale restoration actions. The HOLH project manager characterized the pre-treatment problems at Fitzhugh using this scale. A narrative assessment was provided, rather than using the SER quantitative "Five Star System":

- Absence of Threats:
    - Invasive species: All restoration units were overwhelmingly dominated by non-native invasive species and/or weedy native species.

Prior to restoration treatments RB3 was occupied mostly by invasive species including Japanese stiltgrass (*Microstegium vimineum*) and wineberry (*Rubus phoenicolasius*) (2018).

- Physical conditions:
    - Substrate physical: Riverbank erosion is occurring rapidly within RB4. Soil compaction may be an issue in all meadow units due to land-use history. The extent and severity of soil compaction will be investigated.

Severe erosion along the Potomac riverbank within RB4 threatens to destroy a popular trail and drain an adjacent floodplain pond that provides important habitat for salamanders.

- Species composition:
    - Desirable plants: Restoration units suffered from very low diversity of native plants. Only weedy natives such as wingstem (*Verbesina alternifolia*) and deertongue (*Dicanthelium calndestinum*) persisted in large quantities among the invasives.
    - Undesirable plants: Restoration units were almost completly dominated by non-native invasive species in all strata.
- Structural diversity:
    - All vegetation layers: Meadow restoration units generally contained herbaceous and shrub vegetation strata, although most strata were dominated by invasive species. The riverbank restoration unit is lacking

overstory trees along the bank, and the shrub strata was composed of invasives.

- Ecosystem functionality:
    - Resilience/recruitment: Recruitment of native grassland plants seems to be severely constrained in meadow restoration units, likely due to dominance by invasive species. Erosion and white-tailed deer browse prevent establishment of native trees in the riverbank restoration unit.
    - Habitat and interactions: Low diversity of native plants is not likely to support a diverse pollinator fauna. Native pollinators require floral resources throughout the growing season and depend on successive blooms to provide these resources. The only significant floral resource available in restoration units prior to treatments was provided by *Verbesina alternifolia*, which blooms in mid-late summer.
- External exchanges:
    - Habitat links: A variety of migratory birds use meadows at Riverbend Park, suggesting that these meadows are a component of important linkages between summer and winter songbird habitats.
    - Landscape flows: All restoration areas were dominated by NNI, likely contributing to negative landscape flows. Restoration areas likely served as a source of propagules for NNI species that rely on wildlife for dispersal, such as autumn olive and bush honeysuckle.
    - The Potomac River conveys high amounts of energy that contacts the riverbank restoration unit, removing soil and destabilizing forest plants.

Planning and Design

The overall goal of the project was to restore native plant structure, composition, and function to the greatest extent possible. Natural communities, as defined by the Virginia Department of Conservation and Recreation's (DCR) Natural Heritage Program, were used as restoration targets. An additional goal for RB4 was to reduce riverbank erosion to the greatest extent possible without using an engineered solution.

Restoration targets were developed for each unit using data from a variety of sources. Historic aerial imagery was examined to evaluate site history and successional history. Data on site conditions such as landform, aspect, soils, hydrology, and geographic setting were collected. Existing vegetation throughout the entire park was evaluated by HOLH program staff. Finally, feasibility of different management actions was considered. For example, establishing a forest community was infeasible in RB2 due to the existing telecommunications tower easement.

Data on site conditions, vegetation, and management feasibility were compiled and compared with DCR's database of Virginia Natural Communities. Three separate restoration target communities were identified for Riverbend Park:

Piedmont Prairie (CEGL006572): This is the most applicable extant grassland community classified by DCR in the Virginia Piedmont. Occurrences of this natural community are considered semi-natural because they have developed under a human driven regime of frequent mowing and/or burning. Vegetation composition is very diverse, and characteristic species include Indiangrass (*Sorghastrum nutans*), little bluestem (*Schizachyrium scoparium*), narrowleaf mountain mint (*Pycnanthemum tenuifolium*), and early goldenrod (*Solidago juncea*).

This community was chosen as a restoration target for RB1, RB2, and RB3. There are few examples of intact Piedmont Prairies, and it is unlikely that the vegetation composition of existing reference sites would perfectly fit the conditions of restoration sites at Riverbend Park. Because of this, we used this community as a general framework and modified the composition to suit each individual restoration site. The site conditions within RB1 were conducive to most of the characteristic species found in Piedmont Prairies. However, RB2 and RB3 were more shaded and mesic; therefore species lists for these restoration units were modified from the characteristic species of Piedmont Prairies to ensure successful establishment of a native plant dominated system.

Northern Coastal Plain/Piedmont Mesic Mixed Forest (CEGL006075): These mixed hardwood forests occur on a variety of landforms throughout the Virginia Piedmont and Northern Coastal Plain on mesic sites with deep, acidic, nutrient-poor soils. Dominant canopy trees include tuliptree (*Liriodendron tulipifera*), American beech (*Fagus grandifolia*), red oak (*Quercus rubra*), and white oak (*Quercus alba*). American holly (*Ilex opaca*) and Christmas fern (*Polystichum acrostichoides*) are dominant in the shrub and herbaceous layers, respectively.

This is the dominant upland forest type among high-quality forest stands in Riverbend Park. RB2 had an additional project component of creating an ecotone of short statured woody plants between the meadow and the surrounding Piedmont Mesic Mixed Forest. This community was used to design the edge planting. The edge planting included shrubs and small trees that are typically found in the surrounding forest.

Piedmont-Central Appalachian Rich Floodplain Forest (CEGL004073): These rich floodplain forests and found along terraces and floodplains of large and medium-sized rivers. Flooding is frequent and short-duration, and soils are generally very fertile with high base-saturation and calcium content. The tree canopy is diverse and dominant species include sycamore (*Platanus occidentalis*), bitternut hickory (*Carya cordiformis*), hackberry (*Celtis occidentalis*), tuliptree (*Liriodendron tulipifera*), silver maple (*Acer saccharinum*). The subcanopy is strong dominated by *Acer negundo*. The herb layer is

extremely lush and diverse, composed of spring ephemerals and other nutrient-demanding species; Virginia bluebells (*Mertensia virginica*) are among the most abundant forbs.

This community is dominant throughout most of Riverbend Park's floodplains along the Potomac River. Restoration unit RB4 is a small pocket of riverbank lacking a tree canopy and heavily invaded by bush honeysuckle (*Lonicera maackii*), nested within a high-quality Piedmont Rich Floodplain Forest. Large and medium-sized tree species typical of this community were selected for planting in RB4.

Project Activities

Project activities that were implemented in the field can be generally categorized as invasive vegetation removal, site preparation, seeding, planting, erosion control, and establishment activities. Specific activities are as follows:

<u>Invasive and Undesirable Vegetation Removal:</u>

1. Bare-ground herbicide applications – Foliar herbicide applications were made to herbaceous vegetation. Herbicide was broadcast over the entire restoration unit in order to completely remove existing vegetation and expose a mineral soil seedbed. Patches of desirable vegetation were identified and retained by string trimming prior to herbicide application. Used on RB1, RB2, RB3.
2. Spot herbicide applications – Foliar applications were made to undesirable herbaceous and short/low woody vegetation. Stem applications were made to cut stumps or to girdle cuts ("hack and squirt") for larger plants that could not be safely or effectively treated with foliar applications.
3. Forestry mulching – Large thickets of undesirable woody vegetation were masticated into small pieces of woody debris using a forestry mulcher. Used on RB1, RB2.
4. Hand cutting – Undesirable woody vegetation located in areas inaccessible to the forestry mulcher was removed using hand tools such as loppers and chainsaws. Used on RB2, RB4.

<u>Site Preparation:</u>

1. Mowing and tractor raking – This method was used to remove herbaceous thatch following herbicide applications to expose more bare soil prior to seeding by hand or with a seed drill. Thatch was mowed with a bush hog and subsequently

raked into piles using a tractor-mounted tractor rake, (York brand). Used on RB1, RB2, RB3.

2. Leaf blowing – This method was used prior to seeding in areas with thick leaf litter. Leaves were blown after autumn leaf-fall into adjacent wooded areas to expose bare soil. Used on RB2 and RB3.
3. Harley raking – This method was used to prepare soil prior to hand-seeding native grasses and forbs. A Harley rake, also known as a power landscape rake, was used to till the soil to a depth of about 1/2 inch, in order to fluff the soil and create a high-quality seedbed for native seed. Used on RB2, RB3, and small portions of RB1.
4. Hand raking – This method was used to remove herbaceous thatch and leaf litter and expose mineral soil in areas inaccessible to machinery. Used on RB2 and RB3.

After bare-ground herbicide treatments, tractor raking, and leaf blowing, RB1 is prepared for restoration seeding (April 2019).

<u>Seeding:</u>

1. Hand broadcasting – Seeding by hand, covered extensively in the restoration literature. Used on RB2, RB3, RB4, and for very small seeds (mostly forbs) in RB1.
2. Seed drilling – No-till seed drill application on bare soil. Allows for seeding native grasses and forbs with less soil disturbance than is required for hand

broadcasting. This method is also very effective for establishing native warm season grasses demonstrated by increased rates of germination, increased seedling growth in the first year and higher rates of seedling survival. Not suitable for very steep or very small sites unless part of a group of sites. Used on RB1.

3. Cultipacking – This method was used for meadow restoration areas that were Harley raked and hand broadcasted. After seeding, a hand-pulled lawn roller filled with 20 gallons of water was drawn over the entire restoration unit to press the native seed into the soil. Used on RB2, RB3.

After bare-ground herbicide treatments, tractor raking, and leaf blowing, RB1 is prepared for restoration seeding (June 2019).

Woody Planting:

1. Native trees and shrubs were planted by hand. Planting holes were dug using shovels or a power auger, and one-gallon planting stock was used. Used on RB2, RB4.
2. Plantings were protected from deer herbivory with five foot tall metal wire cages or plastic mesh tree tubes. Cages and tubes were maintained quarterly to remove vines and falling branches; to reposition leaders and branches of plantings within the cage; replace broken stakes and to repair other damage.

The forest edge surrounding RB2 was planted with a variety of shrubs and small trees commonly found in Piedmont Mesic Mixed Hardwood Forests, with the goal of enhancing structural diversity. The planting was implemented by NRB staff, Riverbend Park staff, and volunteers in December 2018.

Erosion Control:

1. Straw application – Wheat straw was applied to areas that were Harley raked, hand-broadcasted, and cultipacked. The straw was applied lightly so that bare soil was still visible through the layer of material. Used on RB2, RB3, and steep/erosive sections of RB1.
2. Silt fencing – Silt fence was used when restoration areas were adjacent to impermeable road surfaces. Silt fence was installed in according with best management practices. Used on RB3.
3. Jute matting – Jute mat was installed on steep/erosive areas adjacent to impermeable road surfaces. Used on RB3.

Establishment:

1. Mowing – During the first season of growth of seedlings, vegetation that reached 12'' tall was mowed to 6'' tall as needed until September 15. Mowing was implemented using a tractor-mounted bush hog or a string trimmer. This allowed light and space for slow growing perennial seedlings to establish despite

competition from fast growing annuals and aggressive perennials. Used on RB1, RB2, RB3.

2. Spot spray – Foliar herbicide was applied to aggressive NNI in establishing stands of native vegetation. Care was taken to avoid damaging native vegetation. Used in RB1, RB2, RB3.

Following seeding of RB2, the unit was protected from erosion with a thin layer of wheat straw. As of 2020, few natives have germinated in RB2. It is unclear why the seeding seems to have failed, but *Artemisia vulgaris* allelopathy may be involved.

Activity Schedule:

RB1

- 10/2018 – Implemented bare-ground herbicide treatment
- 1/2019 – Forestry mulched thickets of undesirable woody vegetation
- 3/2019 – Began tractor raking thatch to expose soil and prepare for seeding
- 4/2019 – Finished tractor raking to remove thatch and prepare for seeding
- 5/2019 – Implemented bare-ground herbicide treatment
- 6/2019 – Seeded natives with a seed drill; small seeds were hand-sown
- 7/2019 – Implemented spot herbicide treatment in establishing vegetation
- 8/2019 – Implemented spot herbicide treatment in establishing vegetation
- 9/2019 – Mowed establishing vegetation with a bush hog
- 6/2020 – Implemented spot herbicide treatment to control undesirable vegetation

- 8/2020 – Implemented spot herbicide treatment to control undesirable vegetation

RB2

- 9/2018 – Implemented bare-ground herbicide treatment
- 11/2018 – Installed woody edge plantings
- 1/2019 – Forestry mulched thickets of undesirable woody vegetation
- 3/2019 – Continued tractor raking thatch to expose soil and prepare for seeding
- 4/2019 – Postponed seeding until Winter 2019 based on poor control of invasives
- 5/2019 – Implemented herbicide treatment
- 7/2019 – Implemented herbicide treatment
- 9/2019 – Implemented herbicide treatment
- 12/2019 – Prepared seedbed using leaf blower and Harley rake; hand-seeded native plant mix and cultipacked using lawn roller
- 12/2019 – Spread light layer of straw over entire unit
- 5/2020 – Mowed establishing vegetation with a string trimmer
- 6/2020 – Implemented spot herbicide treatment in establishing vegetation
- 9/2020 – Mowed establishing vegetation with a bush hog

RB3

- 10/2018 – Installed silt fence
- 10/2018 – Implemented bare-ground herbicide treatment
- 4/2019 – Used leaf blower and hand rakes to expose mineral soil
- 5/2019 – Implemented bare-ground herbicide treatment
- 6/2019 – Prepared seedbed using Harley rake; hand-seeded native plant mix
- 9/2019 – Determined that seeding failed due to seed washout from heavy storms
- 12/2019 – Prepared seedbed using Harley rake; hand-seeded native plant mix and cultipacked using lawn roller
- 12/2019 – Spread layer of straw and installed jute matting over entire unit
- 7/2020 – Mowed establishing vegetation with a string trimmer
- 9/2020 – Mowed establishing vegetation with a string trimmer

RB4

- 11/2018 – Installed woody plantings
- 2018-2019 – Mechanical cutting of woody non-native invasive plant stems
- 4/2020 – Hand-seeded native grasses for additional erosion control

Project Outcomes

Upon completion, the project treated a total of 4.5 acres: 4.25 acres of grassland, and 0.25 acres of floodplain forest. In addition to the hours contributed by NRB and Riverbend Park staff, volunteers contributed about 400 hours of labor to the restoration project.

The project manager has evaluated the restoration work according the SER recovery scale. Significant improvements have been made but continued maintenance will be required to move the system closer to reference community conditions. A narrative assessment was done, rather than using the SER quantitative "Five Star System":

- Absence of Threats:
    - Invasive species: All units have shown a drastic reduction in cover of invasive species. Invasives are still present in small patches and must be managed as needed.
- Physical conditions:
    - Substrate physical: There is no indication that riverbank erosion has slowed in RB4. Planted trees and grasses, once established, may slow erosion by protecting exposed soil and anchoring soil in roots. Due to the size and power of the Potomac River, the efforts in this project may be too small to affect the system dynamics.

By late Summer 2020 native grasses and forbs are fully established in RB1. The growing space is occupied entirely by a diverse mix of at least twenty native grassland species. A diversity of native forbs bloomed from spring through fall, providing floral resources for pollinators throughout the growing season.

- Species composition:
    - Desirable plants: Restoration units are now dominated by native plant species. As of the end of the 2020 growing season, over 20 native herbaceous species have been observed establishing in restoration units. Native perennials are slow to establish, and we expect to observe many more species as the years progress.
    - Undesirable species: Invasive species are no longer dominant and are now restricted to patches within restoration units. These species will continue to be managed. RB2 experiences continued presence of a major invader, *Microstegium vimineum*, and requires continued interventions to control.
- Structural diversity:
    - All vegetation layers: As of the end of the 2020 growing season, the meadow seeding at RB1 is fully established and has multiple vegetation strata. Seedings at RB2 and RB3 are not yet mature enough to assess structural diversity. However, ongoing germination and establishment of grassland plants indicates that the restoration units will eventually have diverse vegetation structure. Structural diversity of the forest edge surrounding RB2 has improved as a result of the edge planting. RB4 now has established tree seedlings, which have the potential to grow into a mature overstory.
- Ecosystem functionality:
    - Resilience/recruitment: Removal of invasive species and seeding native plants has drastically improved recruitment of native grassland species in RB1, RB2, and RB3. When the meadows are fully established, the predominance of a diverse palette of native grassland species should make the meadow more resilient to invasion following disturbances such as mowing and prescribed fire.
    - Habitat and interactions: Higher diversity of native plants should support more complex trophic interactions. Diverse native plants blooming throughout the season should support pollinators throughout the year. Diverse seed sources should support wintering songbird and other wildlife.
- External exchanges:
    - Habitat links: Increased diversity of native plants may provide an enhanced food source for migrating and wintering birds. Vegetation structure has returned since project activities began.
    - Landscape flows: Restoration areas will now likely contribute native plant propagules to landscape flows. While restoration areas are maintained and kept free of NNI, they will not serve as NNI propagule sources.

Lessons Learned

Many methods were used as a part of this project involving many different activities. The results of these activities are captured in the following lessons learned:

1. Seed drilling is an effective way of establishing native warm season grasses: Native warm season grasses (NWSG), such as Indian grass (*Sorghastrum nutans*) and little bluestem (*Schizachyrium scoparium*), were seeded in all grassland restoration units. NWSG were seeded in June 2019 using a Truax native grass seed drill in RB1 and seeded by hand in RB3. Germination was quick and uniform in RB1 yet failed entirely in RB3. Although the site conditions differed considerably among the two restoration units, it is likely that the seed drill provided better germination conditions than hand seeding for NWSG. It is also possible that the seed drill prevented movement and loss of seed during an extreme thunderstorm event in June 2019. Germination across RB1 does not appear to have been affected but it is possible that seed was lost on slopes in RB2 and RB3 which had much lower establishment rates.

Native grass and forbs germinating in seed drill furrows about a month after seeding. Some patches of soil were washed out from a 200-year rainstorm that occurred shortly after seeding, which may have negatively impacted germination.

2. Complete vegetation removal is essential to seeding success: Prior to seeding RB1, existing vegetation (mostly invasive pasture grasses) was removed by broadcast spraying a broad-spectrum herbicide. Throughout most of RB1, herbicide was broadcast twice; once in fall 2018 and once in spring 2019 prior to seeding. Due to contractor error, about ½ acre received only one herbicide application in spring 2019. The difference between the area sprayed twice and the area sprayed once was drastic; the area sprayed twice had less weedy/invasive plants and better native plant establishment, while the area sprayed only once is now dominated by weedy natives such as deer-tongue grass (*Dichanthelium clandestinum*) and patches of invasives such as mugwort (*Artemisia vulgaris*). This illustrates the importance of at least two herbicide applications prior to seeding, in order to deplete the seed bank of undesirable plants.

RB1 after bare-ground herbicide treatments. NRB staff used a tractor rake to prepare the site by removing thatch and exposing mineral soil. This was labor intensive and time-consuming.

3. Thatch removal prior to seeding is a significant time investment: After herbicide applications and prior to seeding, thatch (dead vegetation) must be removed from the grassland restoration site to expose mineral soil and ensure good seed-soil contact. Thatch removal required several passes with a tractor-drawn tractor rake, followed by one pass with a high-powered leaf blower. The tractor rake filled

quickly with thatch and needed to be cleaned by hand after each pass. This process took an estimated 15-20 person hours/acre. Despite the inefficiency of this process, removing thatch is essential to seeding success. Prescribed fire may have provided a more complete means of thatch removal but was not an option for this project due to the proximity of residential properties.

4. Method for protecting desirable plants from broadcast herbicide application: Although grassland restoration units were initially dominated by invasive species, all three units contained patches of desirable native plants such as wingstem (*Verbesina alternifolia*), milkweed (*Asclepias syriaca*), bottlebrush grass (*Elymus hystrix*), and goldenrod (*Solidago spp.*). These patches were dispersed throughout the restoration units, making it impractical to flag each patch for exclusion from herbicide application. Instead, patches of desirable plants were string-trimmed in order to remove all foliage immediately prior to broadcast herbicide application. Without foliage to uptake herbicide, desirable plants were not harmed by the broadcast application. This worked especially well when desirable tall plants such as wingstem (*Verbesina alternifolia*) were mixed in with undesirable short plants such as orchard grass (*Dactylis glomerata*); the low-growing orchard grass retained enough foliage for herbicide uptake even after being mowed.

5. Summer-seeded forbs do not germinate in the first growing season: Unlike NWSG species, many native forb species require a period of cold-stratification before they are able to germinate. This is an adaptation that postpones germination until the spring following seed dispersal, preventing fall germination and winter mortality. This was shown to be true with the summer-seeding of RB1; seeding took place in June 2019, and only NWSG and forbs that do not require cold stratification (*Rudbeckia spp.*, *Chamaecrista fasciculata*, etc) germinated in the first growing season. Only a handful of forbs that require cold stratification were observed in 2020 including butterfly weed (*Asclepias tuberosa*), blue vervain (*Verbena hastata*), and swamp milkweed (*Asclepias incarnata*). Cover of NWSG and forbs that do not require cold stratification remains overwhelmingly dominant; this contrasts with a dormant meadow seeding at Fitzhugh Park, where cover of species requiring cold stratification is similar to species that do not require cold stratification.

6. Special consideration for site preparation near forest edges: Both RB2 and RB3 are near a forest edge. Fall seeding was planned for both units, in order to maximize forb germination. Under normal circumstances in which a restoration unit is not close to a forest edge, site preparation and fall seeding can begin as early as September. However, proximity to the forest edge required that we wait until after leaf-fall to prepare the site for seeding. Once leaf-fall was complete in early December 2019, we used hand tools and leaf blowers to clear the restoration area and expose mineral soil, in order to ensure good seed-soil contact and adequate light for germination/establishment. If fall seeding had occurred prior to leaf-fall, a heavy leaf

mulch may have severely constrained germination and establishment of native grasses and forbs the following spring.

7. Steep grassland restoration sites require erosion control measures: RB1 and RB3 were seeded in June 2019, immediately preceding a 200-year rain event. Neither unit received any erosion control measures. The terrain in RB1 is mostly flat or gently rolling, although there are several steep slopes through the unit. RB3 is a relatively steep roadcut, although the slope extends upward only about 30 feet and does not receive stormwater from upstream. The 200-year rain event washed out and prevented germination in the steep sections of RB1 and the entirety of RB3. As a result, RB3 needed to be completely reseeded and RB1 received supplemental seeding in bare areas. Erosion control measures, such as straw and jute matting, were added to prevent further erosion.

A large amount of mineral soil washed out of RB3 and accumulated behind the silt fence during a 200-year rainstorm shortly after the first seeding attempt in June 2019. The storm may have contributed to the failure of the first seeding attempt.

8. Feasibility of very small restoration units with stormwater features: RB3 is a very small (0.25 acre) restoration area that is immediately adjacent to an asphalt road. Although RB3 is small, this unit incurred almost as much administrative cost as the

larger restoration units. Due to the proximity of RB3 to pavement, silt fence was installed and maintained throughout the project duration, further increasing project costs. This resulted in a much higher cost per acre than larger restoration units. Based on this experience, NRB staff determined that small projects with special consideration (stormwater features, erosion control, etc) would be considered low priority for future HOLH projects.

The second seeding attempt for RB3 occurred in December 2019 and incorporated wheat straw and jute matting for erosion control.

9. Grass-specific herbicides were unreliable in controlling *Microstegium vimineum*: Two different grass-specific herbicides were used to control Japanese stiltgrass (*Microstegium vimineum*) in RB2: clethodim (trade name Intensity One) and fluazifop-p-butyl (trade name Fusilade). These chemicals have a mode of action that affects only graminoids, and they were used to selectively treat stiltgrass that was mixed into desirable vegetation.

   Despite multiple applications within RB2, both chemicals proved to be very unreliable. Stiltgrass responded well in some areas, while adjacent stands of stiltgrass remained completely unharmed. Additionally, *Carex* sedges were killed by clethodim even though the label states that the chemical is not effective on these

species. It is unclear why these chemicals were so unreliable. Several possibilities were considered: one or more genotypes of *Microstegium vimineum* are resistant to these chemicals, site conditions and microclimate impact effectiveness, and/or application must occur while plants are very young for adequate results. Grass-specific herbicides have potential to be effective restoration tools, but more trials are needed to understand how to best utilize them.

This photo was taken in RB2 one year following commencement of restoration treatments. Note that nearly all invasive vegetation has been controlled except for Japanese stiltgrass (*Microstegium vimineum*) due to poor response to application of grass-specific herbicides.

10. Possible allelopathic effects of *Artemisia vulgaris*: Restoration unit RB2 was dormant seeded in December 2019. This method is supported in the literature and was used successfully in RB3 and Fitzhugh Park. Despite the success of RB3 and Fitzhugh Park, very little germination of native seed was observed throughout the entire 2020 growing season in RB2. Weedy vegetation such as *Microstegium vimineum* was dominant in 2020 but was managed with establishment mowings and did not appear dense enough to inhibit seedling germination.

    Although any number of factors may have contributed to germination failure, it is possible that mugwort (*Artemisia vulgaris*) played a role. This species is known to produce allelopathic chemicals, although information on their effects is sparse. RB2

was overwhelmingly dominated by mugwort prior to restoration treatments. This species was removed entirely with herbicide applications prior to seeding, but it is possible that residual allelopathic chemicals remained in the soil and inhibited germination of native seeds.

11. Ecotype of native seed may be an important consideration in meadow restoration: Restoration seedstock for Indiangrass (*Sorghastrum nutans*) and little bluestem (*Schizachyrium scoparium*) was purchased from two native seed vendors: one located in Kentucky and one in Pennsylvania. The HOLH program's policy is to purchase seedstock with a source population as geographically similar to Northern Virginia as possible. In this case, the Indiangrass was sourced from a Kentucky population and little bluestem from a North Carolina population.

Native grasses establishing and growing vigorously about three months following seeding. Establishment of grasses was faster and denser than in previous restoration projects in other locations.

Both grass species turned out to look and behave quite differently from populations native to Northern Virginia. In restoration unit RB1 they established much more rapidly, grew more densely, and in some cases were much taller than the native ecotype. Although these traits were conducive to rapid meadow establishment and suppression of invasive species, they may also have drawbacks. Stands of local-ecotype NWSG usually have abundant space between individual grass clumps,

allowing for diversity of smaller forbs and providing habitat for grassland birds and other wildlife. The stand of NWSG in RB1 grows so dense that there is little room between grass clumps; this may have negative consequences for floral diversity and wildlife habitat. Additionally, these ecotypes may be maladapted for long-term survival in Northern Virginia. Long-term monitoring is needed to track the development of RB1.

Long-Term Management

The restored systems will require on-going management to control NNI, maintain desirable herbaceous cover, and continue to establish restoration plantings. It is recommended that management take place every 2-3 years at a minimum and an ecologist monitoring visit occur every 5 years at a minimum.

Long-term management of RB1, RB2, and RB3 should include periodic mowing, prescribed fire, and herbicide application in order to maintain native herbaceous cover and discourage NNI species. Prescribed fire is an ideal tool for maintaining meadow habitat; fire discourages woody plants, recycles nutrient, reduces pest populations, eliminates thatch, and provides other benefits that mowing alone does not provide. Fire should be the primary management tool used in RB1 and can be implemented every 2-3 years. Prescribed fire can be implemented between late fall and early spring, however burns may be effective at controlling non-native cool season grasses when these species are still actively growing. Meadow restoration units should be allowed to establish for a minimum of 2 growing seasons before burning.

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