Princeton University Stewardship Plan

December 2020

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Friends of Hopewell Valley Open Space

Rose Mallow along the D&R Canal

Introductory Information

Owner:	Princeton University
Project Mapping Acreage:	1,264 acres
County, Municipality:	Mercer County, Municipality of Princeton and West Windsor Township
Wildlife Action Plan Conservation Zone:	Central Piedmont Plains (14)
NJDEP Watershed Management Area:	Millstone (WMA 12)
Waterbodies:	Stony Brook and its Tributaries (including Alexander Creek): 2.3 miles Millstone River and its Tributaries: 1.1 miles Carnegie Lake: 55.9 acres Unnamed Pond 1 (golf course): 0.9 acres Unnamed Pond 2 (southern end of property): 0.1 acres
Numbers of Rare Species Conservation Targets[1]:	Total Number of Animal Species: 3 Total Number of Plant Species: 2 Total Number of Ecological Communities: 0 *Note: Categories below are not mutually exclusive.* Globally Rare Species: 0 Federally Endangered Species: 0 Federally Threatened Species: 0 State Endangered Species: 2 State Threatened Species: 1 State Special Concern Species: 2 State Game Species of Concern: 0 Globally Rare Ecological Communities: 0 State Rare Ecological Communities: 0
Habitat Conservation Targets:	1) Mature Forest, 2) Shrubland, 3) Wildflower Meadow
Landscape-Scale Conservation Areas:	*ENSP Landscape Project Importance Summary* - Largest Habitat Patch – Forest, 11 contiguous acres *New Jersey Natural Heritage Program Priority Sites* - There are no sites that overlap with the Property. *New Jersey Audubon Society Important Bird and Birding Areas* - There are no sites that overlap with the Property.

Species Conservation Target List[1]:

Birds (3)
Great Blue Heron – foraging (Special Concern), Red-headed Woodpecker (State Threatened), Bald Eagle (State Endangered)

Amphibians (0)
None

Retiles (0)
None

Insects (0)
None

Habitats (1)
Potential Vernal Pool Habitat Area (ID 1616)

Plants (2)

From Natural Heritage Grid GIS Layer (not necessarily located on Property):
Smooth Hedge-nettle, *Stachys tenuifolia* (S3), Death-camus, *Zigadenus leimanthoides* (S1, State Endangered)

Plant Communities (0)
None

[1] Species include those confirmed to be present within the Property or its contiguous habitat patch based upon Natural Heritage Grid GIS Layer and Landscape Project Version 3.3. Rank Key: S1=Critically Imperiled/Endangered (< 5 known populations); S2=Imperiled/Threatened (6-20 known populations), S3=Rare/Special Concern (21-100 populations).

Invasive Plant Species List:	Each invasive plant species was assigned an 'Action Code' based upon observations of current extent of infestations on the Reservation and within New Jersey. Codes include: "1" = immediate implementation of an eradication program across the entire Reservation, "2" = selective control measures to minimize negative impacts, especially in particular habitats and "3" = no direct control measures due to low probability of causing significant harm or species is very abundant and control measures are impractical. Particular species may be controlled through specific habitat restoration projects. See report for additional information on distribution, infestation severity and control recommendations. ***Total Number of Mapped Invasive Species: 55*** **Action Code = 1 (29 species)** Amur Corktree, Amur Maple, Boston Ivy, Callery Pear, Chinese Wisteria, Chocolate Vine, Common Barberry, Dame's Rocket, English Ivy, European Buckthorn, Fuzzy-Pride-of-Rochester, Highbush Cranberry, Japanese Clematis, Japanese Maple, Japanese Snowball, Japanese Snowbell, Japanese Wisteria, Japanese Zelkova, Jetbead, Kousa Dogwood, Norway Maple, Oriental Photinia, Siebold's Viburnum, Sycamore Maple, Toringo Crabapple, Weeping Higan Cherry, Wintercreeper, Yellow Iris **Action Code = 2 (20 species)** Amur Honeysuckle, Asiatic Bittersweet, Autumn Olive, Chinese Bushclover, Common Reed, Garlic Mustard, Japanese Aralia, Japanese Barberry, Linden Viburnum, Mile-a-Minute, Mugwort, Multiflora Rose, Narrowleaf Bittercress, Porcelainberry, Privet, Tree-of-Heaven, Wineberry, Winged Burning Bush **Action Code = 3 (6 species)** Black Locust, Carpgrass, Japanese Stiltgrass, Lesser Celandine, Morrow's Bush Honeysuckle, Reed Canary Grass
Overabundant Native Animal Species:	This plan will address management of invasive species in the context of an overabundant deer population, which has a profound negative impact on conservation values. The Property is located within the NJ Division of Fish & Wildlife's Deer Management Zone #14 and Deer Management Units 256 and 270. Hunting dates and harvest regulations may vary by season, but unlimited antlerless deer harvests are allowed throughout most seasons ranging from early September to mid-February.

Executive Summary

Princeton University represents an important example of protection of critical natural, historical and recreational resources in a heavily populated area of New Jersey. This stewardship plan includes results of field investigations conducted at the Reservation and was developed with assistance from County staff and volunteers.

There are three main purposes of this plan. The first is to clearly state the vision and goals for the Reservation including protection of biodiversity and provision of recreational and educational opportunities. The second is to carefully define conservation values, threats to their health, and strategies/actions to mitigate identified threats. The third purpose is to provide ample sources of reference material for the County and the public to effectively navigate the many aspects of the Reservation and guide its adaptive stewardship over time.

The vision for natural lands on the Reservation is to provide model stewardship of biodiversity. Although the primary objective is the enhancement and recovery of natural resources, providing recreational and educational opportunities are considered very high priorities that can be balanced with the requirements of biodiversity.

The primary habitat conservation target is forest, but there are also important meadow habitats including the globally rare traprock glade community. These habitats support multiple common and rare species of our flora and fauna. A total of 25 rare species have been documented at the Reservation (See page ii). All habitats and species are under immediate threat from overabundant deer and invasive species.

Deer management has not occurred at the University and this has significantly contributed to ecological degradation.

However, deer are still having a dramatic negative impact. Most native woodland wildflowers are severely browsed and over 1,500 acres of forest fall into two categories – “Empty Forest Syndrome” (no understory plants) or “Infested Forest Syndrome” (only unpalatable invasive understory plants). Further reduction of deer density less than 20 per square mile (or as low as 5 per square mile to allow recovery of forest wildflowers) is absolutely critical to allow native species, freed from excessive browse, to exert ecological control of invasive species and produce healthy native plant communities. This will require changes to the existing program that facilitates increased harvests including re-establishment of a Community Based Deer Management permit.

The extent of invasive species infestation is significant. A total of 55 invasive species were detected. Approximately 60% of the Property is considered to be heavily infested with one or more species (ca. 30% is considered to have little or no invasive species, the remaining 10% is developed lands). The predominant invaders are Japanese Stiltgrass, Multiflora Rose, Japanese Barberry, Winged Burning Bush and Linden Viburnum. Importantly, 29 emerging invasive species, totaling 461 unique populations, were detected and should be immediately eradicated (e.g., Oriental Photinia) to prevent future damage. A “brute force” approach that seeks direct control of all invasive species is not practical (estimated at nearly 100,000 hours). This plan recommends a strategic approach with the ultimate goal of significantly reducing invasive species through directed active control and ultimate reliance on ecological control to both reverse current infestations and resist future infestations.

Recreational and educational (cultural and natural history) opportunities play a significant role at the Reservation. With over 30 mile of mapped trails and likely 10 or more miles of unmapped trails, there are ample existing resources. Minor changes are recommended to avoid damage to sensitive areas (e.g., globally rare traprock glade communities), including closure of several trails/spurs.

This ambitious plan provides four primary recommendations with twelve associated goals (see next page). Full implementation of these goals is estimated to require over 2,475 hours of County staff and 11,350 hours of volunteer time (valued at $272,400), as well as $156,500 of contractor services. The total plan implementation cost is estimated at approximately $298,250 over the next 10 years or just under $30,000 per year.

Primary Plan Recommendations

This 10-year plan has four primary recommendations and twelve associated goals. Goals are further divided into specific tasks with associated level-of-effort and cost estimates (Table 27).

Recommendation #1: Implement an Effective White-tailed Deer Management Program

Goal #1-1: Reduce deer density to meet forest health goals including a dense understory including native shrubs and wildflowers. Deer density should be kept below 20 deer per square mile; allowing full recovery of forest wildflowers may require a density as low as 5 deer per square mile. This goal will require re-establishment of a Community Based Deer Management permit to allow increased harvesting.

Recommendation #2: Perform Strategic Invasive Species Control

Goal #2-1:

Goal #2-2: Eradicate xx emerging invasive species

Goal #2-3: Protect high quality "Clean" forest areas on xx acres (redundant with #3-1?).

Recommendation #3: Perform Forest and Meadow Habitat Management and Restoration

Goal #3-1: Protect and enhance xx acres of old growth forest with exclosures, mini-exclosures, restoration plantings, etc.

Goal #3-2: Restore or maintain xx acres of native wildflower meadow including wet meadow

Recommendation #4: Perform Community Ecological Health Monitoring

Goal #4-1: Perform ecological health monitoring program for forest and meadow habitats

Table of Contents

List of Tables, Figures, Maps and Appendices

List of Tables

List of Figures

List of Maps

List of Appendices

Individual Invasive Species Maps (arranged alphabetically by common name)

*Maps include field mapped polygons and points entered in the New Jersey Invasive Species Strike Team database (for selected species and areas of the Property).

Section I. Overview

Introduction

Princeton University lands consist of 1,264 acres in the Municipality of Princeton and West Windsor Township, Mercer County (Map 1). This Stewardship Plan was created to collect and consolidate relevant information to develop strategies to improve ecological health. This section provides a brief overview of vision and goals for the Property as well as a summary of conservation values, threats to conservation values, and the context for stewardship actions.

Conservation Values

The Property contains excellent examples of the natural heritage contained within the Piedmont physiographic region, especially those areas containing old growth and riparian forests. There were x different forest types identified during field surveys, including communities dominated by Red Maple, American Beech, various oak species (Red, Chestnut Oak, White), Sugar Maple and Tulip Poplar. Shrubland and meadow communities, along with forest communities, provide habitats harboring diverse elements of our flora and fauna. A total of 0 rare species have been documented at the Reservation (mention possibilities). The Property contains portions of Stony Brook, Millstone River and Carnegie Lake and their associated wetland plant communities. These riparian corridors provide important wildlife corridors through a highly developed landscape including multiple high-traffic highways.

Stewardship Vision and Goals

The stewardship vision for the Property is to provide a model of stewardship for biodiversity within a university setting. The four primary recommendations include: 1) Implement Effective White-tailed Deer Management Program, 2) Perform Strategic Invasive Species Control; 3) Perform Forest and Meadow Habitat Management and Restoration and 4) Perform Ecological Health Monitoring. Each of these recommendations includes action-oriented goals (See Section V) to support both flora and fauna.

Complete realization of the vision and goals for the Property can only be met through the University and its community implementing wise stewardship fueled by deep appreciation of the natural world. Because of the complexity of the task at hand, this plan is considered a living document subject to change over time as additional information becomes available and results from ongoing efforts are evaluated. At a minimum, this stewardship plan should be revised every ten years. The careful stewardship of the Property will provide concrete examples of exemplary stewardship and community support that can be broadly applied throughout New Jersey.

Threats to Conservation Values

This section provides a brief overview of three significant factors that impact ecological health. These factors are interrelated and impact ecological health synergistically. In isolation, deer overabundance is the most severe threat, followed by invasive species and continuing impacts of altered soils from past agricultural use.

Degraded forests in New Jersey generally fall under two ‘syndromes’. The first is the “Empty Forest Syndrome” where all native species have been removed from the forest understory by overabundant deer. These forests also have very low invasive species cover, except where canopy gaps provide additional light resources. This syndrome is usually associated with areas that have never received agricultural soil tillage and associated soil alterations (1930 aerial photography showing mature forest cover can act as a guide to determine the lack of past agricultural land use). The second syndrome is the “Infested Forest Syndrome”, which includes dense invasive species cover and small amounts of native cover that is severely browsed by deer. This syndrome is associated with: 1) upland forests with past agricultural

tillage that has dramatically altered soil characteristics, 2) many wetland forests regardless of past land use, and 3) riparian forests, especially where unnaturally high water flows create severe and repeated physical disturbances.

White-tailed Deer

Statewide deer population size has varied significantly over the last one hundred years (Figure 1). The historical analysis of the white-tailed deer population density in North America (pre-European colonization) is approximately 10 per square mile (McCabe and McCabe 1984). Figure 1 shows the estimated statewide population size based upon the historical estimate for North America and deer population estimates reported by the New Jersey Division of Fish & Wildlife. By 1900, deer were nearly extinct in New Jersey because of unregulated market hunting for the sale of venison. The recovery of the deer population, through the implementation of various game regulations, is a significant conservation success story. However, the deer population mushroomed during the 1900's and peaked in 1995 with 3X more individuals than pre-European estimates. In 2011, there was 1.5X more individuals than pre-European estimates (See notes under Figure 2 for details). In the late 1990's, the NJ Division of Fish & Wildlife implemented changes to reduce the deer herd (e.g., "Earn-A-Buck" program that encouraged harvest of antlerless deer). It is important to note that deer population reduction has occurred when 40-50% of the population is harvested annually (green line in Figure 2) and 60-70% of the harvest is comprised of antlerless deer (orange line in Figure 2). Although there have been recent important changes to facilitate hunting success (e.g., Sunday bow hunting, use of crossbows, reduction in the bow hunting safety zone), population levels continue to exceed pre-European densities with noticeable ecological, economic and human health impacts.

Figure 1. Historic and Current New Jersey Deer Population Estimates

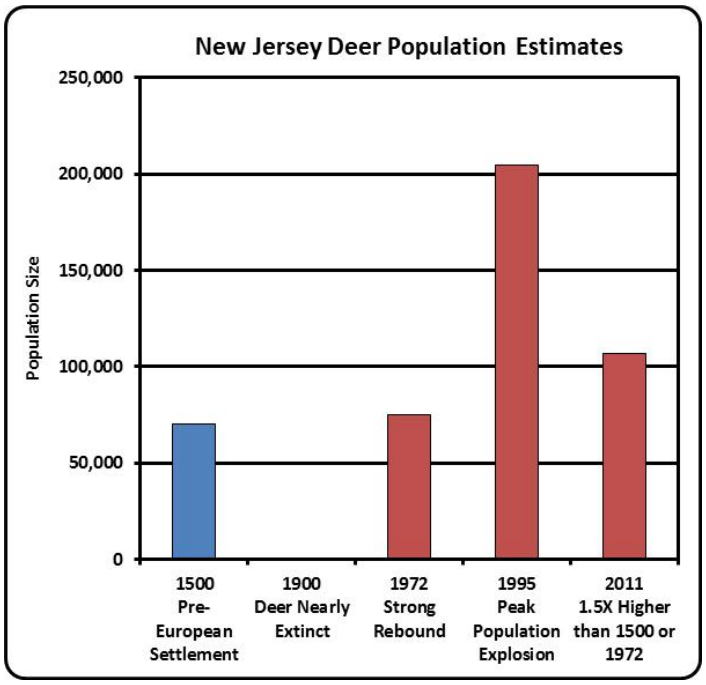
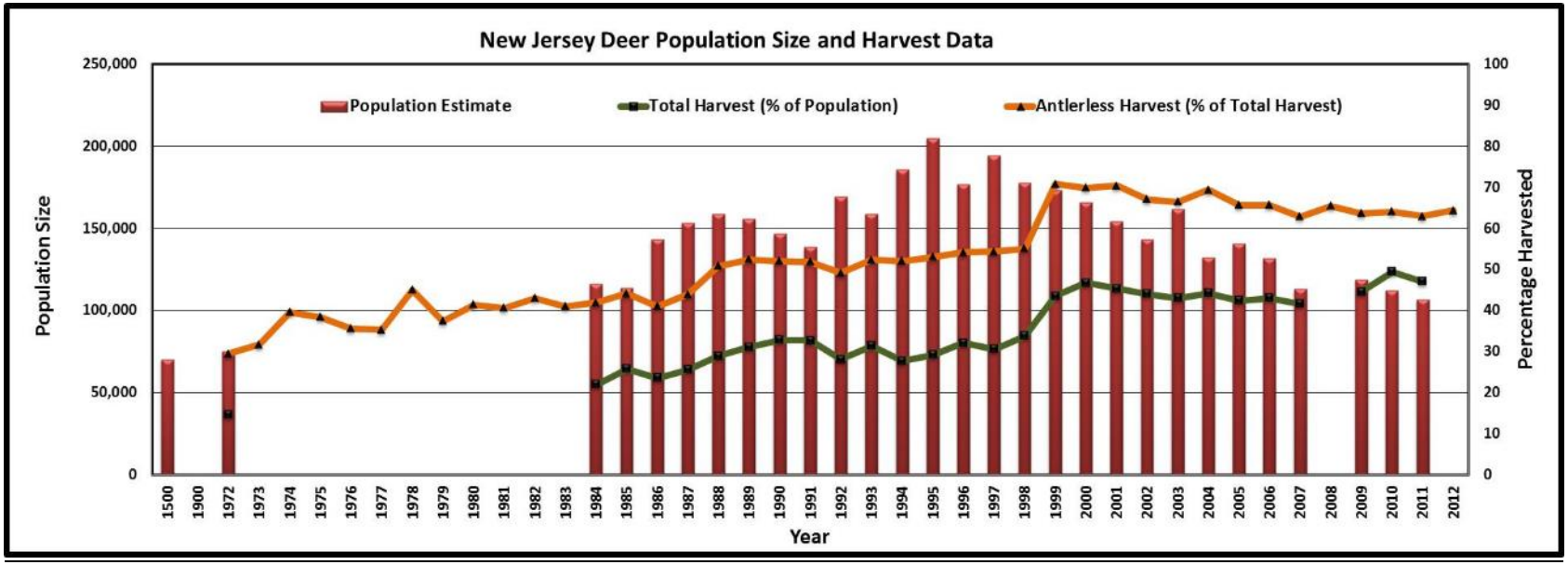


Figure 2. New Jersey Deer Population Size and Harvest Data



Graph prepared using NJ Division of Fish & Wildlife data sources. The estimated number of deer in 1500 is based upon the average deer density across North America (9.5/square mile) reported by McCabe and McCabe (1984) and the NJ land area reported by the US Census Bureau (7,417 square miles). Using this method, overall deer densities in particular years are: 1972 – 10.1; 1995 – 27.6 and 2011 – 14.4

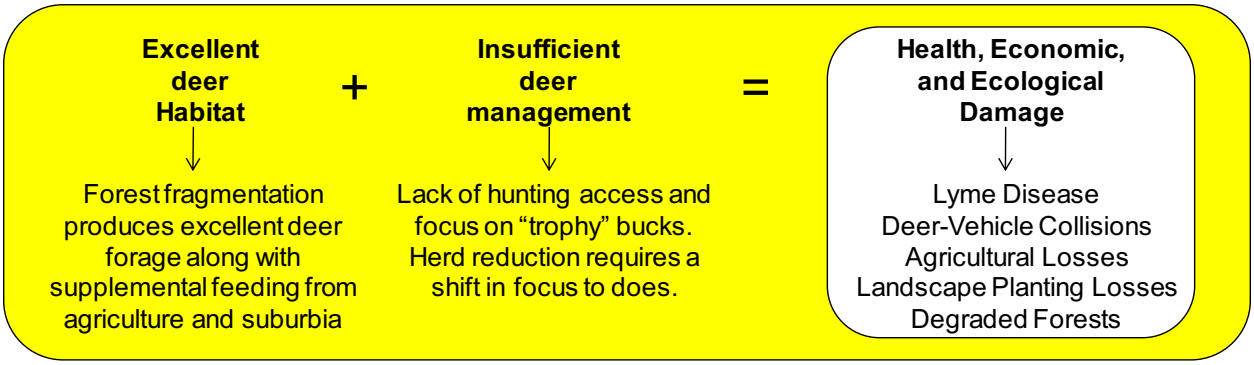
Special Note #1: Deer densities calculated by the Division of Fish & Wildlife are derived from harvest data and do not account for land inaccessible to hunting; therefore, they represent an under-estimate of actual deer population size. Species Note #2: Total population estimates are not available for 2008 or 2012.

The current effective deer densities on forested habitats are significantly greater than pre-Columbian densities because a considerable amount of land in New Jersey is developed / agricultural (ca. 50% of the total land area). In absolute numbers, the New Jersey deer population peaked in 1995 with 2.9X more individuals than pre-Columbian estimates. There is currently 1.5X more individuals than pre-Columbian estimates [but see special note #1 above].

It should be noted that the deer population size or density is less significant than their overall impacts on ecosystem health, which should be measured to inform deer management goals.

A simplified explanation of deer management issues and consequences are depicted in Figure 3. All deer management efforts must consider the current habitat conditions that serve deer population growth. Deer prefer forest edges and fields for feeding and utilize forests for cover and supplemental feeding. Deer also utilize agricultural crops as food sources and residential areas for both food and cover from hunters (state regulations prohibit firearm hunting within 450 feet of an occupied or potentially occupied structure unless written permission is provided by the owner, bow hunting is prohibited within 150 feet). Both restrictions on hunting access and insufficient hunting efficacy, plus the ability of the landscape to serve as an excellent incubator for deer population growth, combine to cause severe deer impacts.

Figure 3. Deer Population Growth Factors and Impacts



The current statewide deer population cannot support healthy forests (and creates significant human health and economic impacts). A healthy forest consists of a canopy of tall, mature trees, a sub-canopy of smaller tree species and an understory of tree saplings & seedlings, shrubs and herbs. Deer prefer to eat native plants over non-native invasive plants leading to further degradation of our forests by allowing invasive species to proliferate. The combination of elevated deer numbers and their preference for native plants has led to degradation of New Jersey's forests by eliminating native understory growth and reducing the abundance of animals that require those plants for their survival. Although the 'correct' number of deer may vary depending upon site and regional conditions, the goal of healthy forest communities that support a diversity of plants and animals is universal.

Deer management at the Reservation over the last 25 years (since 1994) serves as an impressive model for urban forests throughout the country. Exceptional results, including dense native tree sapling and shrub cover, was observed on over 500 acres – this accomplishment cannot be overstated and represents some of the healthiest forests that can be observed in New Jersey.

However, deer are still having a dramatic negative impact on the Property. Most native woodland wildflowers are severely browsed and over 1,500 acres of forest fall into two categories – "Empty Forest Syndrome" (no understory plants) or "Infested Forest Syndrome" (only unpalatable invasive understory plants). Herd reduction to 20 deer per square mile (or as low as 5 per square mile to restore forest wildflowers) is absolutely critical to allow native species, freed from excessive browse, to exert ecological control of invasive species and produce healthy native plant communities. This will require changes to the existing program that facilitates increased harvests.

Invasive Species

Humans have introduced non-native species, both intentionally and unintentionally, to parts of the world outside of their natural range. Only a small percentage of these introduced species become invasive, which is formally defined by the National Invasive Species Council as "a species that is 1) non-native (or

alien) to the ecosystem under consideration and 2) whose introduction causes or is likely to cause economic or environmental harm or harm to human health" (NISC 2001). The financial impacts of invasive species are enormous. Pimentel et al. (2005) estimate an annual cost of $120 billion dollars to agriculture, forestry and recreation. In addition, invasive species are considered the greatest threat to global biodiversity after outright habitat destruction (Wilcove et al. 1998).

From nature's perspective, this problem is relatively new with the first problems becoming apparent in the 1950's (Elton 1958). Accelerating infestations have only been occurring over the last 30 - 60 years in New Jersey (coincident with dramatic increases in the deer herd) with our most serious invasive species originating from areas with similar temperate climates (i.e., Europe and Asia).

Plants - In addition to being less palatable to deer, invasive plant species appear to have left behind many of their native pests and pathogens, which provide them additional benefits. In general, invasive plants are 'weedy' - maturing quickly, producing large seed crops, and having tolerance to a variety of disturbed or human-altered growing conditions. Overall, there are nearly 1,000 non-native plants in New Jersey. There are currently 35 widespread invasive plants and 101 emerging or potentially invasive plants in New Jersey (see New Jersey Invasive Species Strike Team). Unfortunately, the rate of new plant introduction continues to rise. Snyder and Kaufman (2004) estimate fifty new plant introductions to New Jersey over the last twenty-five years (these are species with individuals growing in natural or semi-natural areas outside of human cultivation). There are no estimates of the area infested by invasive plants in New Jersey, but it is likely that hundreds of thousands of acres are impacted.

Some of our most notorious invasive plants include Japanese Barberry, Japanese Stiltgrass and Garlic Mustard. Although these widespread species cause severe harm, they are likely to be significantly reduced through ecological control exerted by taller, shade tolerant native species if deer populations are reduced. Among the emerging invasive species, a new class of invasive species is more threatening to forests than our existing invasives. These new species would be resistant to ecological control by native species because they are very tall (15- 20 feet), shade tolerant (can establish under closed forest canopy) and produce large amounts of bird dispersed seed capable of quickly reaching new locations. The five most troubling species are Oriental Photinia, Common Buckthorn, Siebold's Viburnum, Linden Viburnum (now considered widespread) and Japanese Aralia.

Animals - Invasive animals also cause significant harm to native ecosystems. There are currently 21 widespread invasive animals and 23 emerging or potentially invasive animals in New Jersey (see New Jersey Invasive Species Strike Team). Our most widespread invaders (with impacts in parentheses) include: several earthworm species (all earthworms in New Jersey are non-native and severely alter native soils), Brown-headed Cowbird (nest parasite of many birds including forest interior birds - impacts are highest in fragmented forests), Feral Cats (kill large numbers of birds), European Starling (nest competition, primarily in human-dominated areas), Asian Tiger Mosquito (human pest and unknown ecological damage), Rusty Crayfish (alter aquatic communities), Asiatic Clam (impact aquatic systems), and Red-eared Slider (competes with native turtles, especially painted turtles).

The most troubling emerging or potentially invasive species include Feral Hog, Zebra and Quagga Mussels, Mute Swan, and Nutria, which all cause significant damage in the region. Feral Hogs have been noted in several locations across New Jersey with a significant population in Gloucester County that is has been targeted for eradication by the Division of Fish & Wildlife. This species causes severe harm to forest communities in other parts of eastern North America and is a considerable new threat to New Jersey. Zebra and Quagga Mussels cause significant harm to freshwater systems (zebra mussel has been documented in eastern Pennsylvania). Large populations of Mute Swan impact native waterfowl populations and Nutria (not yet present in New Jersey) compete with native wildlife and alter wetland communities.

Pests and Pathogens - Invasive pest and pathogens have the potential to radically alter plant and animal communities. There are currently 12 widespread invasive pests & pathogens and 20 emerging or potentially invasive pests & pathogens in New Jersey (see New Jersey Invasive Species Strike Team). Some of the most notorious invaders include Chestnut Blight, Hemlock Wooly Adelgid and Gypsy Moth. Chestnut Blight has reduced the once dominant American Chestnut to a transient understory tree that rarely produces fruit, Hemlock Wooly Adelgid has killed over half of the state's Eastern hemlocks (ca. 13,000 acres destroyed) with many remaining trees in poor health, and Gypsy Moth periodically ravages oaks leading to localized death of mature trees (including many 300+ year old trees at Hutchinson Memorial Forest). The Gypsy Moth is the subject of an intensive treatment program that utilizes a bacterium called *Bacillus thuringiensis* to mitigate their impacts and they are also partially controlled by a naturally occurring fungus. The Gypsy Moth Suppression Program consists of a voluntary cooperative between the NJ Department of Agriculture, US Department of Agriculture, NJ Department of Environmental Protection, county agencies and municipalities. Treatments are performed via aerial spraying. While control of pests and pathogens are uncommon, the intensive work on Asian Long Horned Beetle has led to its eradication in New Jersey.

Other important widespread invasive pathogens include Dutch Elm Disease (continuing to cause damage, but mature American Elm and Slippery Elm are still common), Beech Bark Disease (caused tree death throughout the state, remaining trees appear to be mostly immune) and Dogwood Anthracnose (causes sudden death of infected plants, but many plants are not impacted).

There are a number of emerging and potential pests and pathogens that may impact New Jersey. Emerging species already present in New Jersey include Viburnum Leaf Beetle (discovered in 2009, has potential to severely impact species such as maple-leaved viburnum, arrowwood, and other viburnums as evidenced in New York state over the past 10 years) and Bacterial Leaf Scorch (BLS). BLS may infest species within the red oak group (e.g., red oak, scarlet oak, black oak, pin oak). Currently, BLS is associated with street trees and other ornamental plantings (40% of recently tested trees were infested across the state) but spread into more natural settings appears to be occurring (J. Arsenault, personal communication). Ultimate impacts of BLS in natural areas are unknown, but the risk should be considered moderate at this time. Sudden Oak Death (SOD) is also a significant potential threat. The NJ Department of Agriculture was quick to respond to the unintentional introduction of SOD in Cape May in 2004 (introduced via contaminated nursery stock from California). Surveys were conducted for SOD and no infections have been found in wild plants, but there is continued threat of additional introductions to New Jersey. Other potential threats include Pine Flat Bug, Asian Gypsy Moth, Eurasian Nun Moth, Dutch Elm Disease 2, Phytophthera Root Rot, European Oak Bark Beetle, and two species of Ambrosia Beetle.

Unfortunately, Emerald Ash Borer has become established in New Jersey and its impacts are widespread. While a biological control agent (parasitic wasp) is being released currently, it is likely that New Jersey will lose over 90% of its ash trees even if the control agent eventually becomes effective. The latest insect invader, Spotted Lantern Fly, has spread across New Jersey in only several years. This species has a broad diet but requires the invasive Tree-of-Heaven to complete its lifecycle. Impacts on natural systems have not yet been completely realized at this point in time but local impacts include killing of vegetation below Tree-of-Heaven and grape species as the insect releases honeydew that fosters growth of black sooty mold.

Overview of Invasive Species Management - The underlying philosophical context for invasive species management is the obligation to counteract negative human impacts on natural systems, which is often referred to as "stewardship". The guiding principle of stewardship is fostering health of native plant communities that support our flora and fauna, which is indirectly accomplished through the management of invasive species. Management of invasive species is generally achieved through targeted control

measures that minimize, but do not eradicate, particular invasive species. Eradication within pre-defined boundaries should only be considered a valid goal when populations are relatively small, and the threat of continued spread is significant. Eradication should also be considered at 'showcase' lands. In all cases, invasive species management should aim to stimulate native plant communities to resist infestation and minimize the use of pesticides and any other intervention. However, human impacts on natural systems are diverse and perpetual, which will necessitate continuing stewardship of natural lands within the context of a human-dominated environment in order to support healthy native plant and animal communities.

There are two general approaches related to invasive species management. These involve a species-led approach or a habitat-led approach. A species-led approach should be employed when an invasive or potentially invasive species can either be eradicated or contained to reduce impacts across an entire property or to minimize spread onto surrounding areas. This approach is warranted for invasive species that are emerging locally or regionally and for widespread invasive species with limited distribution at a particular property.

A habitat-led approach should be employed when conservation values within a defined area are threatened by invasive species that are widespread throughout the region and the Reservation. This approach involves holistic strategies to promote native plant species assemblages that reduce overall invasive species cover through direct competition for light and soil nutrients. The ultimate goal is to foster native plant communities that resist future infestations.

The management of invasive species can be classified into five broad methods referred to as mechanical, chemical, biological, cultural and ecological control (Table 1). Each control method utilizes multiple techniques and control methods may be used alone or in combination depending upon the resource to be protected and practical constraints (Table 2).

Mechanical control involves physical removal or cutting of invasive species. In the past, many groups performing invasive species control relied entirely on mechanical methods. Although mechanical methods can be the most appropriate choice in limited situations, many groups have abandoned this option because progress is exceedingly slow, and methods are often ineffective.

Chemical control is the most commonly used method. It can be used in concert with mechanical control (e.g., cutting plants and applying herbicide to the stump) or alone (e.g., basal bark applications). However, herbicide use to control invasive species should be judicious to avoid impacts to non-target plants and animals. In all cases, herbicide use should involve the most benign formulations and application methods that effectively control the invasive species being treated.

The application of pesticides is regulated by the NJ Department of Environmental Protection - Pesticide Control Program (PCP). Lead staff members within the University involved with the application of herbicides must become 'commercial pesticide applicators', which requires attendance in a one-day course on pesticide safety, passing PCP's core exam and at least one PCP category exam and completing 40 hours of on-the-job training for each category of pesticide application. There are two categories that cover any potential applications in natural areas and stewards would be required to pass both category exams along with the core exam. These categories include Category 2: Forest Pest Control and Category 5: Aquatic Pest Control (required for wetland applications).

Additional staff or seasonal interns may opt to become 'certified pesticide operators', which requires attendance in a one-day training course on pesticide safety and receipt of 40 hours of on-the-job training for each category of pesticide application. Operators are not required to pass any examinations and must be directly supervised by a certified pesticide applicator. According to current regulations, direct

supervision beyond the 40-hour on-the-job training consists of operators being within “very timely voice contact” and within “three travel hours by land”. Staff members, interns or volunteers that are not certified applicators or operators may still apply herbicides if a certified applicator is always physically present and, in the line-of-sight of the non-certified staff member or volunteer.

The PCP also requires a permit for any wetland applications of pesticides. Currently, this involves a simple reporting form and an associated $75 fee. In some cases, the PCP may require an additional permit from the NJ Department of Environmental Protection - Division of Land Use when control work is deemed to significantly alter the vegetative structure of a wetland (e.g., removal of significant invasive shrub cover to promote an herbaceous wetland).

Multiflora Rose is very prevalent on the Property,
but Rose Rosette Disease is beginning to kill plants growing in sunny areas

Table 1. Description of Invasive Plant Control Methods

Control Method	Description	Pros	Cons	Notes
Biological	Introduction of a biocontrol agent (e.g., insect, pathogen) from the invasive species' native range	Dramatic reduction in abundance with minimal costs; minimal accessibility issues	Limited number of invasive species have agents	Requires extensive resources to provide effective host-specific agents; Numerous federal regulations provide significantly reduced risk of impacts to non-targets species
Mechanical	Physical removal of all or portions of an invasive species	No requirement for specialized training; can be performed by volunteers	Very labor intensive; may require specialized equipment; site accessibility issues, impractical for large infestations; re-sprouting or further invasive species dissemination may occur	Common techniques include mowing, cutting, pulling and girdling
Chemical	Application of herbicide to all or portions of a plant	Most effective and efficient method in most cases; trained staff can be assisted by volunteers	Labor intensive; site accessibility issues; requires specialized training/license and equipment; may require repeated applications for more difficult species	Common applications include foliar, cut stump, basal bark and injection; Mechanical and chemical controls may be combined for cut stump and hack-and-squirt methods
Cultural	Removal of invasive species through broad land use activities	Very cost effective	Does not apply well to forest habitats	Primarily applies to agricultural or horticultural systems, but may apply to the maintenance of early successional natural systems including grasslands; Techniques include prescribed fire and prescribed grazing
Ecological	Allowing natural ecological processes (e.g., competition for light and soil resources, predator-prey relationships, etc.) to reduce invasive species over time	Very cost effective; utilizes natural processes	May not occur in many systems due to persistent or continuing human impacts (e.g., overabundant deer, continual physical disturbance, habitat fragmentation, etc.)	Primarily applies to forest systems; As an example, very strong anecdotal evidence suggests that overabundant deer facilitate infestations by Japanese Stiltgrass and other invasive species in forests by removing the native shrub layer

Table 2. Specific Control Techniques by Invasive Plant Class

Invasive Species Class	Suggested Treatment Techniques [1]	Notes
Large tree	Basal Bark, Girdling or Harvesting	May be combined with herbicide application to girdled area
Large shrub / small tree	Basal bark, Hack-and-Squirt, Cut Stump, Girdling	Mowing may be used as a pre-treatment to reduce plant size prior to chemical treatments
Small shrub / tree sapling	Basal Bark, Foliar Spray, Cut Stump, Pulling	Mowing may be used as a pre-treatment to reduce plant size prior to chemical treatments; Prescribed Fire or Prescribed Grazing may be used in grassland habitat
Large vines	Basal Bark, Cut Stump, Hack-and-Squirt	Many vine species have extensive root systems that require herbicide treatment
Forest herbs, woody seedlings and small vines	Foliar Spray, Pulling	Mulching may be utilized in garden beds or other human-modified areas

Biological control involves the purposeful introduction of an insect or pathogen (biocontrol agent) that attacks an invasive species. The biocontrol agent is usually native to the same point of origin as the invasive species. Biological control is the most effective treatment technology for the limited number of invasive species where biocontrol agents have been developed. Biological control has had notable success stories and notorious failures. For example, the non-native Indian mongoose was released to control non-native rats (European and Asian) in sugarcane plantations in the West Indies. The mongoose was only partially effective (only controlled the Asiatic rat), but proceeded to consume native birds, amphibians, and reptiles and ten species were driven to extinction. They also preyed upon domesticated poultry. Finally, the mongoose became a vector of infectious diseases such as rabies. The total economic cost of the biocontrol agent approaches $50 million dollars per year (Pimentel et al. 2005). Notable success stories include the control of alligator weed (New Zealand, Australia, US), mist flower (Hawaii), nodding thistle (New Zealand), prickly pear (Australia), ragwort (New Zealand) and St. John's wort (New Zealand, Canada). In New Jersey, biological control of purple loosestrife has been remarkably effective toward eliminating persistent infestations, making loosestrife a small component of plant communities with only transient outbreaks that are quickly tamped down. Modern biological control involves thorough testing for 'host specificity' (making sure that the newly released biocontrol agent does not harm anything but the invasive species being targeted). This does not guarantee unintended consequences but provides a reasonable reduction of risk that is assumed to be lower than the risk of damage known to occur through the unchecked spread of the targeted invasive species.

Biological control agents for Mile-a-Minute were introduced by the New Jersey Department of Agriculture in 2007 and again in 2013. They have successfully dispersed throughout the state but have yet to have significant impacts on the plant population. Researchers are developing a biocontrol agent for garlic mustard, which is one of New Jersey's worst invasive species (Van Driesche et al. 2002). Research to determine natural enemies of garlic mustard began in 1998. Five weevil species and one flea beetle species were selected as potential biocontrol agents based upon field observations of host specificity and extent of damage created on garlic mustard in its native range. Researchers are currently in the process of performing laboratory tests of host specificity that includes related native species and agricultural crops in the mustard family (Brassicaceae). In addition, studies will be conducted to determine which biocontrol agents or combination of agents may lead to the greatest impacts on garlic mustard. Some of this research will be conducted during field trials in garlic mustard's native range, while others will occur under

laboratory conditions. All testing will be done using widely standardized techniques and following guidelines established in the literature and by the U.S. Department of Agriculture.

Cultural control is similar to the concept of agricultural best management practices but can be applied to early successional natural systems (e.g., grasslands, meadows). There are numerous practices that could have the effect of reducing invasive species as well as native woody species. These practices could involve planting native warm season grasses, prescribed fire, prescribed grazing and elimination of hedgerows to promote grassland or meadow plant communities that sustain themselves with minimal use of mowing and herbicide application. Prescribed fire can be an effective technique to maintain grasslands and the use of fire for ecological purposes has received attention across the world (Myers 2006 and references therein). The primary benefit of prescribed fire is its combination of cost efficiency and efficacy, especially where native warm season grasses have been established.

Prescribed grazing is defined as the application of a specific kind of livestock at a determined season, duration and intensity to accomplish defined vegetation or landscape goals (Launchbaugh 2006). The benefits of using livestock to control invasive species have been demonstrated for New Jersey's bog turtles (Tesauro 2001). This work primarily involved the use of cows to consume and destroy root mats of invasive species such as Phragmites and purple loosestrife. Another potential application may be the use of goats or other livestock to consume dense thickets of multiflora rose or autumn olive. There are a number of practical considerations (e.g., cost associated with fencing materials), but targeted grazing may be the best option for land managers under certain conditions.

Ecological control of invasive species refers to the reduction of invasive species through competitive interactions with native species. Strong anecdotal evidence of other sites in New Jersey (e.g., portions of Cushetunk Mountain, Stephens State Park, Wawayanda State Park and Ted Stiles Preserve at Baldpate Mountain) indicate that a healthy native forest can ***resist and reverse*** infestations even when invasive species are located nearby or within the forest (invasive species may be restricted to highly disturbed trail edges without proliferating in the forest interior).

Although the removal of invasive species by any method has the implicit goal of fostering native species that will resist future infestations, there are a variety of factors that limit native species ability to exert ecological control. The single largest factor that can be locally remedied is overabundance of white-tailed deer.

Altered Soils from Past Agricultural Use

Natural plant communities growing on former agricultural areas are often beset with infestations of invasive species due to degradation of soils. It is not uncommon to find clear demarcations of infestations in forest habitat (e.g., one side of stone wall or stream is severely infested while the other side is minimally infested). Anecdotally, these demarcations are correlated with former agricultural areas as shown in 1930 historical aerial photography. Presumably, areas showing forest cover in 1930 had never been plowed. It appears reasonable to assume that formerly tilled areas are much more susceptible to invasion than untilled areas.

Native forest soils consist of a series of layers. The "O Horizon" is the top layer and consists of fresh and incompletely decomposed organic matter (i.e., leaves and humus). The next layer is the "A Horizon", which consists of mineral soil mixed with organic material leached down from the O Horizon. The remaining horizons (E, B and C) are defined by chemical leaching and accumulation of minerals over time and contain little or no organic material. Bedrock is located under the C Horizon.

Formerly tilled agricultural soils are quite different than native soils. In general, all soil horizons within one foot of the surface have been mixed into a uniform and unnatural soil horizon. In addition, traditional agricultural activities (e.g., repeated tilling, application of lime and phosphorous, utilization of heavy machinery) create long-term soil changes including loss of organic matter, elevated pH, increased amounts of calcium and phosphorous, and compaction from machinery causing poor water infiltration. These changes also induce fundamental changes in nitrogen cycles and composition of soil microorganism species composition. All of these changes have implications for seed germination and root growth. Although many common native species can grow on these altered soils, it appears that weedy invasive species are most aggressive under these conditions.

The impact of earthworms is also associated with former agricultural activity, but adjacent unplowed forest soils can also be infested. Over time, earthworms mix and eliminate the topsoil horizons and virtually eliminate the O Horizon and change soil microorganism species composition. In addition to changing physical properties of the soil (i.e., removing the O Horizon), earthworms change the natural nitrogen cycle. The result is the conversion of nitrogen into a form more readily used by plants, but this increased availability also increases leaching of nitrogen out of the soils. In addition, this change in nitrogen availability causes a shift in soil microorganisms from being dominated by fungi to being dominated by bacteria. This change may impact roots of many native plants that can be physically connected to particular soil fungi (called mycorrhizal fungi) in a symbiotic relationship that allows plants to absorb particular nutrients from the soil.

Suspected relationships and impacts are presented in Figure 5. Actual data showing changes in forest and untilled soil measured in Hopewell Township, Mercer County, New Jersey are presented in Figure 6.

The combined impacts of past agricultural tilling, alone or in concert with changes induced by invasive earthworms, are profound. However, it is important to note that even though impacted forests may not achieve perfect health, substantial improvements in most New Jersey forests can be obtained by reducing deer browse pressure from native plants that have the ability to survive these altered soil conditions.

Figure 5. Suspected Impacts of Past Agricultural Tilling

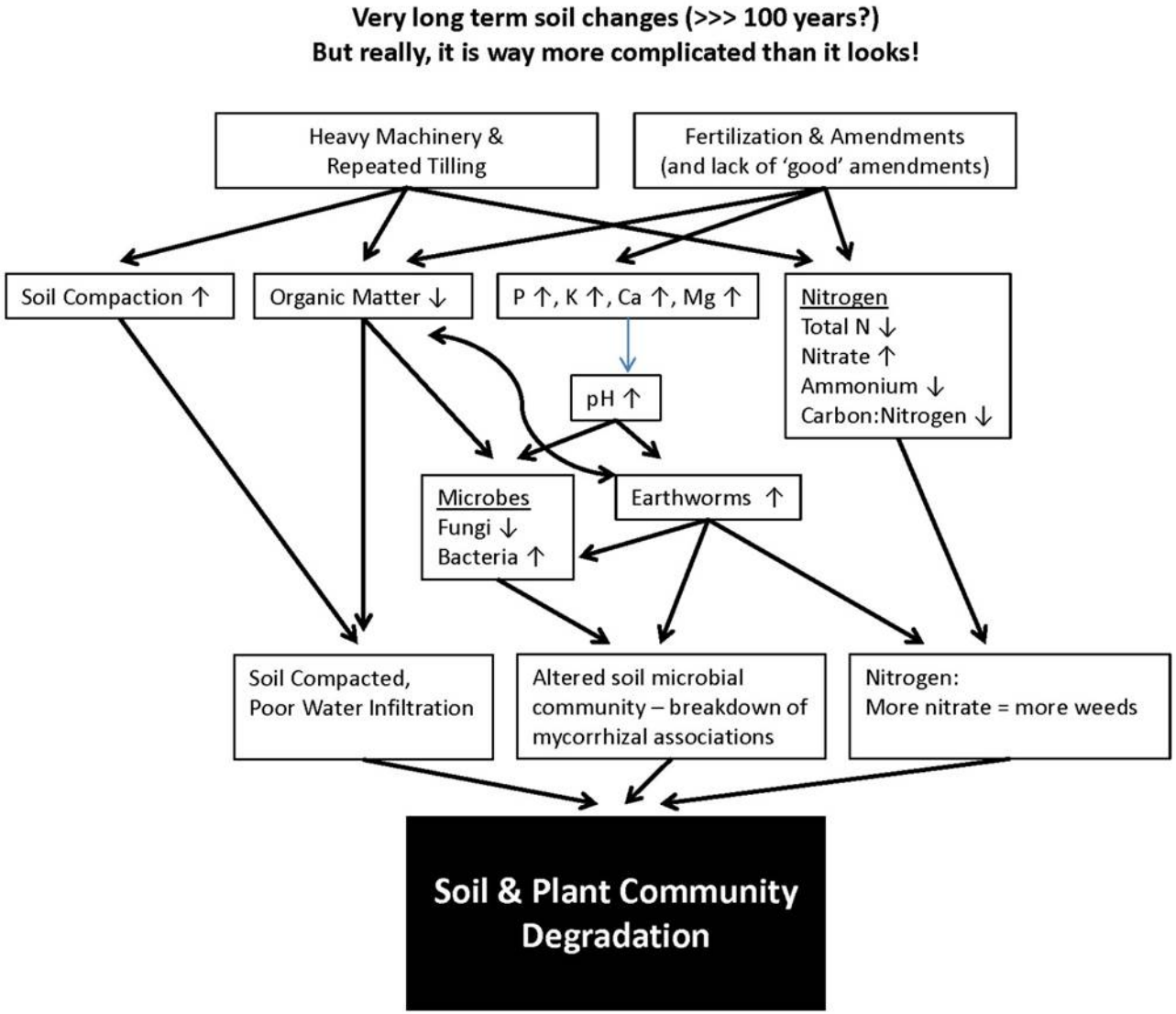
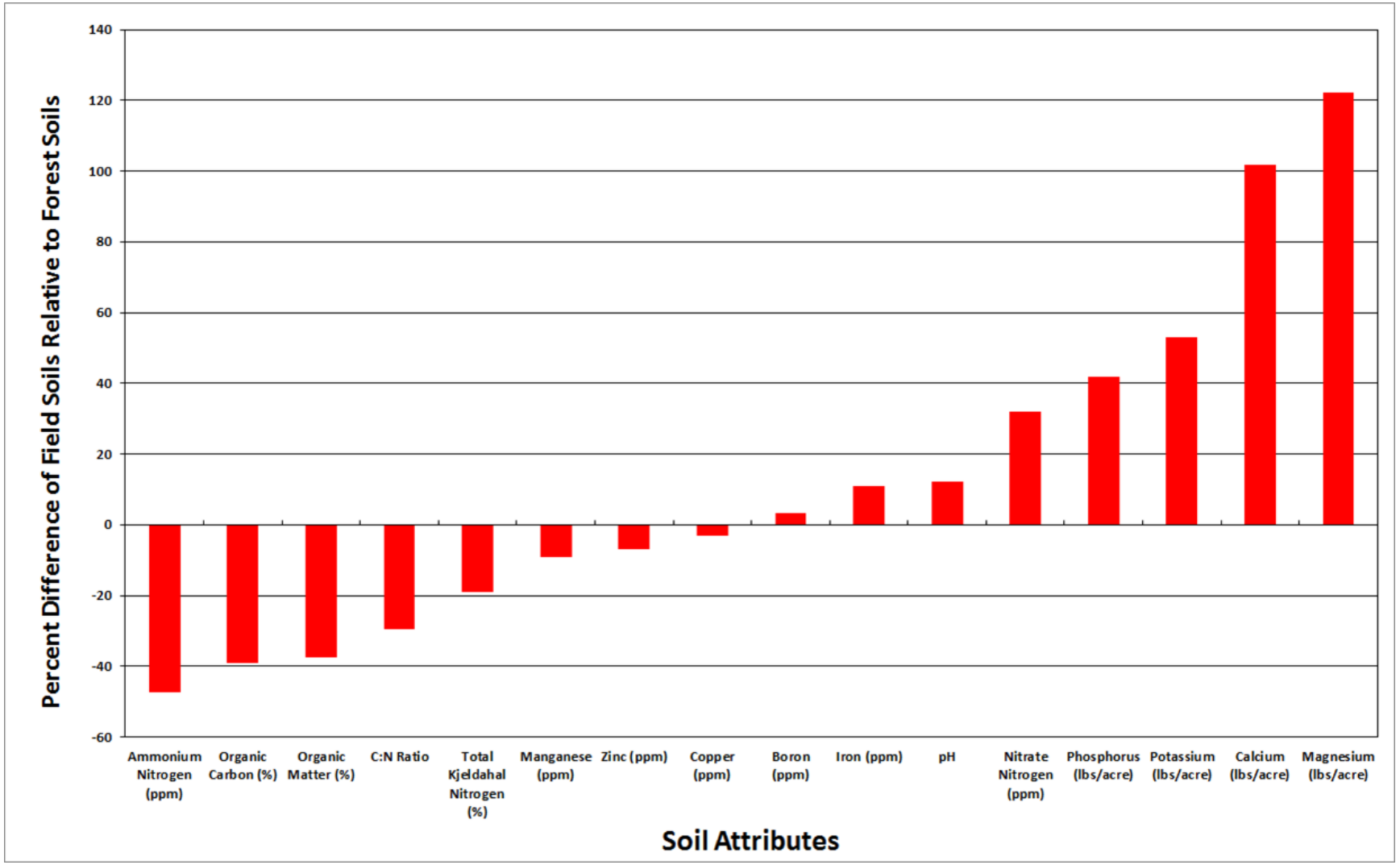


Figure 6. Measured Chemical Changes in Soils from Tilled and Untilled Soils



Stewardship Context

Stewardship activities must consider the context of the Property to maximize effectiveness. This plan section considers physical features and land cover (both historic and current).

Physical Features

Geology – The Property occurs on the Stockton Formation with a small amount of Lockatong Formation in the northern portion of the Property (currently all developed land). The Stockton Formation includes sandstone, mudstone, silty mudstone, argillaceous siltstone and shale. Table 3 provides a summary of the bedrock geology and Map 2 depicts bedrock distribution.

The topography within the Property is generally flat to gently rolling with elevations ranging from 70 to 120 feet above sea level. The steepest areas on the Property occur between Faculty Road and Carnegie Lake (east of Washington Road) and a narrow steep strip between Washington Road and the stadium (north of Faculty Road). Topography is depicted in Map 3.

Table 3. Bedrock Geology Summary

Name	LITHOLOGY	Acres	Percent of Property
Stockton Formation	sandstone, mudstone, silty mudstone, argillaceous siltstone, and shale	1215.3	96.2
Lockatong Formation	dolomitic or silty argillite, mudstone, sandstone, siltstone, and minor silty limestone	48.3	3.8
Totals		**1263.6**	**100**

Soils – There are 28 unique soil types within the Property. The three most predominant soils are Udorthents, bedrock substratum, 0 to 8 percent slopes (39%), Galestown sandy loam, 0 to 5 percent slopes (15%) and Udorthents, gravelly substratum, 0 to 8 percent slopes (5%). The majority of unique soil types (20) are minor (each < 3% of the Property). A summary of soil types is provided in Table 4 and their distribution is depicted in Map 4.

The Udorthents, bedrock substratum consists of loams to approximately 30 inches and is underlain by bedrock. These relatively shallow soils are primarily found in developed areas in the northern and northwestern portions (golf course) of the Property. The Galestown sandy loam is primarily associated with agricultural fields on the Property.

Areas containing the most mature forests (see below) are associated with Bucks silt loam, 6-12 percent slopes, eroded (e.g., Elm Drive Woods and steep area located along western side of Washington Road and north of Faculty Road), Bucks silt loam, 6-12 percent slopes (forest along southern portion of Alexander Creek) and Urdorthents, gravelly substratum, 0 to 8 percent slopes (narrow band of forest north of Carnegie Lake and East of Washington Road).

Table 4. Soil Type Summary

Soil Symbol	Description	Acres	Percent of Property
BHRSB	Birdsboro sandy subsoil variant soils, 2 to 6 percent slopes	2.3	0.2
BHSGB	Birdsboro gravelly solum variant soils, 0 to 6 percent slopes	25.4	2.0
BoyAt	Bowmansville silt loam, 0 to 2 percent slopes, frequently flooded	30.8	2.4
BucB	Bucks silt loam, 2 to 6 percent slopes	56.8	4.5
BucB2	Bucks silt loam, 2 to 6 percent slopes, eroded	32.8	2.6
BucC	Bucks silt loam, 6 to 12 percent slopes	8.3	0.7
BucC2	Bucks silt loam, 6 to 12 percent slopes, eroded	60.1	4.8
DouC	Downer-Urban land complex, 5 to 10 percent slopes	0.02	0.002
DOZA	Doylestown and Reaville variant silt loams, 0 to 2 percent slopes	8.8	0.7
EvgB	Evesboro loamy sand, 0 to 5 percent slopes	0.04	0.00
GafB	Galestown sandy loam, 0 to 5 percent slopes	191.5	15.2
GASB	Galloway variant soils, 0 to 5 percent slopes	8.3	0.7
LbhB	Lansdale sandy loam, 2 to 6 percent slopes	54.6	4.3
LbnC2	Lansdale channery loam, 6 to 12 percent slopes, eroded	48.7	3.9
LbnD2	Lansdale channery loam, 12 to 18 percent slopes, eroded	15.2	1.2
MakAt	Manahawkin muck, 0 to 2 percent slopes, frequently flooded	9.7	0.8
MbaAt	Marsh, fresh water, 0 to 2 percent slopes, frequently flooded	8	0.6
MbpA	Matapeake loam, 0 to 2 percent slopes	36.1	2.9
MBYB	Mattapex and Bertie loams, 0 to 5 percent slopes	1.2	0.1
OthA	Othello silt loams, 0 to 2 percent slopes, northern coastal plain	2.3	0.2
PHG	Pits, sand and gravel	2.2	0.2
PmmwA	Plummer sandy loam, very wet, 0 to 2 percent slopes	0.7	0.1
REFA	Readington and Abbottstown silt loams, 0 to 2 percent slopes	6.3	0.5
RorAt	Rowland silt loam, 0 to 2 percent slopes, frequently flooded	0.2	0.02
SacB	Sassafras sandy loam, 2 to 5 percent slopes, Northern Coastal Plain	25.1	2.0
UdbB	Udorthents, bedrock substratum, 0 to 8 percent slopes	488.8	38.7
UdgB	Udorthents, gravelly substratum, 0 to 8 percent slopes	64.5	5.1
WATER	WATER	74.8	5.9
Totals		**1264**	**100**

Water – Waterbodies and vernal pool habitat is depicted on Map 3. Carnegie Lake, dividing the northern and southern portions of the Property, is the dominant water feature, covering 56 acres. The Stony Brook flows south from the lake with several tributaries draining from the north into the lake. The largest Stony Brook tributary is Alexander Creek, which flows through the golf course, but is also surrounded by a band of mature forest as it enters Stony Brook. The Millstone River branches southward from Carnegie Lake and forms the southeastern boundary of the Property. Riparian habitats along the lake and Millstone River serve as wildlife corridors (Map x).

There is one documented potential vernal pool habitat area on the Property, located south of the golf course and neighboring lands off of the Property.

Land Cover – Historic and Current

The land use (2015) within five miles of the Property is summarized below (Table 5 and depicted in Map 5). Approximately 50% of the area is developed or barren, with 13% cover as agricultural lands. The high percentage of developed lands creates ongoing challenges toward the stewardship of the Property (e.g., deer refugia, sources of invasive species). The majority of natural cover is represented by forest habitat, with small amounts of shrubland and meadow habitats. The Property contains a greater amount of developed land (60%) and a similar amount of agricultural land (14%) relative to its surrounding landscape (See Map 6). Natural cover represents about 26% (327 acres) of the Property.

Table 5. Reservation and Surrounding Area (5 Mile Radius) Land Use / Land Cover Types (2015)

Type	Property Acres	% of Property	5-Mile Radius Acres	% of 5-Mile Radius
Urban	761.3	60.3	24719.3	49.2
Barren	0.0	0.0	617.2	1.2
Agriculture	175.0	13.9	6266.6	12.5
Water	89.2	7.1	1138.0	2.3
Forest - Coniferous - Upland	2.6	0.2	268.5	0.5
Forest - Coniferous - Wetland	0.0	0.0	3.2	0.0
Forest - Deciduous - Upland	92.2	7.3	6592.7	13.1
Forest - Deciduous - Wetland	45.1	3.6	6407.4	12.7
Woodland - Coniferous - Upland	1.6	0.1	84.0	0.2
Woodland - Coniferous - Wetland	0.0	0.0	0.0	0.0
Woodland - Deciduous - Upland	39.5	3.1	887.6	1.8
Woodland - Deciduous - Wetland	0.0	0.0	0.0	0.0
Shrubland - Coniferous - Upland	0.0	0.0	142.6	0.3
Shrubland - Coniferous - Wetland	0.0	0.0	24.7	0.0
Shrubland - Deciduous - Upland	26.5	2.1	1385.3	2.8
Shrubland - Deciduous - Wetland	6.0	0.5	649.1	1.3
Meadow - Upland	21.7	1.7	463.7	0.9
Meadow - Wetland	2.7	0.2	615.1	1.2
Totals	**1263.4**	**100**	**50265**	**100**

The 1930 aerial photography (Map 8) shows that the Property was largely developed or agricultural. Significant natural cover (non-forest) occurred along the edges of waterways, but mature forest patches accounted for less than 8% of the total cover. A total of 96 acres of mature forest was divided into 15 patches (Average = 6.4 acres, Minimum = 0.6 acres, Maximum = 28.4 acres). Current aerial photography showing forest areas are provided on Map 10.

Mature forests (present in 1930 and currently exist) are associated with several soil types (see above) and tend to be areas with greater slopes, rocky soils, and/or reduced soil depth to bedrock. Historically, these areas were least desirable for crop production but may have been logged for firewood or utilized for grazing. However, the age of multiple trees in Elm Drive Woods suggests that some large trees have been present for hundreds of years.

The overlap of 1930 and current forests is summarized in Table 6. Blah, blah.

Table 6. Historic and Current Forest Cover

Year	Acres	% of Property
1930	96	7.6
2020		0.0
1930 and 2020		0.0

This pattern of land use requires careful consideration toward the development of stewardship recommendations. For example, former agricultural lands that have developed into forests are now heavily infested with invasive species, while the original forest area seen in 1930 presents the best opportunity to maintain and improve forest health (e.g., Elm Drive Woods).

Current shrublands and meadows are unlikely to develop into healthy forest habitat, possibly for many hundreds of years or longer as the soils slowly recover. This problem is exasperated but overabundant deer and would be significantly ameliorated by deer herd reduction allowing native plants to compete against less palatable invasive plants, even on altered soils.

Protected Lands – There are numerous patches of protected open space within five miles of the Property, the majority existing as natural islands in a developed landscape (Map 11). These lands include Institute Woods, Mercer County Park, Plainsboro Preserve and numerous small parks. While each of these natural lands are significant, connections between them are generally lacking with the exception of the D&R Canal Park and adjacent parks that run through the middle of the Property on either side of Carnegie Lake.

Striking geological features occur throughout the Reservation

Section II. Conservation Values

Introduction

This section provides conservation values within the Property. It includes landscape-scale values provided through review of information available from the Endangered and Nongame Species Program and Natural Heritage Program of the NJ Department of Environmental Protection. This section provides results of ecological community mapping and botanical survey performed throughout the Property.

The primary habitat conservation values include forest, meadow, shrubland habitats as well as riparian wildlife corridors. Forest communities serve as the basis for a broad range of common plant and animal species typical of the Eastern United States, providing stopover feeding opportunities for Neotropical migrant birds and nesting habitat for many species. There is also great potential for quality meadow and shrubland habitat that would support a large variety of birds and pollinators. Wildlife corridors are especially important in the highly developed central New Jersey region.

Landscape-scale Values

The Landscape Project (Version 3.3) is a product of the New Jersey Department of Environmental Protection, Division of Fish & Wildlife, Endangered and Nongame Species Program (ENSP). The Landscape Project prioritizes sites based upon the biodiversity significance of animal species utilizing patches of habitat. Habitat patches are ranked from 5 (highest) to 1 (lowest). Patch ranks are based upon the level of rarity of the rarest species known to occur within the patch (Note: A single habitat patch may contain multiple species with various ranks, but the overall patch ranking is derived from the occurrence of the species with the highest rank.). A rank of '5' signifies patches containing federally endangered or threatened species, Rank 4 patches contain state endangered species, Rank 3 patches contain state threatened species, Rank 2 patches contain state species of concern, and Rank 1 patches have suitable habitat for rare animals, but do not contain confirmed occurrences. Developed areas are not ranked as potential wildlife habitat.

Patch ranks on the Property are depicted in Map 12 and summarized in Table 7. Habitat patches that intersect with the Property are primarily Rank 1 or 4. Rank 4 lands are occupied habitat for Bald Eagle (state endangered) and Great Blue Heron (special concern). These areas are associated with open water and riparian habitats of Carnegie Lake and the Millstone River. A small Rank 3 area is occupied habitat for Red-headed Woodpecker. It is located east of the intersection of Alexander Creek and Stony Brook in a park-like setting along Alexander Road. Small patches of Rank 2 areas occur along Alexander Creek and small ponds used as foraging areas for Great Blue Heron (special concern).

The Landscape Project also characterizes habitat patch sizes, which are shown in Map 13 and summarized in Table 8. The largest patch is associated with Rank 1 habitat consisting of agricultural fields. The next largest patch is an unbroken portion of Carnegie Lake. The largest natural terrestrial patch is less than 15 acres and includes Elm Drive Woods. While the Property cannot harbor area-demanding species such as Barred Owl, it can provide significant stop-over habitat for migrating birds and other species of birds, reptiles and amphibians as well as providing significant riparian wildlife corridors.

Table 7. Landscape Project Patch Rank Summary

Rank	Acres	% of Property
5	0	0
4	180	14
3	5	0.4
2	6	0.5
1	185	15
Unranked	888	70
Totals	**1264**	**100**

Table 8. Landscape Project Patch Size Summary

Patch Size	Number of Patches	Total Property Acres within Patch Size Class	% of Property
< 10 acres	135	147.1	12
10-25 acres	10	107.8	9
25-50 acres	3	59.9	5
50-100 acres	1	61.7	5
100-1000 acres	0	0	0
Not Defined	N/A	887.5	70
Totals	**149**	**1264**	**100**

The New Jersey Natural Heritage Program (NJNHP) is part of the New Jersey Department of Environmental Protection, Division of Parks and Forestry, Office of Natural Lands Management. The Heritage Program identifies significant natural lands throughout the state, designating them as Natural Heritage Sites or Macrosites. The Property does not contain any Natural Heritage sites. The Heritage Program also provides a GIS layer consisting of grids covering the entire state and identification of rare species known to occur within the grids. There are two rare plant species occurring in grids that overlap the Property (See Map X). These species include Smooth Hedge-nettle (S3) and Death-camus (state endangered).

The Connecting Habitat Across New Jersey (CHANJ) is a project of the Endangered and Nongame Species Program (ENSP). The project is an effort to make the landscape and roadways more permeable for terrestrial wildlife by identifying key areas and actions needed to achieve habitat connectivity across the state. CHANJ offers two main products including a statewide mapping and a guidance document to help prioritize land protection, inform habitat restoration and management, and guide mitigation of road barrier effects on wildlife and their habitats. Mapping products identify core habitats (largest habitat patches, > 200 acres), stepping stone habitats (smaller habitats from 30 to 200 acres) and corridor habitats that connect core and stepping stone habitats. Corridors are categorized from 1 (easiest wildlife passages) to 5 (more difficult wildlife passages). Finally, road culverts and road segments are identified in places where mitigation efforts would be most beneficial.

The context of the Property relative to core, stepping stone and corridors is depicted in Map X. An important corridor is associated with the Property, it includes Carnegie Lake, the Millstone River and their associated riparian habitats. This corridor serves to connect larger habitat patches to the east, west, and south of the Property.

Ecological Communities

Ecological communities were mapped at the Property from August through October 2020. Communities were mapped through a process of crosschecking between three sources of information, which included field survey, 2015 (2020?) aerial orthophotography, GIS-based 2015 land cover classifications and NJDEP GIS wetland status. Field observations of species present within the canopy, sub-canopy, shrub, and herbaceous layers were recorded and correlated with a 'signature' on aerial photography. Ecological community patches occurring within the Property were assigned one of xx broad types (Table 9); forests and woodlands were further characterized by predominant tree species (Table 10). See Appendix F for raw mapping data for each mapped patch.

There was a total of xxx mapped ecological community patches (See Appendix B) across 1,264 mapped acres. In some cases, adjacent patches with the same ecological community designation were provided separate patch designations because of differences in the mapped invasive species cover, which is often a proxy for differences in past land use and canopy density (former agricultural lands and forests with more open canopies have higher amounts of invasive species). Maps depicting various attributes reported in Appendix B are found in the following maps and summarized in associated tables below:

- Map 14 and Table 9 – Broad ecological communities

  Forests are defined as having > 75% canopy cover, while woodlands are defined by having 25 - 75% canopy cover. Shrublands have < 25% tree canopy and > 50% shrub cover. Meadows have < 50% shrub cover and >75% herbaceous cover.

  Forest and woodland habitats (ca. 85% of Reservation cover) are the dominant ecological communities with shrubland (ca. 3%) and meadow (ca. 1%) communities accounting for lesser, but still significant coverage at the Reservation. Developed lands and water are approximately 9% and 1%, respectively.

Table 9. Broad Ecological Community Type Summary

Broad Habitat Type	Acres	Percent of Reservation
Forest - Upland	1,180	57.9
Forest - Wetland	125	6.1
Forest - Upland (Large Gaps)	24	1.2
Woodland - Upland	397	19.5
Woodland - Wetland	15	0.7
Shrubland - Upland	32	1.6
Shrubland - Wetland	34	1.6
Meadow - Upland	21	1.0
Meadow - Wetland	5	0.2
Water	20	1.0
Developed	187	9.2
Totals	**2,039**	**100**

- Map 15 and Table 10 – Predominant Tree Species of Forest and Woodland Communities

  Forest and woodland communities are variable and different types blend into each other. However, an effort was made to simplify these communities by noting predominant tree species. The most common type was formed by various oak species in combination (e.g., Red, White, Black and Chestnut oaks), which covered 36% of the Reservation. Tulip Poplar was the next most abundant type (23%), followed by American Beech (15%) and Red Maple (13%). Sugar Maple types were also common.

Table 10. Forest and Woodland Predominant Tree Species Summary

Predominant Tree	Acres	Percent of Reservation
American Beech	258	15
Chestnut Oak	25	1
Mixed Deciduous (primarly oak species)	625	36
Red Maple	219	13
Red Oak	28	2
Spruce-Pine (former plantations)	60	3
Sugar Maple	115	7
Swamp White Oak	17	1
Tulip Poplar	392	23
Totals	**1739**	**100**

- Map 16 and Table 11 – Ash Decline

  It is important to note that canopy-level ash trees were mapped across nearly xxx acres on the Property. Over xxx acres exhibiting current ash decline was documented. While ash trees form a portion of the tree canopy on xx% of the Property, ash accounts for more than 25% of the canopy on only x acres. The majority of existing and future ash decline (both related and unrelated to EAB) will occur in forest areas with less than 25% ash canopy. It is expected that all mature ash trees will be eliminated from the Property within the next 5 to 10 years, exasperating current trends that already show significantly increased cover of invasive species following ash loss. This ongoing and worsening problem necessitates intensive deer management to allow native species to compete more effectively with invasive species to avoid significant additional degradation of ecological health.

Table 11. Ash Decline Summary

Ash Cover Category	Current Ash Decline (Acres)	Future Ash Decline (Acres)	Total Ash Decline (Acres)
Absent = 1342			
1-10%	159	82	241
11-25%	140	11	150
26-50%	2	6	8
51-75%	0	0	0
76-100%	0	0	0
Totals	**301**	**98**	**399**

- Maps 17 - 19; Tables 12 - 14 – Understory Cover of Native Shrubs and Regenerating Trees and Native Herb Cover

  Native shrubs and herbaceous species (both vulnerable to deer browse) were relatively low across a majority of the Reservation. Ideally, native woody understory cover in healthy forests would be above 70%. Across New Jersey, native understory cover averages less than 20%. Due to effective deer management at the Reservation, nearly 7% or 136 acres of the Reservation has > 75% native woody understory cover. Additionally, native woody understory cover exceeds the statewide average on nearly 550 acres or 27% of the Reservation. Native tree regeneration was extremely impressive in a number of mapped areas, but native shrubs (e.g., Spicebush) were predominant in locations where native woody understory species were present.

  Native shrub cover was relatively high in shrubland habitat, with greater than 85% of shrubland habitat patches having > 25% native cover. These areas were primarily along Lake Surprise and other wetland patches that likely have limited deer access due to regular inundation.

  Native herbaceous species (wildflowers and grasses) were very sparse throughout the Reservation, especially in forest habitats where most areas had only trace amounts of wildflowers, all showing intense deer browse. Unlike forests, meadows can grow dense patches of native wildflowers (primarily due to the sheer amount of plants) and grasses (unpalatable to deer). There were seven meadow patches with notable native cover (See Map 19 and Table 14).

Umbrella Magnolia, a more southern native species,
appears to be spreading at the Reservation, which is likely due to a warming climate

Table 12. Native Shrub and Tree Understory Cover by Community Type

Community Type	Native Shrub and Tree Cover Category	Acres	Percent of Total Community Type Area
Forest	Absent	305	22.9
Forest	< 1%	242	18.2
Forest	1-10%	160	12.0
Forest	11-25%	164	12.3
Forest	26-50%	196	14.7
Forest	51-75%	127	9.5
Forest	76-100%	136	10.2
Forest - Total		**1329**	**100**
Woodland	Absent	42	10.3
Woodland	< 1%	168	40.9
Woodland	1-10%	109	26.4
Woodland	11-25%	4	1.0
Woodland	26-50%	49	12.0
Woodland	51-75%	39	9.4
Woodland	76-100%	0	0.0
Woodland - Total		**412**	**100**
Shrubland	Absent	6	11.4
Shrubland	< 1%	2	3.8
Shrubland	1-10%	0	0.0
Shrubland	11-25%	0	0.0
Shrubland	26-50%	27	52.9
Shrubland	51-75%	14	27.9
Shrubland	76-100%	2	4.0
Shrubland - Total		**50**	**100**
Meadow	Absent	11	43.9
Meadow	< 1%	7	28.2
Meadow	1-10%	7	27.8
Meadow	11-25%	0	0.0
Meadow	26-50%	0	0.0
Meadow	51-75%	0	0.0
Meadow	76-100%	0	0.0
Meadow - Total		**26**	**100**

Table 13. Native Herbaceous Cover by Community Type

Community Type	Native Herb Cover Category	Acres	Percent of Total Community Type Area
Forest	Absent	105	7.9
Forest	< 1%	968	72.9
Forest	1-10%	127	9.6
Forest	11-25%	128	9.7
Forest	26-50%	0	0.0
Forest	51-75%	0	0.0
Forest	76-100%	0	0.0
Forest - Total		**1329**	**100**
Woodland	Absent	28	6.9
Woodland	< 1%	284	68.9
Woodland	1-10%	98	23.8
Woodland	11-25%	2	0.4
Woodland	26-50%	0	0.0
Woodland	51-75%	0	0.0
Woodland	76-100%	0	0.0
Woodland - Total		**412**	**100**
Shrubland	Absent	6	8.5
Shrubland	< 1%	0	0.0
Shrubland	1-10%	10	14.7
Shrubland	11-25%	21	32.0
Shrubland	26-50%	1	1.7
Shrubland	51-75%	1	2.1
Shrubland	76-100%	27	41.0
Shrubland - Total		**66**	**100**
Meadow	Absent	1	3.4
Meadow	< 1%	0	0.0
Meadow	1-10%	6	27.2
Meadow	11-25%	1	4.4
Meadow	26-50%	0.4	1.9
Meadow	51-75%	0	0.0
Meadow	76-100%	13	63.1
Meadow - Total		**21**	**100**

Table 14. Meadow Habitat Condition Summary

Patch ID	Acres	Type	Invasive Species Detected w/Cover Class	Number of Invasive Species	Maximum Individual Species Cover Category	Sum of All Invasive Cover Categories	Relative Quality Rank	Native Shrub Cover	Native Herbaceous Cover	Recommendations
5	2.8	Meadow - Wetland	Reed Canary Grass (1-10%), Mile-a-minute (<1%)	2	1	1	High	None	75-100%	Very wet area resisting many invasives. Monitor and treat if invasive cover increases.
11	0.4	Meadow - Upland	Mugwort (26-50%)	1	3	3	Moderate	None	26-50%	Very small patch. Treatment is low priority.
81	0.7	Meadow - Upland	Chinese Wisteria (<1%), Mugwort (1-10%)	2	1	1	High	None	75-100%	Most visible meadow area. Treat invasive species utilizing aminopyralid (e.g., Milestone or equivalent). Treatment of dense Mugwort on east and west edged of meadow occurred in 2019. Dense Wisteria on northern meadow boundary requires treatment.
159	1.3	Meadow - Wetland	Japanese Stiltgrass (<1%), Multiflora Rose (<1%)	2	1	2	High	< 1%	75-100%	Little Seeley's Pond. Very wet area resisting many invasives. Monitor and treat if invasive cover increases. Roses expected to succumb to Rose Rosette Disease.
171	0.6	Meadow - Wetland	None	0	0	0	Very High	1-10%	75-100%	Monitor and treat new infestations as necessary.
195	1.7	Meadow - Upland	Mugwort (< 1%), Asiatic Bittersweet (<1%), Glossy Buckthorn (<1%), Chinese Bushclover (<1%). Japanese Honeysuckle (<1%), Morrow's Honeysuckle (1-10%), Multiflora Rose (<1%), Wineberry (1-10%)	8	1	2	High	1-10%	75-100%	High quality meadow with small amount of multiple invasive species. Utlize foliar treatments with triclopyr amine (e.g., Garlon 3A) on herbecous herbs and cut stump treatments with glyphosate (eg., Accord) on woody species.
196	0.6	Meadow - Upland	Mugwort (< 1%), Asiatic Bittersweet (<1%), Glossy Buckthorn (<1%), Chinese Bushclover (<1%). Japanese Honeysuckle (<1%), Morrow's Honeysuckle (1-10%), Multiflora Rose (<1%), Wineberry (1-10%)	8	1	2	High	1-10%	75-100%	High quality meadow with small amount of multiple invasive species. Utlize foliar treatments with triclopyr amine (e.g., Garlon 3A) on herbecous herbs and cut stump treatments with glyphosate (eg., Accord) on woody species.
197	0.8	Meadow - Upland	Chinese Bushclover (75-100%), Mugwort (1-10%)	2	5	6	Low	None	1-10%	Requires complete restoration.
198	0.9	Meadow - Upland	Mugwort (75-100%), Chinese Bushclover (1-10%), Morrow's Honeysuckle (1-10%), Multiflora Rose (1-10%)	4	5	8	Low	None	< 1%	Requires complete restoration.
205	5.9	Meadow - Upland	Autumn Olive (<1%), Chinese Bushclover (11-25%), Japanese Stiltgrass (1-10%), Callery Pear (<1%), Multiflora Rose (<1%)	5	2	3	Moderate	< 1%	75-100%	Requires intenstive spot treatments on Chinese Bushclover and basal bark treatments on Autumn Olive and Callery Pear.
210	0.9	Meadow - Upland	Tree-of-Heaven (<1%), Small Carpgrass (26-50%), Mugwort (26-50%)	3	3	6	Low	None	11-25%	Requires intenstive spot treatments on Chinese Bushclover and basal bark treatments on Tree-of-Heaven.
213	4.1	Meadow - Upland	Mugwort (26-50%), Cool Season Grass (<1%), Common Reed (26-50%)	3	5	8	Low	None	< 1%	Requires complete restoration.
Totals	**20.5**									

- Map 20 and Table 15 – Relative patch quality

  This is a subjective characterization based upon the following attributes: land use history, amount of invasive species cover, amount of native shrub and herbaceous cover and presence of regenerating native trees. The relative quality ranks were 'Very High' or 'High' for about 30% of Property and 'Low' for nearly 50%. Community quality rankings were used to determine strategies in Section IV.

Table 15. Relative Patch Quality Summary

Relative Quality Rank	Acres	Percent of Preserve
Very High	590	28.9
High	59	2.9
Moderate	194	9.5
Low	989	48.5
N/A	207	10.1
Totals	**2,039**	**100**

False Foxglove, a deer resistant native species, growing in meadows at the Reservation

Flora

Fauna

There are nine rare animal species that have been documented on the Reservation (Table 19) through a Natural Heritage database search (Appendix A). Field surveys performed for this plan did not involve rare animal surveys, although a Box Turtle observation was made during the course of botanical surveys by G. Milly.

Stewardship recommendations for these species primarily involve improving the ecological health of habitats required by each species – See Section IV. Further future field investigations may result in species-specific stewardship recommendations.

Many of these species require healthy forest habitat, which occurs on approximately 500 acres at the Reservation. Several species require healthy stream and open wetland habitats that can be found in relatively low quantities at the Reservation (e.g., Longtail Salamander, Great Blue Heron, Snowy Egret, and Wood Turtle). The federally listed Bog Turtle had been found in the Reservation, but current conditions will not support this species (requires hummocky bogs that had occurred along the Blue Brook in the past). Species such as the Long Dash (as well as Wood Turtle and Box Turtle) require open meadow and marsh habitats, which are also found in relatively low quantities at the Reservation.

Monarch Butterflies utilize meadow habitat at the Reservation

Table 19. Rare Animals of the Reservation

Taxa	Location	Common Name	Scientific Name	Global Rank	State Rank	State Status	Last Observed Date	Stewardship Notes
Amphibian	Reservation and Vicinity	Longtail Salamander	Eurycea longicauda	G5	S2	State Threatened	Not Recorded	Encourage healthy stream habitat
Bird	Reservation and Vicinity	Barred Owl	Strix varia	G5	S2B, S2N	State Threatened	Not Recorded	Encourage contiguous forest habitat
Bird	Reservation and Vicinity	Great Blue Heron	Ardea herodias	G5	S3B, S4N	Special Concern	Not Recorded	Encourage healthy open water and wetland habitat
Bird	Vicinity	Snowy Egret	Egretta thula	G5	S3B, S4N	Special Concern	Not Recorded	Encourage healthy open water and wetland habitat
Bird	Reservation and Vicinity	Wood Thrush	Hylocichla mustelina	G4	S1	Special Concern	Not Recorded	Encourage forest health
Invertebrate	Reservation	Long Dash	Polites mystic	G5	S3?	None	Not Recorded	Encourage meadow health (upland and wetland)
Reptile	Reservation	Bog Turtle	Glyptemys muhlenbergii	G3	S1	Federally Listed Threatened, State Endangered	Not Recorded	Unlikely to occur on the Reservation due to lack of suitable habitat
Reptile	Reservation	Box Turtle	Terrapene carolina	G5	S3	Special Concern	2019 (G. Milly)	Encourage forest and meadow health
Reptile	Reservation and Vicinity	Wood Turtle	Glyptemys insculpta	G2	S2	State Threatened	Not Recorded	Encourage healthy stream, meadow, and forest habitats

Vernal Habitat – There is one potential vernal pool habitat area noted in the Landscape Project (See Map 3). The importance of vernal habitat to many amphibians, especially given the significant roadless expanses of habitat within the Reservation, warrants additional surveys to determine vernal habitat presence important for a number of common salamanders (e.g., Spotted Salamanders) and frogs (e.g., Wood Frogs) that require such habitats.

Section III. Conservation Challenges

Introduction

This section describes an evaluation of the two primary threats to ecological health at the Reservation – overabundance of white-tailed deer and invasive species. The impacts of white-tailed deer and the extent and severity of invasive plant species infestations were mapped from May to October 2019. An exemplary deer management program has occurred at the Reservation for over 20 years, but there still was significant ecological damage due to deer overabundance. The scope of the invasive species problem is significant with 57% of the Reservation having severe infestations of one or more species. Approximately 28% of the Reservation was virtually free of invasive species, while approximately 4% was lightly to moderately infested (ca. 10% of Reservation has development as recreational facilities or buildings).

A brief discussion is provided for two additional factors that impact ecological health – relatively small habitat patch size and past agricultural land uses. These factors cannot be remedied but inform stewardship strategies (See Section IV).

Evaluation of White-tailed Deer Impacts

Despite ongoing deer management at the Reservation, large portions of forests at the Reservation show either the "Empty Forest Syndrome" or the "Infested Forest Syndrome" (See Section I). Ecological impacts of white-tailed deer are severe across three-quarters of the Reservation's forests with little understory growth of native trees, shrubs and wildflowers and/or significant infestations of unpalatable invasive species. However, tree regeneration is strong in selected areas and overall cover of native woody understory plants are significant (See Table 12) and notably better than most forests in New Jersey.

Native shrubs and herbaceous species (both vulnerable to deer browse) were relatively low across a majority of the Reservation. Ideally, native woody understory cover in healthy forests would be above 70%. Across New Jersey, native understory cover averages less than 20%. Due to effective deer management at the Reservation, nearly 7% or 136 acres of the Reservation has > 75% native woody understory cover. Additionally, native woody understory cover exceeds the statewide average on nearly 550 acres or 27% of the Reservation. Native tree regeneration was extremely impressive in a number of mapped areas, but native shrubs (e.g., Spicebush) were predominant in locations where native woody understory species were present.

Native shrub cover was relatively high in shrubland habitat, with greater than 85% of shrubland habitat patches having > 25% native cover. These areas were primarily along Lake Surprise and other wetland patches that likely have limited deer access due to regular inundation.

Native herbaceous species (wildflowers and grasses) were very sparse throughout the Reservation, especially in forest habitats where most areas had only trace amounts of wildflowers, all showing intense deer browse. Unlike forests, meadows can grow dense patches of native wildflowers (primarily due to the shear amount of plants) and grasses (unpalatable to deer). There were seven meadow patches with notable native cover (See Map 19 and Table 14).

However, there are opportunities for ecological recovery, especially in forest areas that had never been under agricultural uses. These areas have low levels of invasive species (except for canopy gaps) and directed stewardship activities can begin the restoration process (See Section IV), especially toward fostering growth of native forest wildflowers that are most underrepresented at the Reservation.

A series of photographs with captions are provided below to highlight severe, but variable deer impacts at the Reservation. Despite severe deer impacts across the majority of the Reservation, approximately 25% of the Reservation has healthy native woody understory. Sensitive native wildflowers are suffering throughout the Reservation.

Hundreds of oak seedlings (above) can lead to hundreds of oak saplings (below).

Dense native Spicebush thickets have formed over large areas within Tulip Poplar forests (above) and small patches of lightly browsed Maple-leaved Viburnum are producing fruit. (below). Spicebush is vulnerable to deer browsing, but much less so than Maple-leaved Viburnum.

However, large portions of the Reservation exhibit either the “Infested Forest Syndrome” (above; condition occurs where high deer densities occur in areas formerly plowed for agricultural use) or the “Empty Forest Syndrome” (below; condition occurs where high deer densities occur in areas without past agricultural plowing, and existing soils resemble native forest soils.

Canopy gaps conditions are variable at the Reservation, but mostly in poor condition due to deer over browsing. Japanese Stiltgrass growing in two gaps. Note browsed oak seeding in bottom photo.

The best and the worst.
An ‘ecological dystopia’ on sloped woodlands consisting of Japanese Aralia, Mile-a-Minute, Asiatic Bittersweet, Japanese Stiltgrass, etc., along with an absence of native trees and shrubs (above), and robust native tree regeneration in a forest canopy gap (below). This suggests that deer browse is not even across the Reservation.

Most Maple-leaved Viburnum, a species sensitive to deer browse, are badly browsed by deer (above). White Wood Aster, another sensitive species, are very common but always badly browsed throughout the Reservation (below). The future of forest wildflowers is dim unless the deer population is further reduced.

Evaluation of Invasive Species Impacts

Mapping Protocols

The method used to map invasive plant species involved the delineation of mapping areas. The mapping area technique is a coarse method to broadly define the extent and intensity of invasive species infestations. Mapping areas were delineated as locations containing relatively uniform ground cover for each invasive species present within the defined area or 'patch'. Within each patch, each invasive plant species was assigned a cover class score. Cover class scores included: "0": absent, "Trace" or < 1% cover, "1": 1-10% ground cover, "2": 11-25% ground cover, "3": 26-50% ground cover, "4": 51-75%, and "5": 76-100% ground cover. See Appendix F for raw mapping data for each mapped patch.

Overall Scope

A total of 225 unique mapped patches totaling 2,039 acres were recorded (Table 20). The scope of the invasive species problem is significant with 57% of the Reservation having severe infestations of one or more species (invasive cover > 50%). Approximately 28% of the Reservation was virtually free of invasive species, while approximately 4% was lightly to moderately infested (ca. 10% of Reservation has development as recreational facilities or buildings). Map 22 depicts the cumulative infestation scores by mapped patches.

Table 20. Invasive Species - Summary of Infestations by Mapped Patch

Mapped Patch Infestation Summary

Combined Infestation Score per Patch	Combined Infestation Score Category	Total Acreage	Percentage of Reservation
N/A	N/A	206.7	10.1
0*	"Clean"	577.0	28.3
1	Low	51.7	2.5
2	Moderate	20.4	1.0
3	Moderate	11.4	0.6
4	High	193.6	9.5
5	High	152.1	7.5
6	Very High	94.0	4.6
7	Very High	139.7	6.9
8	Extremely High	142.6	7.0
9	Extremely High	137.9	6.8
10	Extremely High	154.3	7.6
11	Extremely High	37.2	1.8
12	Extremely High	60.4	3.0
13	Extremely High	12.2	0.6
14	Extremely High	2.4	0.1
15	Extremely High	0.0	0.0
16	Extremely High	43.2	2.1
17	Extremely High	1.8	0.1
Totals		**2039**	**100**

*May contain one or more species at "Trace" amounts

Mapped Patch Infestation Summary

Combined Infestation Score per Patch	Combined Infestation Score Category	Total Acreage	Percentage of Reservation
N/A	N/A	206.7	10.1
0*	"Clean"	577.0	28.3
1	Low	51.7	2.5
2-3	Moderate	31.8	1.6
4-5	High	345.7	17.0
6-7	Very High	233.7	11.5
> 7	Extremely High	592.0	29.0
Totals		**2039**	**100**

*May contain one or more species at "Trace" amounts

Each invasive species was assigned an 'Action Code' based upon its threat level to conservation values, current extent of infestation within the Reservation and known invasive status in New Jersey (Table 21). Overall, 33 species are considered invasive – ten should be subject to an eradication program, seven should be subject to a selective control program. Specific management recommendations for particular species and areas within the Reservation are presented in Section IV.

Table 21. Invasive Species - Action Code Summary

Action Code	Action Code Explanation	Treatment Recommendations	Number of Species	Listed Species
1	Species has limited distribution (but is highly threatening) within the Reservation	Eradicate	29	Amur Corktree, Amur Maple, Boston Ivy, Callery Pear, Chinese Wisteria, Chocolate Vine, Common Barberry, Dame's Rocket, English Ivy, European Buckthorn, Fuzzy-Pride-of-Rochester, Highbush Cranberry, Japanese Clematis, Japanese Maple, Japanese Snowball, Japanese Snowbell, Japanese Wisteria, Japanese Zelkova, Jetbead, Kousa Dogwood, Norway Maple, Oriental Photinia, Siebold's Viburnum, Sycamore Maple, Toringo Crabapple, Weeping Higan Cherry, Wintercreeper, Yellow Iris
2	Species has widespread distribution within the Reservation and is considered highly threatening	Selective Control	20	Amur Honeysuckle, Asiatic Bittersweet, Autumn Olive, Chinese Bushclover, Common Reed, Garlic Mustard, Japanese Aralia, Japanese Barberry, Linden Viburnum, Mile-a-Minute, Mugwort, Multiflora Rose, Narrowleaf Bittercress, Porcelainberry, Privet, Tree-of-Heaven, Wineberry, Winged Burning Bush
3	Species has limited distribution and/or is not considered to be highly threatening to conservation values and/or meaningful control is not feasible within the Reservation	No Treatment	6	Black Locust, Carpgrass, Japanese Stiltgrass, Lesser Celandine, Morrow's Bush Honeysuckle, Reed Canary Grass
TOTAL			**55**	

Species Patterns

There were twenty-nine different emerging invasive plant species detected within the Reservation that should be considered for eradication (See Action Code 1 species in Table 21 above), totaling 461 unique populations (Appendix G provides details from the Strike Team database). All of these species are considered highly threatening to ecological health. Every invasive species, both emerging and widespread, have maps depicting their coverage within mapped patch / polygon and Strike Team database points (if recorded) – See "Individual Invasive Species Maps".

Table 22 contains data for each invasive species mapped within the Reservation, including the "Relative Infestation Index Category." This index provides a coarse characterization of both distribution and intensity of infested acreage within the Reservation. It is intended to provide a rapid assessment of species that currently have the greatest impacts. Values include 'High', 'Medium', and 'Low', which correspond to ranges of Infestation Index Scores derived by multiplying the number of acres where a species was present by its cover class score within mapped patches. Species labeled as 'High' are those with widespread distributions and/or consist of dense stands. Conversely, 'Low' species have limited distribution and/or primarily occur at low cover classes.

In order of abundance, the five most abundant species are Japanese Stiltgrass, Multiflora Rose, Japanese Barberry, Winged Burning Bush and Linden Viburnum. Additional species with high infestation levels were (in order of index scores): Asiatic Bittersweet, Japanese Aralia, Japanese Honeysuckle, Amur Honeysuckle, Wineberry, Privet, Garlic Mustard, Mile-a-Minute and Japanese Knotweed.

Table 22 also includes the number of populations recorded in the Strike Team database, as well as eradication status.

Spatial Patterns

The most severe combined infestations and number of invasive species per patch, and maximum single species infestations (See Maps 22-24, respectively) tended to occur in former agricultural areas. Further amplifying this phenomenon is the prominence of ash decline within some of these same areas, which decreases shade provided by canopy trees and therefore increases the growth of invasive species such as Multiflora Rose. Importantly, Multiflora Rose is beginning to succumb to Rose Rosette Disease in sunny areas. While ash decline may initially promote rose growth, increased light may ultimately reduce its cover over time in woodland habitats.

Areas without a history of agricultural tilling and a relatively dense tree canopy tended to be areas considered to be "Clean" or have "Low" or "Moderate" infestation levels. However, some areas without agricultural tilling still had significant infestations of species, especially Japanese Stiltgrass in moist ravines within forest habitat.

Regardless of past agricultural land use, canopy gaps and thinner canopy woodland habitat (either created through loss of ash or areas on steep, rocky slopes that do not seem to support dense tree canopies – e.g., slopes on the eastern boundary of the Reservation) were highly infested by a variety of invasive species. Deer frequent these areas (probably instinctively to seek plants with robust growth due to increased sunlight) and remove palatable native species while leaving behind unpalatable invasive species.

Oriental Photinia is one of the most threatening emerging invasive species. It is becoming very abundant in portions of New Jersey, but only six small populations were detected at the Reservation.

Table 22. Invasive Species – Individual Species and Their Relative Infestation Levels

Table 22. Invasive Species – Individual Species and Their Relative Infestation Levels (continued)

Table 22. Invasive Species – Individual Species and Their Relative Infestation Levels (continued)

Section IV. Strategies and Actions

Figure 11. Stewardship Philosophy

'Nature manages itself' is commonly heard from those that feel stewardship of natural lands is inappropriate. In some cases, this is based upon a simplistic understanding of natural systems and the forces that create or maintain them. Some proponents of this view fail to acknowledge that there are many indirect impacts of human activities on natural systems (e.g., introductions of non-native species, irreversible fragmentation of natural areas that support deer population growth, profound alteration of soils from past agricultural use, etc.). Other proponents of this view suggest that nature will have to balance itself within the framework established by human activities and that we should not intervene further. Finally, there are well-qualified experts including some experienced natural historians and research professors that understand that our knowledge of natural systems is incomplete and suggest that stewardship should not be practiced until we learn more about natural systems and how they will react to particular management regimes.

In contrast, proponents of stewardship proceed from the viewpoint that human activities directly and indirectly shape the remainder of our natural world and that there is an obligation to intervene to promote ecological health and avoid further losses to biodiversity. In short, stewardship may be defined as 'the mitigation of human impacts on natural systems'. Stewards feel that action is required when human impacts severely threaten ecological health, thereby consciously reducing human impacts through management strategies and actions.

In most cases, stewards strive for short-term interventions that correct natural systems with declining trajectories. Examples of short-term interventions include significant reductions of the white-tailed deer population (i.e., culling) and control of nascent populations of invasive species. In other cases, the continuing needs of the human population require that active management be perpetual (e.g., creation and maintenance of early successional habitats because catastrophic wildfires must be suppressed or a continuing Deer Management Programs to maintain a smaller deer herd).

In general, there are relatively few compromises available to proponents of the extremes of these two opposing viewpoints. However, most individuals realize that a balance is possible, especially when stewardship is coupled with careful monitoring or designed research experiments that provide greater insights to practice adaptive management. Overall, stewardship strategies should seek to utilize minimal human intervention to foster ecological health and stimulate research to provide a better understanding of the natural world.

Introduction

A significant and persistent effort will be required to improve ecological health at the Reservation. This plan has four primary plan recommendations. The first involves continued reduction of the deer population so that native plants can exert ecological control on invasive species. The second involves strategic invasive species control, especially to protect rare species and the globally rare traprock glade plant community, as well as keeping invasive species out of areas currently clean areas. The third involves performing forest and meadow habitat maintenance and restoration. The fourth involves performing ongoing survey and monitoring for rare species as well as forest and meadow community health evaluations. Each of these recommendations is accompanied by specific goals - there is a total of twelve specific stewardship goals.

It is essential that a very effective Deer Management Program continue in perpetuity across the entire Reservation. Significant reduction of the deer herd is absolutely critical to improve ecological health through increased native plant growth, which in turn will exert ecological control over invasive species (thereby lessening the need for ongoing labor-intensive chemical control methods). Invasive species are likely to be present in perpetuity, but they are much less likely to form dense infestations with lower deer densities.

Recommendations for control of particular invasive species were prioritized based upon their level of threat to further degrade ecological health (e.g., potential to significantly increase their abundance at the

Reservation and infestations located within or adjacent to areas with high conservation value). Species-specific recommendations are provided below. Treatment prescriptions and species phenology are provided through the New Jersey Invasive Species Strike Team, which updates its recommendations annually.

A summary of specific goals with suggested completion timeframes and estimated costs is summarized in Table 27. Full plan implementation is estimated to require 2,475 hours of County staff (estimated cost of $123,750), 11,350 volunteer hours (estimated value of $272,400), $18,000 of material costs and $156,500 for contractors over the next 10 years - total cost is estimated at $298,250.

It is realized that full plan implementation costs may be prohibitive. Recommendations #1 and #2 are considered minimal requirements to responsibly steward the Reservation. The combined estimated costs for these recommendations are $209,500. Implementing Recommendations #3 and #4 would be considered a relatively lower priority, perhaps being partially funded through public or private grant sources. The combined estimated costs to implement these two recommendations is $88,750.

In addition to County funds, it is recommended that grants and cost-sharing be sought to implement several goals. Federal programs include the United States Fish & Wildlife Service – Partners for Fish and Wildlife (provide expertise, materials and project implementation assistance), Natural Resources Conservation Service – Environmental Quality Incentive Program (provide expertise and cost-sharing – funds must be provided to a private non-profit to be applied at the Reservation), NJDEP Green Acres Stewardship Program (provide matching grants, review application for eligibility), Franklin Parker Conservation Excellence Program (small grants up to $5,000) and private foundations such as the Union Foundation.

Recommendation #1: Improve Effective White-tailed Deer Management Program

Goal #1-1: Reduce deer density to meet forest health goals including a dense, native understory

The Reservation has had a long history of effective deer management for over 25 years since 1994 (See Figure 4). However, the Reservation continues to be heavily impacted by deer browse and deer density has increased in recent years. It is recommended that the County re-establish its NJ Division of Fish & Wildlife Community Deer Management Permit (CBDMP). CBDMP provide significantly improved harvest opportunities, which can be paired with the current allowance of recreational hunting to safely reduce the deer population. It will be necessary to increase deer harvests with a goal of achieving a deer density less than 20 deer per square mile (or as low as 5 per square mile to allow recovery of forest wildflowers). This goal is supported by the literature.

- The historical analysis of the white-tailed deer population density in North America (pre-European colonization) is approximately 10 per square mile (McCabe and McCabe 1984).
- In general, native species diversity / abundance and overall forest health drop significantly with increasing deer herd size. An often-cited research project that provides quantitative guidance on deer population levels associated with ecological damage was performed by David deCalesta, based at the US Forest Service in Pennsylvania (deCalesta 1994, deCalesta 1997). Over the course of a 10-year study using forest enclosures with known densities of deer, deCalesta determined that native forest herbs and tree seedlings became less abundant with deer densities between 10 and 20 per square mile. At densities exceeding 20 per square mile, palatable native plant species disappear, and forest shrub-nesting songbirds drop in abundance with the loss of the shrub layer.
- Human health impacts may also be associated with deer densities exceeding 10 deer per square mile. According to a study reported from Connecticut (Stafford 2007), deer population size is linked to incidences of Lyme disease. This relationship is dependent upon a threshold deer

population size, requiring a population size of 10-12 deer per square mile to show substantial reduction in human cases of Lyme disease.

The estimated cost to complete this goal is $21,000 over the 10-year implementation period (See Table 27). An additional $60,000 of volunteer value is also required for this goal.

Recommendation #2: Perform Strategic Invasive Species Control

A complete list of invasive species along with control goals (i.e., "Action Code") and strategies is provided in Table 25. Treatment prescriptions are available through the New Jersey Invasive Species Strike Team, which updates them annually based upon newly available information. The following annotated recommendations are provided as specific tasks within Table 27 along with cost estimates and timeframes. Many treatments can be done by County staff and its volunteers (WRIP - Watchung Reservation Invasive Plant Strike Force). For particular tasks, it is recommended that the County hire professional contractors with particular expertise in the identification and treatment of invasive species and protection of rare species (e.g., New Jersey Invasive Species Strike Team) or specialized equipment (e.g., use of forestry mowers for heavy clearing). Ecological control exerted by native species is the ultimate goal to curb invasive plant species. This should not be expected without further reduction of the deer herd (See Goal #1-1).

The estimated cost to complete all goals under this recommendation is $188,500 over the 10-year implementation period (See Table 27). An additional $148,800 of volunteer value is also required for this recommendation.

Volunteers, led by Maggie Southwell, eliminated nearly 4,000 stems of Japanese Aralia in 2019 alone.

Goal #2-2: Eradicate 29 Emerging Invasive Species

Emerging invasive species should be the highest species priority for control efforts because they threaten the Reservation and the region with future ecological degradation. This strategy, known as Early Detection & Rapid Response, represents an efficient and effective strategy to prevent damage (and minimize future stewardship costs). There are currently 29 emerging species designated as 'Action Code 1' (i.e., complete eradication is the ultimate goal, See Appendix G for details). Currently, there are 461 mapped known populations of these 29 emerging species. Initial priority should be placed on species with the fewest populations so that they can be completely eliminated before spreading further.

The estimated cost to complete this goal is $29,500 over the 10-year implementation period (See Table 27). An additional $2,400 of volunteer value is also required for this goal.

Goal #2-3: Protect High Quality "Clean" Areas on 555 Acres

This goal includes approximately 555 acres of forest habitat that are only lighted impacted by invasive species infestations. Table 26 provides Patch ID numbers along with invasive species noted during surveys of each patch. The goal for "clean" areas is to maintain less than 10% cover for all invasive species. All selected areas should be monitored annually, and invasive species should be treated over the next 10 years. Ultimately, ecological control of invasive species should maintain these areas with reduced risk of new infestations.

The estimated cost to complete this goal is $21,000 over the 10-year implementation period (See Table 27). An additional $24,000 of volunteer value is also required for this goal.

Clean areas often feature dense native shrubs and tree saplings that resist infestation, but canopy gaps and forest edges remain susceptible.

Some WRIP members at a recent workday at the Reservation

Table 25. Invasive Species - Control Strategy Summary

Common Name	Scientific Name	Growth Form	Action Code	Number of Recorded Populations	Completed Eradication	Initiated Eradications	Control Strategy	Control Methods
Amur Corktree	*Phellodendron amurense*	Tree	1	1	0	0	Eradicate all known occurrences; Maintain continual searching and eradication	Basal Bark, Foliar Spray, Cut Stump (winter only if using glyphosate), EZ-Ject w/imazapyr
Amur Honeysuckle	*Lonicera maackii*	Shrub	2	1	0	0	Selective Control - Isolated plants within highest quality areas only	Basal Bark, Foliar Spray, Cut Stump
Amur Maple	*Acer ginnala*	Tree	1	10	0	0	Eradicate all known occurrences; Maintain continual searching and eradication - Significant population located in former nursery behind education center	Basal Bark, Foliar Spray, Cut Stump (winter only if using glyphosate), EZ-Ject w/imazapyr
Asiatic Bittersweet	*Celastrus orbiculata*	Vine	2	12	0	0	Selective Control - Prioritize all vines in highest quality areas, followed by female plants in more degraded areas	Basal Bark, Foliar Spray, Cut Stump (winter only if using glyphosate), EZ-Ject w/imazapyr
Autumn Olive	*Elaeagnus umbellata*	Shrub	2	3	0	0	Selective Control - Isolated plants within highest quality areas only	Basal Bark, Foliar Spray, Cut Stump (winter only if using glyphosate), EZ-Ject w/imazapyr
Black Locust	*Robinia pseudoacacia*	Tree	3	2	0	0	No Direct Action - Species native to North America, but consider control in meadow habiat as necessary	Basal Bark, Hack-and-Squirt, Foliar Spray, Cut Stump (winter only if using glyphosate) - Most effective herbicide is aminopyralid
Boston Ivy	*Parthenocissus tricuspidata*	Vine	1	1	0	0	Eradicate all known occurrences; Maintain continual searching and eradication	Basal Bark, Cut Stump
Callery Pear	*Pyrus calleryana*	Tree	1	3	0	1	Eradicate all known occurrences; Maintain continual searching and eradication	Basal Bark, Foliar Spray, Cut Stump (winter only if using glyphosate), EZ-Ject w/imazapyr
Carpgrass	*Arthraxon hispidus*	Grass	3	0	0	0	No Direct Action - Ecological control through deer herd reduction	Foliar Spray, Pre-Emergent Spray; Species is annual
Chinese Bushclover	*Lespedeza cuneata*	Herb	2	1	0	0	Selective Control - Forest - Eradicate Fruiting Individuals (esp. high quality areas); Meadow - Eradicate all individuals in high quality habitats and Control via hand treatments or forestry mowing as feasible	Foliar Spray (aminopyralid or triclopyr) - Consider cutting in early June and allowing regrowth to 2' tall before treating
Chinese Wisteria	*Wisteria sinensis*	Vine	1	21	0	0	Eradicate all known occurrences; Maintain continual searching and eradication	Basal Bark, Foliar Spray, Cut Stump (winter only if using glyphosate if using glyphosate), EZ-Ject w/imazapyr
Chocolate Vine	*Akebia quinata*	Vine	1	5	0	0	Eradicate all known occurrences; Maintain continual searching and eradication	Foliar Spray (Utilize Clean Cut surfactant or equivalent); Cut stems infesting trees prior to treatment
Common Barberry	*Berberis vulgaris*	Shrub	1	5	0	2	Eradicate all known occurrences; Maintain continual searching and eradication	Foliar Spray, Cut Stump
Common Reed	*Phragmites australis*	Grass	2	9	0	0	Selective control of patches near Lake Surprise - Consider hiring professional lake managers to treat	Foliar Spray, Cut Stump - Most effective herbicide is imazapyr; Consider cutting in early June and allowing regrowth to 3' tall before treating
Dame's Rocket	*Hesperis matronalis*	Herb	1	2	0	0	Eradicate all known occurrences; Maintain continual searching and eradication	Foliar Spray, Hand Pulling in May to avoid seed set (species is biennial)
English Ivy	*Hedera helix*	Vine	1	8	0	0	Eradicate all known occurrences; Maintain continual searching and eradication	Basal Bark, Foliar Spray (utilize Clean Cut surfactant or equivalent), Cut Stump (winter only if using glyphosate)
European Buckthorn	*Rhamnus catharitica*	Shrub	1	15	0	0	Eradicate all known occurrences; Maintain continual searching and eradication	Basal Bark, Foliar Spray, Cut Stump (winter only if using glyphosate), EZ-Ject w/imazapyr
fuzzy-pride-of-Rochester	*Deutzia scabra*	Shrub	1	8	0	0	Eradicate all known occurrences; Maintain continual searching and eradication - Significant population located in former nursery behind education center	Basal Bark, Foliar Spray, Cut Stump (winter only if using glyphosate)

Table 25. Invasive Species - Control Strategy Summary (continued)

Common Name	Scientific Name	Growth Form	Action Code	Number of Recorded Populations	Completed Eradication	Initiated Eradications	Control Strategy	Control Methods
Garlic Mustard	*Alliaria petiolata*	Herb	2	1	0	0	Selective Control - Treat all encountered individuals while performing eradication surveys for species such as Oriental Photinia and Linden Viburnum	Foliar Spray, Hand Pulling in May to avoid seed set (species is biennial)
Glossy Buckthorn	*Frangula alnus*	Shrub	1	31	0	0	Eradicate all known occurrences; Maintain continual searching and eradication	Basal Bark, Foliar Spray, Cut Stump (winter only if using glyphosate)
Highbush Cranberry	*Viburnum opulus*	Shrub	1	1	0	0	Eradicate all known occurrences; Maintain continual searching and eradication	Basal Bark, Foliar Spray, Cut Stump
Japanese Aralia	*Aralia elata*	Tree	2	227	10	20	Selective Control - Initial focus on areas within and near trap rock glade habitat, followed by populations farther away	Basal Bark, Foliar Spray, Cut Stump (winter only if using glyphosate), EZ-Ject w/imazapyr
Japanese Barberry	*Berberis thunbergii*	Shrub	2	40	0	10	Selective Control - Isolated plants within highest quality areas only	Basal Bark, Foliar Spray, Cut Stump
Japanese Clematis	*Clematis terniflora*	Vine	1	3	0	0	Eradicate all known occurrences; Maintain continual searching and eradication	Foliar Spray (Utilize Clean Cut surfactant or equivalent); Cut stems infesting trees prior to treatment
Japanese Honeysuckle	*Lonicera japonica*	Vine	2	5	0	0	Selective Control - Prioritize within highest quality areas only	Foliar Spray (cut stems infesting trees prior to treatment)
Japanese Knotweed	*Polygonum cuspidatum*	Herb	2	15	0	3	Selective Control - Prioritize within highest quality areas only	Foliar Spray, Cut Stump, Stem Injection; Consider cutting in early June and allowing regrowth to 3' tall before treating
Japanese Maple	*Acer palmatum*	Tree	1	5	1	0	Eradicate all known occurrences; Maintain continual searching and eradication	Basal Bark, Foliar Spray, Cut Stump (winter only if using glyphosate), EZ-Ject w/imazapyr
Japanese Snowball	*Viburnum plicatum*	Shrub	1	15	0	0	Eradicate all known occurrences; Maintain continual searching and eradication	Basal Bark, Foliar Spray, Cut Stump (winter only if using glyphosate)
Japanese Snowbell	*Styrax japonicus*	Shrub	1	9	0	0	Eradicate all known occurrences; Maintain continual searching and eradication - Significant population located in former nursery behind education center	Basal Bark, Foliar Spray, Cut Stump (winter only if using glyphosate)
Japanese Stiltgrass	*Microstegium vimineum*	Grass	3	2	0	0	No Direct Action - Ecological control through deer herd reduction	Foliar Spray, Pre-Emergent Spray, Well-timed cutting (ca. mid August)
Japanese Wisteria	*Wisteria floribunda*	Vine	1	11	0	0	Eradicate all known occurrences; Maintain continual searching and eradication	Basal Bark, Foliar Spray, Cut Stump (winter only if using glyphosate if using glyphosate), EZ-Ject w/imazapyr
Japanese Zelkova	*Zelkova serrata*	Tree	1	3	0	0	Eradicate all known occurrences; Maintain continual searching and eradication	Basal Bark, Foliar Spray, Cut Stump (winter only if using glyphosate), EZ-Ject w/imazapyr
Jetbead	*Rhodotypos scandens*	Shrub	1	22	1	1	Eradicate all known occurrences; Maintain continual searching and eradication	Foliar Spray, Cut Stump
Kousa Dogwood	*Cornus kousa*	Tree	1	5	0	0	Eradicate all known occurrences; Maintain continual searching and eradication	Basal Bark, Foliar Spray, Cut Stump (winter only if using glyphosate), EZ-Ject w/imazapyr
Lesser Celandine	*Ranunculus ficaria*	Herb	3	3	1	0	No Direct Action - Ecological control through deer herd reduction	Foliar Spray; Species is dormant in summer
Linden Viburnum	*Viburnum dilitatum*	Shrub	2	166	29	8	Selective Control - Prioritize within highest quality areas only	Basal Bark, Foliar Spray, Cut Stump (winter only if using glyphosate), EZ-Ject w/imazapyr
Mile-a-Minute	*Persicaria perfoliatum*	Vine	2	34	0	0	Selective Control - Prioritize within highest quality areas only	Foliar Spray, Pre-Emergent Spray, Well-timed cutting (by early July and/or mid August); Species is annual
Morrow's Bush Honeysuckle	*Lonicera morrowii*	Shrub	3	0	0	0	No Direct Action - Ecological control through deer herd reduction	Basal Bark, Foliar Spray, Cut Stump
Mugwort	*Artemisia vulgaris*	Herb	2	6	0	0	Selective Control - Eliminate from high quality meadow habitat only	Foliar Spray (aminopyralid or triclopyr only) - Consider cutting in early June and allowing regrowth to 2' tall before treating

Table 25. Invasive Species - Control Strategy Summary (continued)

Common Name	Scientific Name	Growth Form	Action Code	Number of Recorded Populations	Completed Eradication	Initiated Eradications	Control Strategy	Control Methods
Multiflora Rose	*Rosa multiflora*	Shrub	2	25	0	3	Selective Control - Prioritize within highest quality areas only; Rose Rosette Disease is expected to eliminate all plants growing in sunny conditions	Foliar Spray, Cut Stump
Narrowleaf Bittercress	*Cardamine impatiens*	Herb	2	10	0	0	Selective Control - Isolated plants within highest quality areas only	Foliar Spray, Hand Pulling in May to avoid seed set (species is biennial)
Norway Maple	*Acer platanoides*	Tree	1	2	0	0	Eradicate all known occurrences; Maintain continual searching and eradication	Basal Bark, Hack-and-Squirt, Foliar Spray, Cut Stump (winter only if using glyphosate), EZ-Ject w/imazapyr
Oriental Photinia	*Photinia villosa*	Shrub	1	6	0	0	Eradicate all known occurrences; Maintain continual searching and eradication	Basal Bark, Foliar Spray, Cut Stump (winter only if using glyphosate), EZ-Ject w/imazapyr
Porcelainberry	*Ampelopsis brevipedunculata*	Vine	2	20	0	0	Selective Control - Prioritize within highest quality areas only	Basal Bark, Foliar Spray, Cut Stump (winter only if using glyphosate), EZ-Ject w/imazapyr
Privet	*Ligustrum obtusifolium*	Shrub	2	0	0	0	Selective Control - Isolated plants within highest quality areas only	Basal Bark, Foliar Spray, Cut Stump
Reed Canary Grass	*Phalaris arundinacea*	Grass	3	0	0	0	No Direct Action - But consider professional wetland applicator contractors	Foliar Spray; Consider cutting in early June and allowing regrowth to 1' tall before treating
Siebold's Viburnum	*Viburnum sieboldii*	Shrub	1	6	1	0	Eradicate all known occurrences; Maintain continual searching and eradication	Basal Bark, Foliar Spray, Cut Stump (winter only if using glyphosate), EZ-Ject w/imazapyr
Sycamore Maple	*Acer pseudoplatanus*	Tree	1	1	0	0	Eradicate all known occurrences; Maintain continual searching and eradication	Basal Bark, Hack-and-Squirt, Foliar Spray, Cut Stump (winter only if using glyphosate), EZ-Ject w/imazapyr
Toringo Crabapple	*Malus toringo*	Tree	1	9	0	0	Eradicate all known occurrences; Maintain continual searching and eradication	Basal Bark, Foliar Spray, Cut Stump (winter only if using glyphosate), EZ-Ject w/imazapyr
Tree-of-Heaven	*Ailanthus altissima*	Tree	2	11	0	0	Selective Control - Isolated plants within highest quality areas only	Basal Bark, Foliar Spray, Cut Stump (winter only if using glyphosate), EZ-Ject w/imazapyr
Weeping Higan Cherry	*Prunus subhirtella*	Tree	1	7	1	0	Eradicate all known occurrences; Maintain continual searching and eradication	Basal Bark, Hack-and-Squirt, Foliar Spray, Cut Stump (winter only if using glyphosate), EZ-Ject w/imazapyr
Wineberry	*Rubus phoenicolasius*	Shrub	2	5	0	4	Selective Control - Isolated plants within highest quality areas only	Foliar Spray, Cut Stump
Winged Burning Bush	*Euonymus alata*	Shrub	2	16	0	5	Selective Control - Isolated plants within highest quality areas only	Basal Bark, Foliar Spray, Cut Stump
Wintercreeper	*Euonymous fortunei*	Vine	1	5	0	0	Eradicate all known occurrences; Maintain continual searching and eradication	Basal Bark, Foliar Spray (utilize Clean Cut surfactant or equivalent), Cut Stump (winter only if using glyphosate)
Yelllow Iris	*Iris pseudacorus*	Herb	1	4	0	0	Eradicate all known occurrences; Maintain continual searching and eradication	Foliar Spray
Totals				**838**	**44**	**57**		

Table 26. Clean Forest Patches

Patch ID	Acres	Invasive Species Detected (Trace Amounts)
15	11	Winged Burning Bush
26	18	Japanese Barberry, Japanese Stiltgrass, Multiflora Rose, Wineberry
38	76	None
40	15	Japanese Barberry, Japanese Stiltgrass, Linden Viburnum
44	7	Japanese Barberry, Japanese Stiltgrass, Linden Viburnum
46	13	None
50	52	None
52	9	Japanese Barberry, Japanese Stiltgrass, Wineberry
56	18	Japanese Barberry, Japanese Stiltgrass, Wineberry
64	5	Japanese Stiltgrass, Wineberry
69	39	Japanese Barberry, Japanese Stiltgrass, Wineberry, Linden Viburnum
72	29	Japanese Barberry, Japanese Stiltgrass, Wineberry, Linden Viburnum
85	1	None
86	1	None
96	21	Japanese Barberry
97	3	Japanese Barberry, Asiatic Bittersweet, Japanese Stilgrass, Multiflora Rose, Wineberry
99	17	None
100	7	None
101	5	None
104	14	None
105	16	Japanese Barberry, Winged Burning Bush, Multiflora Rose, Linden Viburnum
107	26	Japanese Barberry, Winged Burning Bush, Multiflora Rose, Linden Viburnum
116	10	None
118	1	None
130	10	None
131	4	Japanese Stiltgrass, Multiflora Rose
133	6	Garlic Mustard, Japanese Barberry, Linden Viburnum
136	1	Garlic Mustard, Japanese Barberry, Linden Viburnum
137	3	Japanese Barberry, Japanese Stiltgrass
138	14	None
141	14	Japanese Barberry
146	4	None
147	5	Japanese Stiltgrass, Multiflora Rose
152	21	Japanese Stiltgrass
154	3	None
178	9	Japanese Barberry
181	16	Japanese Barberry, Winged Burning Bush, Japanese Stiltgrass
186	1	None
189	1	Linden Viburnum
215	11	Asiatic Bittersweet, Winged Burning Bush, Japanese Knotweed, Multiflora Rose
222	18	Asiatic Bittersweet, Winged Burning Bush, Privet, Japanese Stiltgrass, Multiflora Rose, Wineberry
Totals	**555**	

Recommendation #3: Perform Forest and Meadow Habitat Maintenance and Restoration

The maintenance and enhancement of meadow and forest habitats are an important goal. The Reservation harbors 21 acres of upland and wetland meadows (Map 19, Table 14). In addition, existing forest exclosures are in need of repair and additional 'mini-exclosures' should be constructed to protect sensitive forest wildflowers (Goal #3-2) - all of these fenced areas will allow the natural establishment of native trees and shrubs required to maintain forest cover and can be planted with additional wildflower species that are suspected to have been lost from the Reservation over the years. Goal #3-3 involves restoration of the spruce/pine plantation that is part of the historic resources of the Reservation.

Proposed restoration activities will require substantial funding, perhaps utilizing grants from private and public organizations. It is also important to note that the scale of each proposed restoration project can be reduced based upon available funds (e.g., restore 2 acres of meadow instead of 6 acres).

The estimated cost to complete all goals under this recommendation is $33,750 over the 10-year implementation period (See Table 27). An additional $63,600 of volunteer value is also required for this recommendation.

Goal #3-1: Restore or Maintain 21 Acres of Native Wildflower Meadow

Meadow habitat is relatively limited at the Reservation. Several meadows show high quality while others are heavily degraded, requiring complete restoration (i.e., eliminating all existing vegetation and seeding with native grasses and wildflowers). Table 14 provides a summary of current conditions and stewardship recommendations (meadow areas are depicted on Map 19) – 7 acres are currently considered high quality, 6 acres are low quality, requiring intensive restoration and the remainder are considered moderate quality.

The maintenance or restoration of high-quality meadows will provide critical pollinator habitat and an aesthetically pleasing landscape that can be enjoyed by the public. If stewardship is not employed, these areas will likely become infested by woody invasive species. Cost estimates included in Table 27 include selective hand treatment of invasive species, as well as complete restoration of six acres of meadows that are too degraded to bring back to health without significant inputs (includes two contracted field sprayings, utilization of a seed drill to plant native seeds, and follow up spot treatments). All upland meadows should be mowed every two years during the dormant season to keep them free of trees and shrubs.

The estimated cost to complete this goal is $21,000 over the 10-year implementation period (See Table 27). An additional $24,000 of volunteer value is also required for this goal.

Goal #3-2: Repair Existing Exclosures and Install a Series of New Mini-Exclosures to Protect and Enhance Existing Forest Wildflower Patches

Deer exclosures are referred to as the 'Noah's Ark' concept whereby restoring small areas could ultimately restore the entire Reservation (following deer herd reduction). The Reservation currently has three exclosures (two located near the Nature and Science Center and a third located in the southern tip of the Reservation across from the Hovnanian development). Each of these exclosures requires repair, which can be conducted by County staff and volunteers (e.g., Eagle Scouts).

In addition, a series of 25 'mini-exclosures' is proposed to protect sensitive woodland wildflowers located throughout the Reservation (focusing on trailside areas within clean forest areas, See Table 26). The most common species suffering from intense deer browse is White Wood Aster, which can form the focus of

this goal. It is recommended that additional woodland wildflowers be planted within these exclosures to increase diversity. These exclosures should consist of 5-foot tall, woven wire fencing with a maximum perimeter of 100 feet (although relatively short, deer typically do not jump into small exclosed areas).

The estimated cost to complete this goal is $6,500 over the 10-year implementation period (See Table 27). An additional $31,200 of volunteer value is also required for this goal.

Recommendation #4: Perform Community Ecological Health Monitoring

This recommendation includes higher levels of stewardship activity including ecological monitoring of forest habitat and monitoring of rare species. Ecological monitoring provides accountability and forms the basis for the adaptive management process. Monitoring should be performed by professional consultants with experience with rare species and monitoring techniques.

The estimated cost to complete all goals under this recommendation is $55,000 over the 10-year implementation period (See Table 27).

Goal #4-2: Perform Ecological Health Monitoring for Forest and Meadow Habitats

Ecological health should be monitored regularly in forests and meadows at the Reservation to evaluate stewardship activities and guide adaptive management over time. Forest health should be monitored every 3-5 years. Key attributes should include the abundance of native and non-native trees, shrubs and herbaceous plants, along with canopy coverage and presence of regenerating trees. Baseline measurements were recorded by Jay Kelly and his students from Raritan Valley Community College in 2019 (report not yet available).

The estimated cost to complete this goal is $27,500 over the 10-year implementation period (See Table 27).

Table 33. Detailed Goals for 10-Year Implementation Period

Recommendation	Goal #	Goal Description	Total Estimated Level of Effort (Staff Hours)	Estimated Staff Costs @ $50/hour	Estimated Material Cost	Estimated Contractor Cost	Total Plan Cost	Average Cost per Year	Total Estimated Level of Effort (Volunteer Hours)	Volunteer Value @ $24/hour	Notes
Deer Management	1-1	Administer DMP through CBDMP and recreational hunting opportunities	400	$20,000	$1,000	$0	$21,000	$2,100	2500	$60,000	Volunteer hunters
Strategic Invasive Species Control	2-1	Selective Control to Protect Rare Plants and Traprock Glade Community - Maintain and Enhance Globally Rare Traprock Glade Communities including 6 rare plant species	200	$10,000	$1,000	$12,000	$23,000	$2,300	500	$12,000	Herbicide, Tools
Strategic Invasive Species Control	2-1	Selective Control to Protect Rare Plants - Protect 9 rare plant species not located on traprock glades	200	$10,000	$1,000	$25,000	$36,000	$3,600	2000	$48,000	Herbicide, Tools
Strategic Invasive Species Control	2-2	Eradicate 29 Emerging Invasive Species (Action Code #1 species)	200	$10,000	$5,000	$14,500	$29,500	$2,950	100	$2,400	Herbicide, Tools
Strategic Invasive Species Control	2-3	Protect 555 acres of "Clean" forest habitat	200	$10,000	$1,000	$10,000	$21,000	$2,100	1000	$24,000	Herbicide, Tools
Strategic Invasive Species Control	2-4	Utilize Sensory Trail control project to train WRIP volunteers and serve as demonstration area for public	200	$10,000	$2,000	$0	$12,000	$1,200	2000	$48,000	Herbicide, Tools
Strategic Invasive Species Control	2-5	Maintain History Trail and other important public access areas	100	$5,000	$1,000	$50,000	$56,000	$5,600	500	$12,000	Herbicide, Tools, Contractor with heavy mower for intial clearing
Strategic Invasive Species Control	2-6	Public outreach to encourage use of native species, discourage use of invasive species and dumping of yard waste	200	$10,000	$1,000	$0	$11,000	$1,100	100	$2,400	Printing brochures and sigage
Forest and Meadow Stewardship	3-1	Restore or maintain 21 acres of wildflower meadows (See Table 14)	400	$20,000	$1,000	$0	$21,000	$2,100	1000	$24,000	Herbicide, Tools, Contractor with heavy mower for intial clearing
Forest and Meadow Stewardship	3-2	Repair existing exclosures and install 25 'mini-exclosures'	100	$5,000	$1,500	$0	$6,500	$650	1300	$31,200	Fencing materials and supplies
Forest and Meadow Stewardship	3-3	Restore historic spruce / pine plantation near Sky Top Picnic Pavilion	75	$3,750	$2,500	$0	$6,250	$625	350	$8,400	Plants, materials and supplies
Ecological Monitoring	4-1	Rare species survey and monitoring	100	$5,000	$0	$22,500	$27,500	$2,750	0	$0	Professional Botanical Consultant
Ecological Monitoring	4-2	Ecological health monitoring (forest and meadow habitat)	100	$5,000	$0	$22,500	$27,500	$2,750	0	$0	Professional Botanical Consultant
Totals			**2,475**	**$123,750**	**$18,000**	**$156,500**	**$298,250**	**$29,825**	**11,350**	**$272,400**	

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