White Lake Natural Resource Area
Invasive Species Management Plan

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Grass of Parnassus (Parnassia glauca)
A unique plant found in a unique limestone fen community at White Lake

Introductory Information

Property:	White Lake Natural Area
Property Acreage:	515 acres
County, Municipality:	Warren County, Hardwick Township (See Map 1)
Wildlife Action Plan Conservation Zone:	Skylands - Upper Delaware River & Kittatinny Ridge (20)
NJDEP Watershed Management Area:	Upper Delaware (WMA 01)
Waterbodies:	Paulinskill River tributaries: 1st Order = 0.4 miles, Paulinskill River forms much of eastern property boundary; White Lake (70 acres); Unnamed Pond (1.2 acres)
Invasive Plant Species List:	Each invasive plant species was assigned an 'Action Code' based upon observations of current extent of infestations on the Property and within New Jersey. Code Key: "1" = immediate implementation of an eradication program across the entire Property, "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. See report for additional information on distribution, infestation severity, and control recommendations. ***Total Number of Mapped Invasive Species: 34*** **Action Code = 1 (11 species)** Beauty Bush, Broad Winged Thistle, European Buckthorn, Fuzzy Deutzia, Jetbead, Norway Maple, Oriental Photinia, Poison Hemlock, Siebold's Crabapple, Yellow Archangel, Yellow Iris **Action Code = 2 (18 species)** Amur Honeysuckle, Autumn Olive, Border Privet, Common Reed, Garlic Mustard, Japanese Barberry, Japanese Honeysuckle, Mile-a-Minute, Multiflora Rose, Morrow's Honeysuckle, Mugwort, Oriental Bittersweet, Purple Loosestrife, Reed Canarygrass, Tree of Heaven, Wineberry, Winged Burning Bush, Yellow Bedstraw **Action Code = 3 (5 species)** Black Locust, Cool Season Grasses, Japanese Stiltgrass, Sweet Cherry, White Mulberry
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 #5 and Deer Management Units 53 and 71. Hunting dates and harvest regulations may vary by season, but up to 9 antlerless deer can be taken by an individual hunter during each hunting season (total annual maximum is 45). Seasons range from early September to January 31.

Executive Summary

This 10-year invasive species management plan includes results of field investigations with recommendations to improve ecological health of natural areas at White Lake Natural Resource Area.

There are three main purposes of this plan. The first is to clearly state the vision and goals including protection of biodiversity. 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 baseline conditions and ample sources of reference material to effectively navigate the many aspects of the Property and guide its adaptive stewardship over time.

The vision for the Property is to provide a model of stewardship for biodiversity. The two primary recommendations include: 1) Conduct an Effective White-tailed Deer Management Program and 2) Perform Strategic Invasive Species Control. Each of these recommendations includes action-oriented goals (See Section IV) to support both flora and fauna.

The primary habitat conservation targets are: 1) limestone fen communities (globally rare), 2) habitat for Northern Metalmark Butterfly (globally rare), 3) mature limestone forest, 4) special plant species and communities of statewide importance, and 5) pollinator meadows. All habitats and species are under immediate threat from overabundant deer and invasive species.

Deer are overabundant on the property and throughout New Jersey, which has led to severe ecological degradation. Nearly all forests on the property fall into two impaired categories – “Empty Forest Syndrome” (few understory plants) or “Infested Forest Syndrome” (only unpalatable invasive understory plants). Ecological impacts of white-tailed deer are severe with little forest understory growth of native trees, shrubs, and wildflowers and/or significant infestations of unpalatable invasive species. However, there are several exceptions with relatively higher tree regeneration and shrub layer cover – these areas exhibit that greatest relative quality and should be the focus of stewardship activities in forest habitat.

Reduction of the deer density to 20 per square mile (or as low as 10 per square mile to allow recovery of the most sensitive forest wildflowers) is critical to allow native species, freed from excessive browse, to exert ecological control over invasive species and produce healthy native plant communities.

The extent of invasive species infestation is severe. A total of 34 invasive species were detected with 64% of the Property having severe infestations of one or more species. Only 18% of the Property is considered virtually free of invasive species, while an additional 18% is lightly to moderately infested. The three most abundant species are Japanese Barberry, Autumn Olive, and Multiflora Rose. Importantly, there were eleven detected emerging invasive species or nascent populations of widespread species that should be eradicated. This strategy is referred to as early detection / rapid response, which is the most cost effective method to avoid future degradation of ecological health.

A “brute force” approach that seeks direct control of all invasive species is not practical (estimated to require nearly 18,000 hours of effort). This plan recommends a strategic approach involving eradication of eleven species that are newly emerging on the Property, and improvements for the highest priority habitats and species. The ultimate goal is significantly reducing invasive species through directed active control and ultimate reliance on ecological control through deer herd reduction to both reverse current infestations and resist future infestations.

Primary Plan Recommendations

This 10-year plan has two primary recommendations and 5 associated goals. See Section IV for details.

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

Goal #1-1: Reduce deer density to meet ecological health goals

- The goal is meeting forest health goals including a dense understory with native shrubs and wildflowers. Deer density should be kept below 20 deer per square mile but allowing full recovery of forest wildflowers may require a density of 10 deer per square mile. Significant progress toward this goal can be made through an annual Deer Management Program but reaching this goal will ultimately require participation of neighboring landowners.

Recommendation #2: Perform Strategic Invasive Species Control

Goal #2-1: Eradicate 11 emerging invasive species (Action Code 1 species, 19 known populations)

- The goal is intended to reduce future damage by addressing species that have not yet established large, extensive populations throughout the property. Accomplishing this goal will also fulfill 'ecological responsibility' by preventing spread of newly emerging harmful invasive species beyond the Property.
- See Table 8 for a list of species and Table 9 & Map 14 for locations

Goal #2-2: Protect and Enhance Globally Rare Limestone Fen Communities (16.7 acres, Maps 17 & 18)

- Control all lakeshore Phragmites with care not to damage limestone fens. Three strategies have been recommended:
    - Broadcast spraying from boat where limestone fens do not occur in the vicinity (4.3 acres)
    - Hand treatments from land where limestone fens co-occur with Phragmites (8.0 acres)
    - Hybrid of the above with hand treatment within/near sensitive areas to create a buffer, followed by broadcast spraying from a boat in nearby but less sensitive areas (4.4 acres)
- Protection of Grass of Parnassus (and its globally rare pollinator)
    - Control Japanese Barberry and thin Red Cedar along forest/fen edges
        - Consult with Max McCarthy, Rutgers graduate student

Goal #2-3: Protect and Enhance Globally Rare Northern Metalmark Butterfly Habitat (4.3 acres, Map 19)

- Maintain abundance of required larval food plant (Roundleaf Ragwort) and restore nectar plants
    - Larval Plants - Within Red Cedar woodlands, control woody invasive species such as Autumn Olive and Asiatic Bittersweet
        - Do not thin Red Cedar woodlands unless larval food plant diminishes in future
    - Nectar Plants - Restore nectar plants within existing pollinator strips through control of Wineberry and repeated planting of Black-eyed Susan and Butterfly Milkweed

Goal #2-4: Protect and Enhance Additional High Priority Habitat Patches (130 acres, Map 16, Table 13)

- Primary strategy is control of Action Code 2 species in relatively high quality patches
    - Protect mature limestone forest (120 acres)
        - Initial focus on patches with the most diverse wildflowers
    - Protect habitat patches containing state listed rare plants and vernal pools (< 1 acre)
    - Protect priority meadow patches (10 acres)

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Individual Invasive Species Maps (arranged alphabetically by scientific name)

*Maps include field mapped polygons for the entire Property

Scientific Name	Common Name
Acer platanoides	Norway Maple
Ailanthus altissima	Tree of Heaven
Alliaria petiolata	Garlic Mustard
Artemisia vulgaris	Mugwort
Berberis thunbergii	Japanese Barberry
Carduus acanthoides	Broad Winged Thistle
Celastrus orbiculatus	Oriental Bittersweet
Conium Maculatum	Poison Hemlock
Deutzia scabra	Fuzzy Deutzia
Elaeagnus umbellata	Autumn Olive
Euonymus alatus	Winged Burning Bush
Galium verum	Yellow Bedstraw
Iris pseudacorus	Yellow Iris
Lamium galeobdolon	Yellow Archangel
Ligustrum obtusifolium	Border Privet
Linnaea amabilis	Beauty Bush
Lonicera japonica	Japanese Honesuckle
Lonicera maackii	Amur Honeysuckle
Lonicera morrowii	Morrow's Honeysuckle
Lythrum salicaria	Purple Loosestrife
Malus sieboldii	Siebold's Crabapple
Microstegium vimineum	Japanese Stiltgrass
Morus alba	White Mulberry
N/A	Cool Season Grasses
Persicaria perfoliata	Mile-a-Minute
Phalaris arundinacea	Reed Canarygrass
Photinia villosa	Oriental Photinia
Phragmites australis	Common Reed
Prunus avium	Sweet Cherry
Rhamnus cathartica	European Buckthorn
Rhodotypos scandens	Jetbead
Robinia pseudoacacia	Black Locust
Rosa Multiflora	Miltiflora Rose
Rubus phoenicolasius	Wineberry

Section I. Overview

Introduction

The White Lake Natural Resource Area consists of 515 acres in Hardwick Township, Warren County (Map 1). This Invasive Species Management Plan was created to collect and consolidate relevant information to develop strategies that 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 significant examples of the natural heritage including globally rare limestone fen communities featuring a significant diversity of plants, globally rare Northern Metalmark Butterfly population, mature limestone forest, and excellent pollinator meadow for a diversity of pollinators.

Stewardship Vision and Goals

The stewardship vision for the Property is to provide a model of stewardship for biodiversity. The two primary recommendations include: 1) Conduct an Effective White-tailed Deer Management Program and 2) Perform Strategic Invasive Species Control, which includes multiple specific goals (See Section IV).

Complete realization of the vision and goals for the Property can only be met by 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 plan should be revised every ten years. The careful stewardship of the Property will provide concrete examples of exemplary stewardship.

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 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 were 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 consists 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

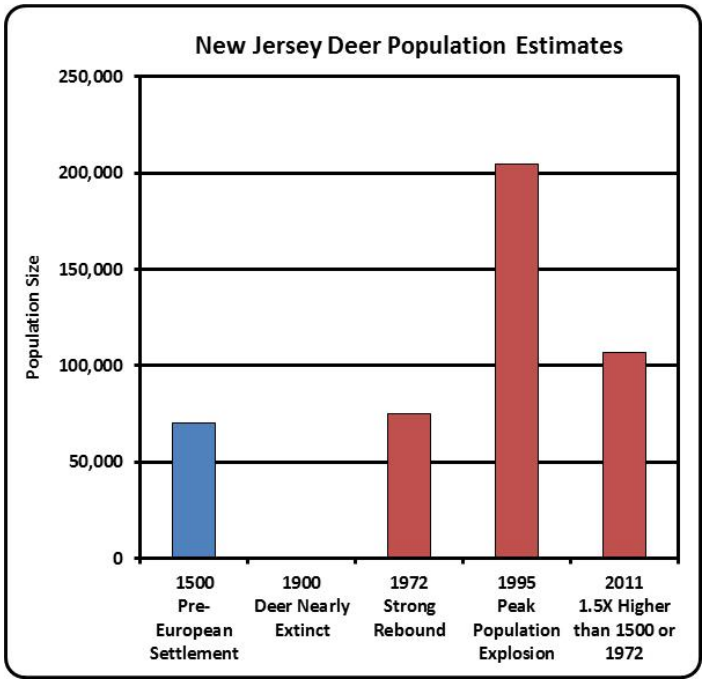
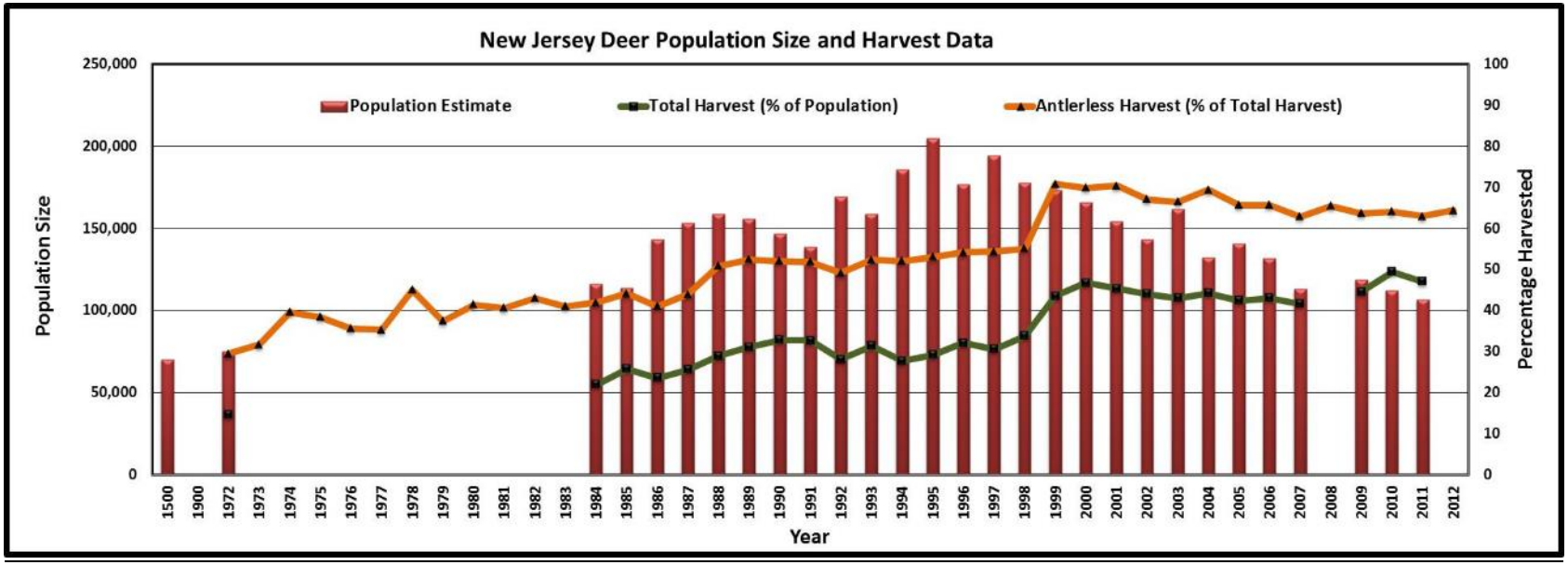


Figure 2. New Jersey Deer Population Size and Harvest Data



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

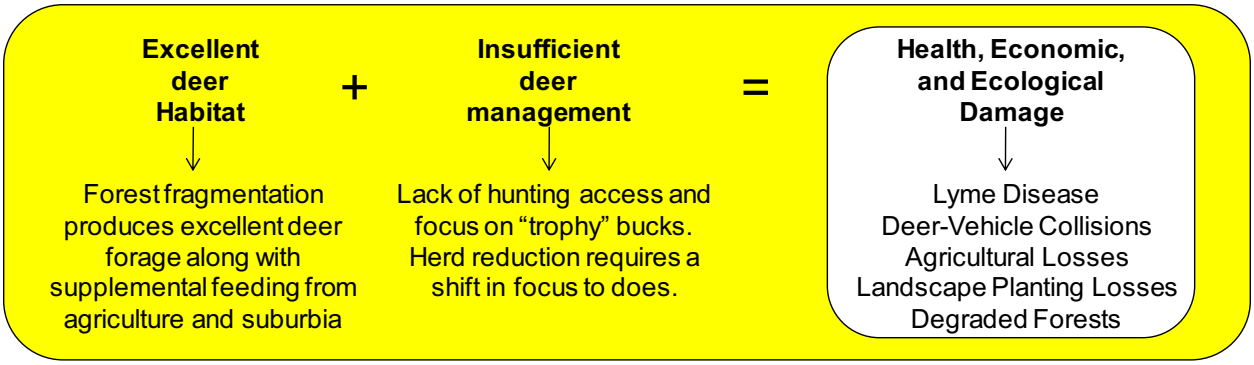
Special Note #1: Deer densities calculated by the Division of Fish & Wildlife are derived from harvest data and do not account for land inaccessible to hunting; therefore, they represent an under-estimate of actual deer population size. Species Note #2: Total population estimates are not available for 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 wildflowers. 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 are having a dramatic negative impact on the Property. Most native forest wildflowers are severely browsed, and populations are sparse. Both the "Empty Forest Syndrome" (no understory plants) or "Infested Forest Syndrome" (only unpalatable invasive understory plants) can be found on the Property. Herd reduction to 20 deer per square mile (or as low as 10 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 a robust deer management program with paid hunters to dramatically reduce herd size.

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 have long been 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 to mitigate periodic large outbreaks. 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 moderately aged 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 the 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 Property. 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 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).

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, 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 that 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 from 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 phosphorus, 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 4. Actual data showing changes in forest and untilled soil measured in Hopewell Township, Mercer County, New Jersey are presented in Figure 5.

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 on native plants that have the ability to survive these altered soil conditions.

Figure 4. Suspected Impacts of Past Agricultural Tilling

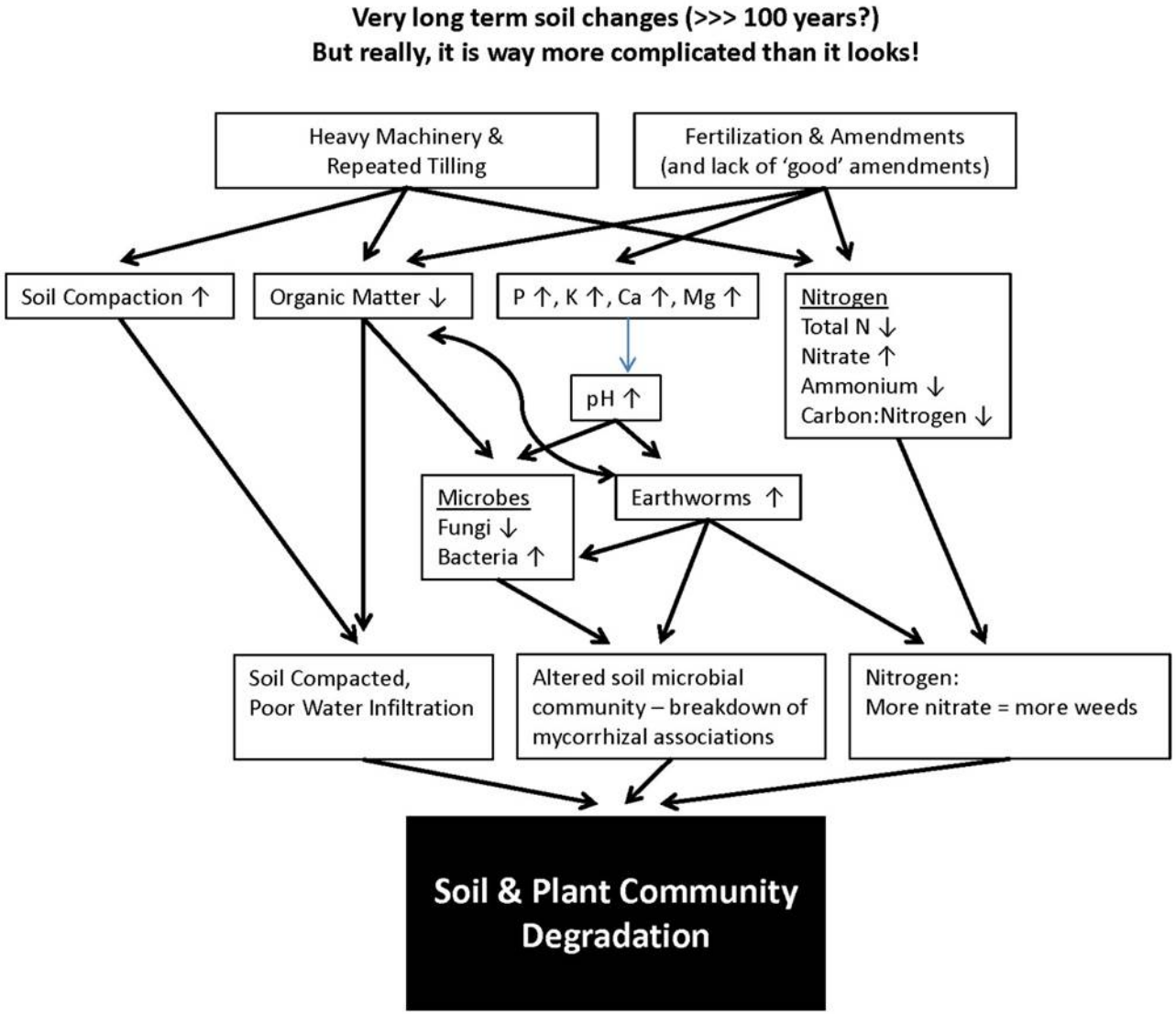
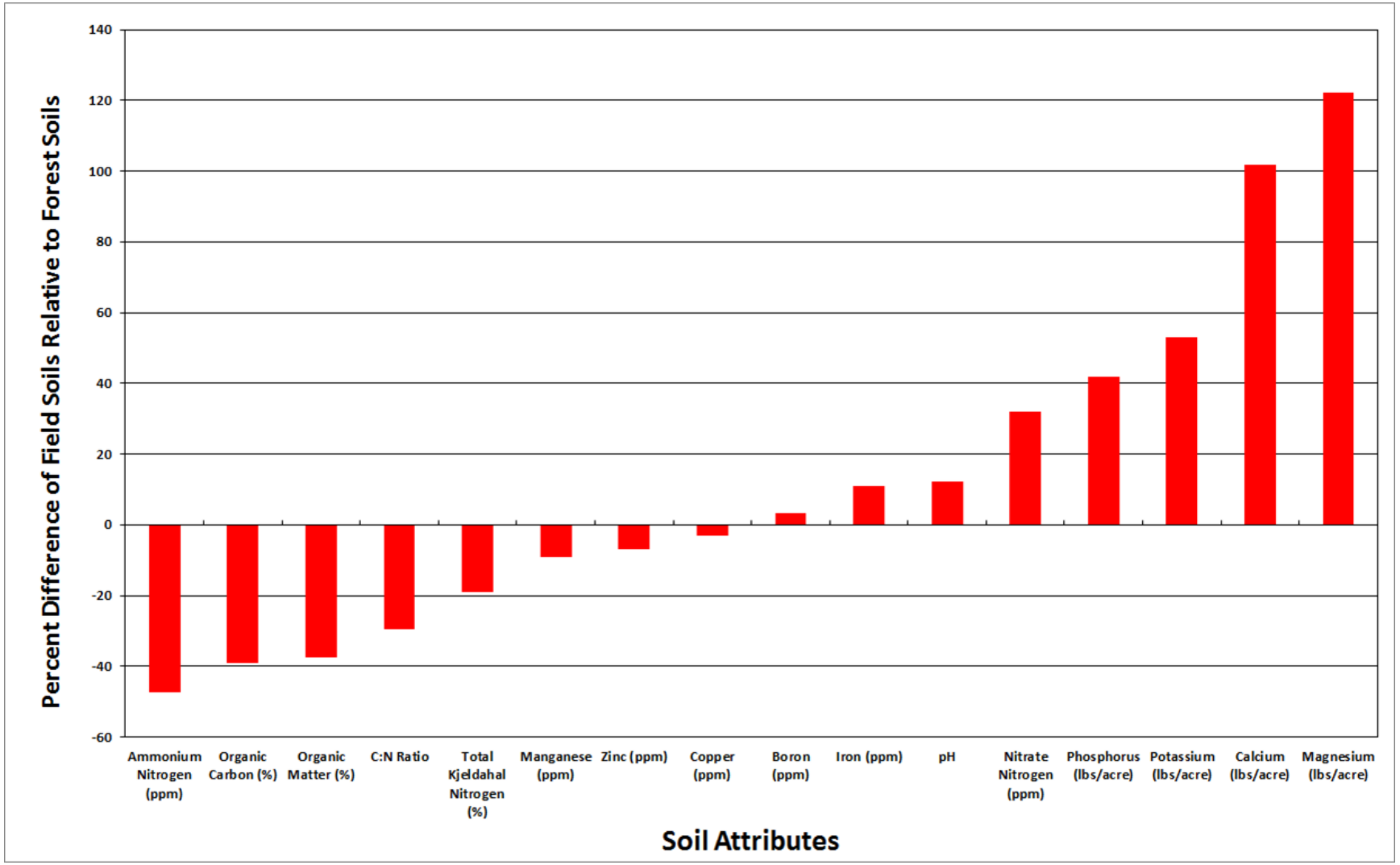


Figure 5. Measured Chemical Changes in Soils from Tilled and Untilled Soils



Stewardship Context

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

Physical Features

Geology and Topography- The Property primarily occurs on the limestone geology (505 acres or 98% of Property) with notable amounts of limestone outcrops (90 acres or 17% of Property) - See Map 2.

The Property has a generally flat to rolling topography with elevations ranging from 500 to 520 feet above sea level (Map 3). Relatively rolling topography is generally associated with outcrops oriented Northeast-Southwest, typical of formerly glaciated portions of New Jersey.

Forest Cover - Historic and Current

Historic and current forest cover is depicted on Maps 4-7 and summarized in Table 3. In 1890 (Vermeule), forest cover accounted for 38% of the Property. In 1930, forest cover rose slightly to 43%. In 2022, we mapped a significant increase to 66% of the Property. Current forest includes approximately 185 acres (36% of the Property) mapped as forest in 1890. These older forests are higher quality than forests that arose from former agricultural lands since 1930, making them a higher priority for stewardship efforts relative to younger and more degraded forest patches.

Table 3. Historic and Current Forest Cover
Note: 1930 aerial photography is poorly aligned / only partially accurate for the Property

Year	Acres	% of Property
1890	194	38
1930	222	43
2022	341	66
1890 and 1930	149	29
1930 and 2022	207	40
1890 and 2022	185	36

Section II. Conservation Values

Introduction

This section provides results of ecological community mapping performed throughout the Property and is informed by conservation 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.

The primary habitat conservation targets are: 1) limestone fen communities (globally rare), 2) habitat for Northern Metalmark Butterfly (globally rare), 3) mature limestone forest, 4) special plant species and communities of statewide importance, and 5) pollinator meadows.

Ecological Communities

Ecological communities, within the context of 'invasive species stands' were mapped at the Property from June through September 2022. All mapped patches conform to the boundaries of mapped stands provided by NJ Audubon in May 2022, but individual stands contain multiple mapped patches to show distribution of invasive species within each forest stand.

Mapped patches were delineated through a process of crosschecking between four sources of information, which included field survey, NJ Audubon forest stands, 1930 & 2015 aerial orthophotography, GIS-based 2015 land cover classifications and NJDEP GIS wetland status. Field observations of species present within the canopy, shrub, and herbaceous layers were recorded and correlated with a 'signature' on aerial photography. Ecological community patches occurring within the Property were assigned broad (e.g., Forest, Woodland, etc. – See Table 4 and Appendix A for raw mapping data for each mapped patch).

There were a total of 209 mapped patches across 515 mapped acres (Map 8). 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

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. 70% of Property) are the dominant natural ecological communities (Map 9). Woodland/meadow mosaic accounts for 5% and meadows account for 10%. Lakeshore communities, including globally rare limestone fen, account for 3.2% of the Property (ca. 17 acres). Developed lands, agricultural lands, and open water are approximately 1%, 2% and 13%, respectively.

Natural communities were also divided into moisture categories determined by affinities of plant species present and landforms (Table 4, Map 10). These categories included upland, wetland and transitional (areas with components including upland and wetland species and mixed landforms). Upland, transitional, and wetland types accounted for approximately 84%, 8%, and 8% of natural habitats on the Property, respectively.

Table 4. Broad Ecological Community Type Summary

Community Type	Acres	Percent of Property	Percent of Natural Habitats
Forest	305.2	59.3	69.1
Woodland	30.6	5.9	6.9
Shrubland	1.7	0.3	0.4
Mosaic - Woodland/Meadow	26.4	5.1	6.0
Meadow	51.3	10.0	11.6
Lakeshore - Fen Areas	7.9	1.5	1.8
Lakeshore - Meadow	8.6	1.7	1.9
Lakeshore - Shrubland	0.1	0.0	0.0
Hay Field	10.1	2.0	2.3
Urban	5.3	1.0	N/A
Water	67.4	13.1	N/A
Totals	**515**	**100**	**100**

Habitat Type Moisture Categories (Natural Habitats Only)	Acres	Percent of Property
Upland	372.7	84.3
Transitional	36.5	8.3
Wetland	32.9	7.5
N/A (Urban/Water)	72.7	16.4
Totals	**515**	**100**

Globally Rare Communities Limestone fens are considered the highest priority on the Property. They are globally rare communities that are under great stress from a growing infestation of Phragmites – see Sections III and IV for details on impacts and stewardship, respectively.

Flora & Fauna

Plant species were recorded during field surveys that had the primary purpose of mapping ecological communities and invasive species. Therefore, this list is not considered comprehensive. However, a comprehensive source is the White Lake Natural Resource Area Inventory and Management Plant, which compiled lists from botanists (The Nature Conservancy, 2003).

A total of 560 species were documented on the Property (Appendix B, summarized by growth form in Table 5). Species include 437 native species (78% of total number of species) and 123 non-native species (34 mapped as invasive species, see Section III).

The Natural Heritage Database search outlines numerous rare plant species. A large number of these are associated with limestone fens which are the highest priority for invasive species control recommendations. But other rare plants are reported, and might be found throughout the Property. Rare plant species were not the focus of field surveys, but a small population of the state rare American Ginseng was discovered on the Property.

Table 5. Plant Species Summary

Growth Form	Native	Non-native	Totals
Tree	44	8	**52**
Shrub	37	16	**53**
Vine	8	4	**12**
Graminoid	89	20	**109**
Ferns & Allies	38	0	**38**
Herbaceous	221	75	**296**
Totals	**437**	**123**	**560**

Animal species were not recorded during field surveys. The Property is expected to have the full complement of animals expected in the Limestone Valley region. Rare species are provided from the Natural Heritage Database Search.

The globally rare Northern Metalmark Butterfly occurs in a single area on the Property (although there were three areas in the relatively recent past). Impacts on this species and stewardship to encourage growth of the currently small population are provided in Sections III and IV.

Section III. Conservation Challenges

Introduction

This section describes an evaluation of the two primary threats to ecological health – overabundance of white-tailed deer and invasive species. The impacts of white-tailed deer and the extent and severity of invasive plant infestations were mapped from June to September 2022. The status of deer management on the Property is not known, however, deer impacts are significant throughout the Property. A consistent, successful deer management program can significantly improve ecological health in coming years.

The extent of invasive species infestation is severe. A total of 34 invasive species were detected with 64% of the Property having severe infestations of one or more species. Only 18% of the Property is considered virtually free of invasive species, while an additional 18% is lightly to moderately infested. The three most abundant species are Japanese Barberry, Autumn Olive, and Multiflora Rose. Importantly, there were eleven detected emerging invasive species or nascent populations of widespread species that should be eradicated. This strategy is referred to as early detection / rapid response, which is the most cost effective method to avoid future degradation of ecological health.

Extensive photographic documentation of current conditions is provided at the end of this section.

Evaluation of White-tailed Deer Impacts

Nearly all forest habitats on the Property show either the "Empty Forest Syndrome" or the "Infested Forest Syndrome" (See Section I). Ecological impacts of white-tailed deer are severe with little forest understory growth of native trees, shrubs, and wildflowers and/or significant infestations of unpalatable invasive species. However, there are several exceptions with relatively higher tree regeneration and shrub layer cover – these areas exhibit that greatest relative quality and should be the focus of stewardship activities.

The regeneration of native trees is abysmal on the Property (Table 6). There were eight patches with notable amounts of trees seedlings > 3' tall. Generally, cover was low (1-10%). Notable exceptions did occur in small portions of the Property, including areas with thinning hemlock canopy.

Table 6. Tree Regeneration Summary

Habitat Patch ID	Patch Acres	Cover Category	Species
47	2.26	11-25%	Tulip Poplar (4'), Ironwood (8')
49	2.06	76-100%	Hickory, Elm, Ironwood (8')
50	1.62	1-10%	Sweet Birch, White Ash, Yellow Oak, Shagbark Hickory (3')
80	1.71	11-25%	Hackberry, Elm, Yellow Oak, Flowering Dogwood, Ironwood (8')
84	2.17	1-10%	Ironwood, Pagoda Dogwood, Red Oak (4')
85	7.79	1-10%	Whtie ash (3')
87	4.24	1-10%	White ash (4')
91	0.34	51-75%	Tulip Poplar (4'), Ironwood (dom), Black Tupelo, Sweet Birch (6')
Totals	**22.2**		

Native shrubs were very sparse. Approximately 22 acres of forest had > 50% shrub cover (primarily Spicebush) - mapped patches with higher shrub cover included #26, #27, #28, #104, #120, and #122.

Native forest wildflowers were very sparse. Approximately 21 acres of forest had > 25% wildflower cover (includes only 'conservative species' as defined by the Plant Stewardship Index) - mapped patches with higher wildflower cover included #7, #8, #10, #26, #27, and #127.

All areas with greater cover of regenerating trees, understory shrubs or understory wildflowers were associated with older forest patches, presumably due to healthier soils.

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 A for raw mapping data for each mapped patch.

It is important to note that all mapped patches were defined by forest stands delineated by NJ Audubon. However, individual stands contain multiple mapped patches to reflect intra-stand differences of invasive species.

Overall Scope

A total of 201 unique mapped patches totaling 442 acres were recorded (Map 8 and Table 7 - excludes water, agricultural, and urban cover types). The extent of invasive species infestation is severe. A total of 34 invasive species were detected with 64% of the Property having severe infestations of one or more species. Only 18% of the Property is considered virtually free of invasive species, while an additional 18% is lightly to moderately infested.

The most severe combined infestations, number of invasive species per patch, and maximum single species infestations (See Maps 11-13, respectively) tended to occur in former agricultural areas.

Areas without a history of agricultural tilling and a relatively dense tree canopy (e.g., healthy hemlock forest) tended to be areas considered to be "Clean" or have "Low" or "Moderate" infestation levels.

In general, canopy gaps and thinner canopy woodland habitat were 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. However, there were some minor exceptions (see above regarding areas with higher amounts of tree regeneration and understory native shrubs).

Table 7. 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 Natural Habitats
0*	"Clean"	80.5	18.2
1	Low	42.4	9.6
2	Moderate	10.5	2.4
3	Moderate	27.2	6.2
4	High	15.8	3.6
5	High	94.6	21.4
6	Very High	31.8	7.2
7	Very High	62.3	14.1
8	Extremely High	14.8	3.3
9	Extremely High	32.1	7.3
10	Extremely High	12.6	2.9
11	Extremely High	1.0	0.2
12	Extremely High	0.6	0.1
13	Extremely High	15.7	3.5
Totals		**442**	**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 Natural Habitats
0*	"Clean"	80.5	18.2
1	Low	42.4	9.6
2-3	Moderate	37.8	8.5
4-5	High	110.4	25.0
6-7	Very High	94.1	21.3
> 7	Extremely High	76.9	17.4
Totals		**442**	**100**

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

Individual Invasive Species

Each invasive species was assigned an 'Action Code' based upon its threat level to conservation values, current extent of infestation on the Property, and known invasive status in New Jersey (Table 8). Overall, 34 species are considered invasive – eleven should be subject to an eradication program and eighteen should be subject to a selective control program. Five species are not considered for active control.

The eleven 'Action Code 1' species include emerging invasive plant species or nascent widespread species that should be considered for eradication. 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 patches – this includes cover category across the mapped patch as well as specific GPS locations for selected populations (See "Individual Invasive Species Maps"). Table 9 includes population sizes and GPS coordinates for points taken during the field mapping (this list should not be considered exhaustive). Mapped points are depicted on Map 14.

Table 10 contains data for each invasive species from mapped patches, including the "Relative Infestation Index Category." This index provides a coarse characterization of both distribution and intensity of infested acreage. 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. The three most abundant species are Japanese Barberry, Autumn Olive, and Multiflora Rose. Three additional high abundance species include Japanese Stiltgrass, Asiatic Bittersweet, and Wineberry. Control recommendations for all invasive species are provided in Table 11.

Table 8. 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 Property	Eradicate all known occurences. Maintain continual searching and eradication	11	Beauty Bush, Broad Winged Thistle, European Buckthorn, Fuzzy Duetzia, Jetbead, Norway Maple, Oriental Photinia, Poison Hemlock, Siebold's Crabapple, Yellow Archangel, Yellow Iris
2	Species has widespread distribution within the Property and is considered highly threatening	Selective control - Focus on highest quality areas only	18	Amur Honeysuckle, Autumn Olive, Border Privet, Common Reed, Garlic Mustard, Japanese Barberry, Japanese Honeysuckle, Mile-a-Minute, Multiflora Rose, Morrow's Honeysuckle, Mugwort, Oriental Bittersweet, Purple Loosestrife, Reed Canarygrass, Tree of Heaven, Wineberry, Winged Burning Bush, Yellow Bedstraw
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 Property	No direct action	5	Black Locust, Cool Season Grasses, Japanese Stiltgrass, Sweet Cherry, White Mulberry
TOTAL			**34**	

Table 9. Invasive Species - Point Locations

Point ID	Scientific Name	Common Name	Population Size	Latitude	Longitude
1	Rhodotypos scandens	Jet Bead	10-100	40.997146	-74.920131
2	Rhodotypos scandens	Jet Bead	100-1000	40.998024	-74.921754
3	Carduus acanthoides	Broad Winged Thistle	100-1000	40.998991	-74.921928
4	Acer platanoides	Norway Maple	2-10	41.000683	-74.919596
5	Malus sieboldii	Siebold's Crabapple	2-10	41.002052	-74.915732
6	Rhamnus cathartica	European Buckthorn	2-10	41.002166	-74.914608
7	Deutzia scabra	Fuzzy Deutzia	2-10	41.002632	-74.914688
8	Deutzia scabra	Fuzzy Deutzia	11-100	41.003978	-74.911467
9	Linnaea amabilis	Beauty Bush	2-10	41.003897	-74.911113
10	Ailanthus altissima	Tree of Heaven	2-10	41.008982	-74.907762
11	Ailanthus altissima	Tree of Heaven	2-10	41.007493	-74.906680
12	Persicaria perfoliata	Mile-A-Minute	2-10	41.013483	-74.898541
13	Conium Maculatum	Poison Hemlock	2-10	41.013407	-74.895037
14	Lamium galeobdolon	Yellow Archangel	100-10	41.009482	-74.895519
15	Lamium galeobdolon	Yellow Archangel	1000+	41.002287	-74.898120
16	Rhamnus cathartica	European Buckthorn	2-10	41.001305	-74.907349
17	Malus sieboldii	Siebold's Crabapple	2-10	40.998456	-74.909360
18	Rhodotypos scandens	Jet Bead	10-100	40.998495	-74.909495
19	Malus sieboldii	Siebold's Crabapple	2-10	40.998551	-74.909636

Table 10. Invasive Species – Individual Species and Their Relative Infestation Levels

							Acreage by Percent Ground Cover Categories						
Scientific Name	Common Name	Action Code	Infestation Index Score[1]	Relative Infestation Index Category[2]	Number of Recorded Populations	Total Acres Present	Category 0: 0%	Category Trace: < 1%	Category 1: 1-10%	Category 2: 10-25%	Category 3: 25-50%	Category 4: 50-75%	Category 5: 75-100%
Acer platanoides	Norway Maple	1	0.5	Low	2	5.4	509.3	5.4	0.0	0.0	0.0	0.0	0.0
Ailanthus altissima	Tree of Heaven	2	43.0	Moderate	25	125.6	389.1	101.0	22.2	0.0	0.0	1.4	1.0
Alliaria petiolata	Garlic Mustard	2	54.7	Moderate	42	172.8	341.9	132.6	39.1	1.2	0.0	0.0	0.0
Artemisia vulgaris	Mugwort	2	89.7	Moderate	30	96.3	418.4	43.1	43.6	0.6	1.8	1.0	6.3
Berberis thunbergii	Japanese Barberry	2	487.0	High	96	300.1	214.6	101.2	60.8	45.4	45.4	47.3	0.0
Carduus acanthoides	Broad Winged Thistle	1	0.4	Low	1	4.0	510.7	4.0	0.0	0.0	0.0	0.0	0.0
Celastrus orbiculatus	Oriental Bittersweet	2	189.1	High	75	207.9	306.8	69.2	110.8	13.7	13.1	1.2	0.0
Conium Maculatum	Poison Hemlock	1	0.4	Low	1	4.4	510.3	4.4	0.0	0.0	0.0	0.0	0.0
Deutzia scabra	Fuzzy Deutzia	1	0.3	Low	2	3.2	511.5	3.2	0.0	0.0	0.0	0.0	0.0
Elaeagnus umbellata	Autumn Olive	2	297.0	High	92	320.5	194.2	175.9	73.5	16.8	46.4	6.6	1.4
Euonymus alatus	Winged Burning Bush	2	22.2	Moderate	22	150.1	364.6	142.1	8.0	0.0	0.0	0.0	0.0
Galium verum	Yellow Bedstraw	2	47.0	Moderate	2	9.4	505.3	0.0	0.0	0.0	0.0	0.0	9.4
Iris pseudacorus	Yellow Iris	1	0.5	Low	2	5.3	509.4	5.3	0.0	0.0	0.0	0.0	0.0
Lamium galeobdolon	Yellow Archangel	1	1.4	Low	2	14.2	500.6	14.2	0.0	0.0	0.0	0.0	0.0
Ligustrum obtusifolium	Border Privet	2	3.4	Low	9	19.9	494.8	18.3	1.6	0.0	0.0	0.0	0.0
Linnaea amabilis	Beauty Bush	1	0.4	Low	1	3.5	511.2	3.5	0.0	0.0	0.0	0.0	0.0
Lonicera japonica	Japanese Honesuckle	2	13.8	Moderate	8	19.9	494.8	6.8	13.1	0.0	0.0	0.0	0.0
Lonicera maackii	Amur Honeysuckle	2	1.4	Low	3	13.6	501.1	13.6	0.0	0.0	0.0	0.0	0.0
Lonicera morrowii	Morrow's Honeysuckle	2	79.7	Moderate	47	119.1	395.6	78.5	23.8	2.3	14.5	0.0	0.0
Lythrum salicaria	Purple Loosestrife	2	8.0	Low	14	26.6	488.1	21.3	5.0	0.0	0.3	0.0	0.0
Malus sieboldii	Siebold's Crabapple	1	1.8	Low	3	18.5	496.3	18.5	0.0	0.0	0.0	0.0	0.0
Microstegium vimineum	Japanese Stiltgrass	3	207.4	High	66	239.7	275.0	144.6	40.0	26.7	16.0	10.6	1.9
Morus alba	White Mulberry	3	0.4	Low	2	3.6	511.1	3.6	0.0	0.0	0.0	0.0	0.0
N/A	Cool Season Grasses	3	151.1	High	17	46.3	468.4	4.0	8.4	7.2	2.8	0.0	23.9
Persicaria perfoliata	Mile-a-Minute	2	1.5	Low	4	14.9	499.9	14.9	0.0	0.0	0.0	0.0	0.0
Phalaris arundinacea	Reed Canarygrass	2	10.6	Low	2	5.3	509.4	0.0	0.0	5.3	0.0	0.0	0.0
Photinia villosa	Oriental Photinia	1	0.1	Low	1	0.8	513.9	0.8	0.0	0.0	0.0	0.0	0.0
Phragmites australis	Common Reed	2	74.1	Moderate	54	16.6	498.1	0.1	0.9	0.2	1.5	0.9	12.9
Prunus avium	Sweet Cherry	3	1.1	Low	4	10.8	504.0	10.8	0.0	0.0	0.0	0.0	0.0
Rhamnus cathartica	European Buckthorn	1	0.4	Low	5	4.0	510.7	4.0	0.0	0.0	0.0	0.0	0.0
Rhodotypos scandens	Jetbead	1	7.7	Low	5	25.5	489.2	19.8	5.7	0.0	0.0	0.0	0.0
Robinia pseudoacacia	Black Locust	3	0.9	Low	2	4.2	510.5	4.0	0.0	0.2	0.0	0.0	0.0
Rosa Multiflora	Multiflora Rose	2	230.6	High	92	287.1	227.7	134.3	100.6	39.9	12.2	0.0	0.0
Rubus phoenicolasius	Wineberry	2	180.6	High	82	272.4	242.3	152.1	78.0	41.1	0.2	0.4	0.7
Totals					**815**								

[1] The Infestation Index Score combines the extent of acreage infested and the intensity of the infestation. It was derived by multiplying the cover class number by the number of acres within each cover class.

[2]The Relative Infestation Index Categories include Low, Medium and High to represent Infestation Index Scores of < 10, 10-100 and > 100, respectively.

Table 11. Invasive Species - Species-Specific Control Strategies and Methods

Common Name	*Scientific Name*	Growth Form	Action Code	Control Strategy	Control Methods
Amur Honeysuckle	*Lonicera maackii*	Shrub	2	Selective control - Focus on highest quality areas only	Basal Bark, Foliar Spray, Cut Stump
Autumn Olive	*Elaeagnus umbellata*	Shrub	2	Selective control - Focus on highest quality areas only	Basal Bark, Foliar Spray, Cut Stump (winter only if using glyphosate), EZ-Ject w/imazapyr
Beauty Bush	*Linnaea amibilis*	Shrub	1	Eradicate all known occurences. Maintain continual searching and eradication	Basal Bark, Cut Stump
Black Locust	*Robinia pseudoacacia*	Tree	3	No direct action	Basal Bark, Hack-and-Squirt, Foliar Spray, Cut Stump (winter only if using glyphosate) - Most effective herbicide is aminopyralid
Border Privet	*Ligustrum obtusifolium*	Shrub	2	Selective control - Focus on highest quality areas only	Basal Bark, Foliar Spray, Cut Stump
Broad Winged Thistle	*Carduus acanthoides*	Herb	1	Eradicate all known occurences. Maintain continual searching and eradication	Foliar Spray
Common Reed	*Phragmites australis*	Grass	2	Selective control - Focus on highest quality areas only	Foliar Spray, Cut Stump - Most effective herbicide is imazapyr; Consider cutting in early June and allowing regrowth to 3' tall before treating
Cool Season Grasses	*N/A*	Grass	3	No direct action	Foliar Spray
European Buckthorn	*Rhamnus cathartica*	Shrub	1	Eradicate all known occurences. Maintain continual searching and eradication	Foliar Spray, Basal Bark (July-Sept)
Fuzzy Deutzia	*Deutzia scabra*	Shrub	1	Eradicate all known occurences. Maintain continual searching and eradication	Foliar Spray, Basal Bark, Cut-Stump
Garlic Mustard	*Alliaria petiolata*	Herb	2	Selective control - Focus on highest quality areas only	Foliar Spray, Hand Pulling in May to avoid seed set (species is biennial)
Japanese Barberry	*Berberis thunbergii*	Shrub	2	Selective control - Focus on highest quality areas only	Basal Bark, Foliar Spray, Cut Stump
Japanese Honeysuckle	*Lonicera japonica*	Vine	2	Selective control - Focus on highest quality areas only	Foliar Spray (cut stems infesting trees prior to treatment)

Table 11 (continued). Invasive Species - Species-Specific Control Strategies and Methods

Common Name	*Scientific Name*	Growth Form	Action Code	Control Strategy	Control Methods
Japanese Stiltgrass	*Microstegium vimineum*	Grass	3	No direct action	Foliar Spray, Pre-Emergent Spray, Well-timed cutting (ca. mid August)
Jetbead	*Rhodotypos scandens*	Shrub	1	Eradicate all known occurences. Maintain continual searching and eradication	Foliar Spray, Cut Stump
Mile-a-Minute	*Persicaria perfoliatum*	Vine	2	Selective control - Focus on 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	2	Selective control - Focus on highest quality areas only	Basal Bark, Foliar Spray, Cut Stump
Mugwort	*Artemisia vulgaris*	Herb	2	Selective control - Focus on highest quality areas only	Foliar Spray (aminopyralid or triclopyr only) - Consider cutting in early June and allowing regrowth to 2' tall before treating
White Mulberry	*Morus alba*	Tree	3	No direct action	Foliar Spray, Basal Bark (July-September), EZJect (imazapyr), Cut Stump (winter only)
Multiflora Rose	*Rosa multiflora*	Shrub	2	Selective control - Focus on highest quality areas only	Foliar Spray, Cut Stump
Norway Maple	*Acer platanoides*	Tree	1	Eradicate all known occurences. Maintain continual searching and eradication	and-Squirt, Foliar Spray, Cut Stump (winter only if using glyphosate), EZ-Ject w/imazapyr
Oriental Bittersweet	*Celastrus orbiculata*	Vine	2	Selective control - Focus on highest quality areas only	Basal Bark, Foliar Spray, Cut Stump (winter only if using glyphosate), EZ-Ject w/imazapyr
Oriental Photinia	*Photinia villosa*	Shrub	1	Eradicate all known occurences. Maintain continual searching and eradication	Basal Bark, Foliar Spray, Cut Stump (winter only if using glyphosate), EZ-Ject w/imazapyr
Poison Hemlock	*Conium Maculatum*	Herb	1	Eradicate all known occurences. Maintain continual searching and eradication	Foliar Spray
Purple Loosestrife	*Lythrum salicaria*	Herb	2	Selective control - Focus on highest quality areas only	Foliar Spray, Presence of biological control beetles often preclude need for herbicide treatments

Table 11 (continued). Invasive Species - Species-Specific Control Strategies and Methods

Common Name	*Scientific Name*	Growth Form	Action Code	Control Strategy	Control Methods
Reed Canary Grass	*Phalaris arundinacea*	Grass	2	Selective control - Focus on highest quality areas only	Foliar Spray; Consider cutting in early June and allow ing regrow th to 1' tall before treating
Siebold's Crabapple	*Malus sieboldii*	Tree	1	Eradicate all know n occurences. Maintain continual searching and eradication	Foliar Spray, Basal Bark (July-September), EZJect (imazapyr), Cut Stump (w inter only)
Sw eet Cherry	*Prunus avium*	Tree	3	No direct action	Basal Bark, Hack-and-Squirt, Foliar Spray, Cut Stump (w inter only if using glyphosate), EZ-Ject w /imazapyr
Tree-of-Heaven	*Ailanthus altissima*	Tree	2	Selective control - Focus on highest quality areas only	Basal Bark, Foliar Spray, Cut Stump (w inter only if using glyphosate), EZ-Ject w /imazapyr
Wineberry	*Rubus phoenicolasius*	Shrub	2	Selective control - Focus on highest quality areas only	Foliar Spray, Cut Stump
Winged Burning Bush	*Euonymus alata*	Shrub	2	Selective control - Focus on highest quality areas only	Basal Bark, Foliar Spray, Cut Stump
Yellow Archangel	*Lamium galeobdolon*	Vine	1	Eradicate all know n occurences. Maintain continual searching and eradication	Foliar Spray
Yellow Bedstraw	*Galium verum*	Herb	2	Selective control - Focus on highest quality areas only	Foliar Spray
Yelllow Iris	*Iris pseudacorus*	Herb	1	Eradicate all know n occurences. Maintain continual searching and eradication	Foliar Spray

Relative Patch Quality and Stewardship Priority

Table 12 contains a summary of relative patch quality and stewardship priority. Patch quality is a subjective characterization based upon the following attributes: invasive species cover, native shrub and wildflower cover, and presence of regenerating native trees. The relative quality ranks were 'High' or 'Moderate' across 240 acres (ca. 54% of the natural habitats) and 'Low' for remaining areas (Map 15).

The underlying conservation importance, along with relative quality rankings were used to determine stewardship priorities. Strategies by plan goals are provided in Section IV and summarized in Table 12 below. A total of 154 acres have been identified as having the highest stewardship priority (Map 16).

In some cases, there are disconnects between 'relative quality rank' and 'stewardship priority rank' (i.e., high priority despite relatively low quality). This generally reflects the low community quality of habitats for Northern Metalmark Butterflies that contain high invasive species cover. For forests, all high stewardship priorities are aligned with areas of low invasive species cover.

Special attention was paid to past and present lakeshore communities because of the presence of globally rare limestone fens. Since 2000, total acreage containing Phragmites has doubled, with large increases in the highest cover class (76-100% cover). See Section IV for additional information.

Table 12. Relative Patch Quality and Stewardship Priority Summary

Relative Quality Rank	Acres	Percent of Natural Habitats
High	130	29.4
Moderate	110	24.9
Low	202	45.7
Totals	**442**	**100**

Stewardship Priority Rank	Acres	Percent of Natural Habitats
High	154	34.8
Moderate	97	22.0
Low	191	43.2
Totals	**442**	**100**

Table 13. Highest Stewardship Priority Patches

Project Area	NJA Forest Stands	Patch Numbers	Total Patch Acres	Stewardship Recommendations	Priority Invasive Species	Priority Native Species
Limestone Fens - Goal 2-2: Phragmites Broadcast Treatments from Lake Side	N/A	48, 49, 52, 77, 78, 79, 80, 87, 91, 93, 159, 179, 180, 181, 182	4.3	Broadcast spraying of Phragmites -- Sensitive habitats not within or immediately adjacent to Phragmites	Phragmites	Diversity of wildflowers, graminoids and shrubs
Limestone Fens - Goal 2-2: Hybrid Phragmites Treatment - Hand Treatment from Shore Side to Create Buffer Before Broadcast Treatments from Lake Side	N/A	60, 66, 68, 100, 153, 184, 191, 195, 196, 198, 199	4.4	Hybrid Phragmites Treatment -- Senstive habitats immediately adjacent to Phragmites, hand treat these areas to provide safe buffer prior to broadcast spraying from the lake side	Phragmites	Diversity of wildflowers, graminoids and shrubs
Limestone Fen - Goal 2-2: Very Senstive Areas - Phragmites Hand Treatments Only	N/A	53, 59, 61, 62, 63, 64, 65, 67, 69, 70, 71, 72, 74, 75, 82, 83, 84, 85, 88, 89, 90, 95, 96, 97, 98, 99, 101, 149, 150, 151, 152, 154, 157, 158, 160, 161, 183, 185, 186, 187, 188, 189, 190, 192, 193, 194, 197	8.0	Hand treatment of Phragmites only -- Sensitive habitats co-minged with Phragmites	Phragmites	Diversity of wildflowers, graminoids and shrubs
Limeston Fen - Goal 2-2: Treat Japanese Barberry and Thin Red Cedar to Support Grass of Parnassus	N/A	59, 61, 62, 63, 64, 65, 67, 69, 70, 71, 72, 74, 75, 186, 187, 190, 193, 194	0.9	Provide additional sunlight to Grass of Parnassus by 1) Selective thinning of Red Cedar and control; 2) Cut stump treatments of Japanese Barberry in winter. This should be done in consultation with Max McCarthy, Rutgers graduate student studying Grass of Parnassus.	Japanese Barberry	Grass of Parnassus and other fen elements
Northern Metalmark - Goal 2-3: Protect Population Core (Knoll)	8	117	0.3	1) Cut stump treatments of woody invasive plants in winter, 2) Hand cutting or pulling of Japanese Stiltgrass in mid-August. Care should be taken to avoid trampling patches of Roundleaf Ragwort where	Moderate amounts of Autumn Olive, Small amounts of Wineberry, Japanese Barberry, Asiatic Bittersweet, Japanese Stiltgrass	Roundleaf Ragwort (larval food plant), Black-eyed Susan and Oxeye Sunflower (nectar food plant)
Northern Metalmark - Goal 2-3: Support Larval Food Plants. Areas include Red Cedar Forest/Woodland.	8	113, 114, 115	1.9	1) Cut stump treatments of woody invasive plants in winter (avoiding trampling dense patches of Roundleaf Ragwort where Metalmark catepillars overwinter), 2) Thinning of Red Cedar is not currently warranted because there are large amounts of Roundleaf Ragwort. If numbers of ragwort reduce over time, careful mild thinning should be considered.	Large amounts of Wineberry, Asiatic Bittersweet, Autumn Olive, and Japanese Stiltgrass. Small amounts of other woody invasive shrubs.	Roundleaf Ragwort (larval food plant)

Table 13 (continued). Highest Stewardship Priority Patches

Project Area	NJA Forest Stands	Patch Numbers	Total Patch Acres	Stewardship Recommendations	Priority Invasive Species	Priority Native Species
Northern Metalmark - Goal 2-3: Support Nectar Food Plants. Areas include restored pollinator meadow and pollinator strips.	8	116, 118, 162, portion of 115	1.8	1) Annually mow to reduce woody invasive species (especially Wineberry), 2) Selective treatment to thin woody invasive species, 3) Annually create patches for seeding of Black-eyed Susan and Butterfly Milkweed. Create 3 x 10 square foot patches annually by spraying all existing vegetation, utilizing a rake to expose mineral soil, and applying heavy seeding of Black-eyed Susan. These species do not typically hold their ground and are outcompeted by more agressive species. Therefore, patches need to be constantly created to assure adequate nectar sources.	Large amounts of Wineberry, Asiatic Bittersweet, Autumn Olive, and Japanese Stiltgrass. Small amounts of other woody invasive shrubs. Note: Restored meadow (Patch 162) is largely free of invasive species.	Black-eyed Susan, Butterfly Milkweed, and Oxeye Sunflower (nectar food plant)
Additional High Priorities - Goal 2-4: American Ginseng	2	24	0.2	1) Less than 10 observed plants, additional survey in the vicinity is required to determine size and extent of population, 2) Consider installation of small exclosure to protect plants from deer browse, 3) Cut stump treatments of woody invasives in the immediate vicinity of ginseng plants, 4) After full survey completed and population evaluated, consider selective canopy thinning along with additinal exclosures and invasive species treatments to foster fruit production.	Small to moderate amounts of Multiflora Rose, Wineberry, Japanese Barberry, and Japanese Stiltgrass	American Ginseng

Table 13 (continued). Highest Stewardship Priority Patches

Project Area	NJA Forest Stands	Patch Numbers	Total Patch Acres	Stewardship Recommendations	Priority Invasive Species	Priority Native Species
Additional High Priorities - Goal 2-4: Meadows	N/A	146, 155	9.5	1) Mow each patch every other year to reduce woody species, 2) Selective treatment of woody invasives using basal bark or cut stump treatments, 3) Selective treatment of Mugwort in October using Milestone foliar spray -- If unchecked, Mugwort can dominate these meadows. These meadows have an infestation of Yellow Bedstraw, but this species would be nearly impossible to eliminate without destroying native species. At the moment, it appears that the bedstraw is co-occurring with native species, not wiping them out.	Small to moderate amounts of Autumn Olive, Multiflora Rose, Mugwort, and Purple Loosestrife [Note: an emerging population of Sickleweed was eradicated, but constant vigilence is recommended]	Variety of native wildflowers and grasses
Additional High Priorities - Goal 2-4: Vernal Pools	1	4, 6	0.5	Vernal pools provide breeding habitat for many amphibians. At present, there are no required stewardship actions. If woody invasives begin to esblish, then they should be eliminated.	Moderate amounts of Japanese Stiltgrass	Variety of native wildflowers and grasses
Additional High Priorities - Goal 2-4: Limestone Forest	1	1, 9	63.9	These forests are dominated by hemlock and contain relatively small amounts of native understory species or invasive species. 1) Selective control of woody invasive species.	Very small amounts of Tree-of-Heaven, Garlic Mustard, Japanese Barberry, Autumn Olive, and Winged Burning Bush	Variety of native trees, shrubs, wildflowers, and grasses
Additional High Priorities - Goal 2-4: Limestone Forest	2	10, 17, 22, 25, 26, 28	27.6	These forests are somewhat variable, but all have very low amounts of invasive species. Patch #10 contains the richest diversity and highest ground cover of native forest wildflowers. Patch #28 contains dense Spicebush. 1) Selective contrl of woody and herbacous invasive species.	Small amounts of Tree-of-Heaven, Japanese Barberry, Asiatic Bittersweet, Autumn Olive, Winged Burning Bush, Japanese Honeysuckle, European Buckthorn, Multiflora Rose, Japanese Stiltgrass, and Garlic Mustard	Variety of native trees, shrubs, wildflowers, and grasses
Additional High Priorities - Goal 2-4: Limestone Forest	3	36, 37	5.8	These forests have relatively large amounts of tree regeneration and good diversity of native wildflowers. 1) Selective control of woody invasive species.	Moderate amounts of Japanese Barberry and small amounts of Autumn Olive and Morrow's Honeysuckle	Variety of native trees, shrubs, wildflowers, and grasses

Table 13 (continued). Highest Stewardship Priority Patches

Project Area	NJA Forest Stands	Patch Numbers	Total Patch Acres	Stewardship Recommendations	Priority Invasive Species	Priority Native Species
Additional High Priorities - Goal 2-4: Limestone Forest	4	40	2.1	These forests have a dense Spicebush layer. 1) Selective control of woody invasive species.	Small amounts of Japanese Barberry, Asiatic Bittersweet, and Autumn Olive	Variety of native trees, shrubs, wildflowers, and grasses
Additional High Priorities - Goal 2-4: Limestone Forest	5	43, 45	9.7	These forests have very high diversity of native wildflowers, but they are severely hampered by overabundant deer. 1) Selective control of woody invasive species.	Small amounts of Japanese Barberry, Autumn Olive, Winged Burning Bush, Border Privet, and Morrow's Honeysuckle	Variety of native trees, shrubs, wildflowers, and grasses
Additional High Priorities - Goal 2-4: Limestone Forest	7	104	1.4	This forest, despite not consisting of older growth forest, has a good diversity of native wildflowers and understory trees/shrubs. 1) Selective control of woody species.	Small amounts of Multiflora Rose, Asiatic Bittersweet, Japanese Barberry, Morrow's Honeysuckle, Autumn Olive and Japanese Stiltgrass	Variety of native trees, shrubs, wildflowers, and grasses
Additional High Priorities - Goal 2-4: Limestone Forest	9, 10	122, 127	2.8	These forests have very high diversity of native wildflowers, but they are severely hampered by overabundant deer. 1) Selective control of woody invasive species.	Small amounts of Multiflora Rose, Asiatic Bittersweet, Japanese Barberry, Morrow's Honeysuckle, Autumn Olive and Japanese Stiltgrass	Variety of native trees, shrubs, wildflowers, and grasses
Additional High Priorities - Goal 2-4: Limestone Forest - Riparian	11, 12	130, 133, 136	8.5	These forests are relatively healthy, especially for riparain forests. 1) Selective control of woody invasive species using cut stump applications.	Small amounts of Multiflora Rose, Asiatic Bittersweet, Japanese Barberry	Variety of native trees, shrubs, wildflowers, and grasses
TOTAL			**153.7**			

Photographic Documentation

Nearly all forests on the Property exhibit either the “Infested Forest Syndrome” (above; condition occurs where high deer densities occur in areas formerly plowed for agricultural use leading to infestations) 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).

In general, canopy gaps are leading to increases of invasive species and not leading to tree regeneration. Hemlock forest canopy gap (above and below).

In general, canopy gaps are leading to increases of invasive species and not leading to tree regeneration. Loss of ash due to Emerald Ash Borer and resulting increase of invasive species (above and below).

Many native shrubs and trees are heavily browsed.
Spicebush with heavy browse (above) and browsed
with dense stand of Japanese Barberry in background (below).

Species most sensitive to deer browse are often only found as small specimens.
Red Oak (above), Maple-leaved Viburnum (below)

The most notable exceptions to tree regeneration occur in areas less accessible to deer and receiving significant light levels. Within marl works (above), stand of Ironwood on a steep slope below thinning hemlock (below).

However, there were some isolated exceptions.
Tulip Poplars (above), Red Oak (below)

With minor exceptions, native understory shrubs are very sparse on the Property.
But native Spicebush occurs in several areas (above and below).

There was an isolated narrow limestone rock outcrop area that exhibited excellent forest health. Physical example of outcrop (above) and oak and hickory regeneration (below).

There was an isolated narrow limestone rock outcrop area that exhibited excellent forest health. Solomon's Seal with fruit (above) and Purple-node Joe-Pye (below).

Other special communities included Hemlock Forest (above) and Vernal Pools (below).

Globally rare Northern Metalmark Butterfly.
A knoll with thin soil is the epicenter of the population (above)
that harbors its sole larval food plant, Senecio obovatus (below).

Globally rare Northern Metalmark Butterfly.
Adjacent Red Cedar woodland is critical habitat of Senecio obovatus –
to varying degrees, invasive shrubs threaten Senecio populations (above and below).

Globally rare Northern Metalmark Butterfly.
Previous stewardship (tree girdling) to encourage Senecio has led to invasive species proliferation (above).
Pollinator strips to encourage nectar food plants have led to invasive species proliferation (below).

Meadow habitat near the parking lot is providing excellent pollinator habitat.
Butterfly Milkweed (above) and Tiger Swallowtail on Wild Bergamot (below).

Limestone fen communities found at White Lake are globally rare.
There are herbaceous / low shrub types (above) and mixed shrub / Red Cedar types (below).
Both types have exceptional diversity of herbaceous plants.

Limestone fens feature Picher Plants (above) and
Grass of Parnassus (below, red flags marking plants being studied by Max McCarthy from Rutgers University).

Phragmites has already destroyed multiple areas of limestone fens. The leading edge often starts sparsely, and individual stems can be treated without harm to the fens (above). Dense stands eventually lead to the complete elimination of fen plants (below), but multiple areas have a mixture of Phragmites and fen plants.

Where fens meet woodland edges, Japanese Barberry becomes problematic (above).
In some areas, fens are being squeezed from the lakeside by Phragmites and the woodland side by barberry (below).

Invasive Species of Particular Concern:
Yellow Archangel (above) is not a typical invasive plant,
but a large patch was discovered, and it should be eradicated.

European Buckthorn (below, right) and Oriental Photinia (below, right) have few individuals on the Property. These species are particularly threatening and should be eradicated to prevent future damage.

Section IV. Strategies and Actions

Figure 6. 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. This plan has two primary plan recommendations. The first involves significant reduction of the deer population so that native plants can exert ecological control over invasive species. The second involves strategic invasive species control with multiple specific goals for the highest priority areas of the Property.

It is essential that a highly effective Deer Management Program continue in perpetuity. 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 will be present in perpetuity, but they are much less likely to form dense infestations with lower deer densities.

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

Goal #1-1: Reduce deer density to meet ecological health goals

The current deer population is too high, and decades of overabundance have led to profound ecological damage including the removal of most native vegetation below five feet and fostering extensive infestations by unpalatable invasive species. Deer density must be reduced to 20 deer per square mile (or as low as 10 per square mile to allow recovery of forest wildflowers). These goals will be challenging to meet on the Property, but it is hoped that a maximum density of 30 deer per square mile can be reached. A brief literature review to support this goal is provided below.

- 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.

Recommendation #2: Perform Strategic Invasive Species Control

A complete list of invasive species along with control goals (i.e., "Action Code") is provided in Table 8, number of populations by size categories and GPS locations are provided in Table 9 (please note that this is incomplete and additional populations may be discovered through stewardship efforts). Treatment prescriptions are available through the New Jersey Invasive Species Strike Team, which updates them annually based upon newly available information, but Table 11 provides a summary of species-specific control strategies and methods. Ecological control exerted by native species is the ultimate goal to curb invasive plant species, but this should not be expected without significant reduction of the deer herd (See Goal #1-1).

Goal #2-1: Eradicate 11 emerging invasive species (Action Code 1 species, 19 known populations)

- The goal is intended to reduce future damage by addressing species that have not yet established large, extensive populations throughout the Property. Accomplishing this goal will also fulfill 'ecological responsibility' by preventing spread of newly emerging harmful invasive species beyond the Property.
- See Table 8 for a list of species and Table 9 & Map 14 for locations

Emerging invasive species should be the highest priority for control efforts because they threaten the Property and the region with future ecological degradation. Nascent populations of widespread invasive species are also included in this goal to prevent their inevitable spread. 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 11 emerging and nascent widespread species designated as 'Action Code 1' (i.e., complete eradication is the ultimate goal). Currently, there are 19 mapped known populations of these 11 species (Table 9), but additional searching is likely to detect additional populations. Treatment guidance is provided in Table 11. Initial treatments on the large Jetbead population were performed by the Strike Team in September 2022. Eradication of each population for all 11 listed species should be completed by the end of 2023.

Goal #2-2: Protect and Enhance Globally Rare Limestone Fen Communities (16.7 acres, Maps 17 & 18)

- Control all lakeshore Phragmites with care not to damage limestone fens. Three strategies have been recommended:
    - Broadcast spraying from boat where limestone fens do not occur in the vicinity (4.3 acres)
    - Hand treatments from land where limestone fens co-occur with Phragmites (8.0 acres)
    - Hybrid of the above with hand treatment within/near sensitive areas to create a buffer, followed by broadcast spraying from a boat in nearby but less sensitive areas (4.4 acres)
- Protection of Grass of Parnassus (and its globally rare pollinator)
    - Control Japanese Barberry and thin Red Cedar along forest/fen edges
        - Consult with Max McCarthy, Rutgers graduate student

Map 17 depicts limestone fen communities including past and current fen distribution. Map 18 depicts the lakeshore Phragmites treatment plan.

Limestone fen communities are known for their unique plant species and assemblages of plant species. They are highly threatened by Phragmites, and immediate action is required to protect remaining fens. To gain control of all lakeshore Phragmites, it is recommended that three application methods be conducted based upon risk to harming fen communities (see above). Hand treatments may include foliar spraying with a backpack sprayer in some circumstances but cut stump treatments are required over a significant area. This will be arduous work likely to take 3-5 years with a concerted effort. But as Table 14 shows, this important work is required to save these globally rare communities.

Limestone fen communities and Phragmites infestations were mapped by K. Walz in approximately 2000, these findings were compared to findings from 2022 (See Table 14). Overall lakeshore Phragmites has more than doubled over the last 20 years. Importantly, dense infestations (76-100% cover) has significantly increased from 2.5 to 7.9 acres.

In 2000, there were 9.9 acres of fen communities and Phragmites was present in 2.4 acres of them. Fens mapped in 2000 now have Phragmites present in 5.5 acres, with the densest cover class more than doubling over the last 20 years.

Fen communities were re-mapped in 2022. There are currently 7.9 acres or 2.0 acres less than those mapped in 2000 (20% reduction) - some areas noted as fen in 2000 no longer had any fen-related species (e.g., Shrubby Cinquefoil), they were most often directly replaced with Phragmites or a combination of Phragmites and native non-fen specific wetland species (e.g., Bidens sp.). Phragmites is present in 3.3 acres of current fen areas with dense infestations in 0.9 acres. Without concerted stewardship effort, these globally rare communities will continue to diminish over time.

Grass of Parnassus is a unique element of limestone fens on the Property. It occurs within fens but appears to be particularly robust along portions of fens closer to the fen/forest edge. In addition to Phragmites, Japanese Barberry is an additional threat that should be treated using cut stump applications

in winter. Finally, it is possible that thinning of red cedar along the forest edge may increase light in support of Grass of Parnassus. Max McCarthy is a graduate student from Rutgers University that is studying the species. He should be consulted to formulate a cedar thinning strategy.

Table 14. Past and Present Lakeshore Fens and Phragmites

Phragmites Cover Class (%)	Entire Lakeshore Year - 2000	Entire Lakeshore Year - 2022		Phragmites Cover Class (%)	2000 Mapped Fen Areas - Year 2000	2000 Mapped Fen Areas - Year 2022		Phragmites Cover Class (%)	2022 Mapped Fen Areas - Year 2022
Absent	N/A	N/A		Absent	7.5	4.4		Absent	4.6
1-10	0.4	1.0		1-10	0.1	0.5		1-10	0.8
11-50	1.3	1.7		11-50	0.5	1.2		11-50	1.1
51-75	1.2	1.1		51-75	0.4	0.7		51-75	0.6
76-100	2.5	7.9		76-100	1.4	3.2		76-100	0.9
Total Acres	**5.3**	**11.8**		**Total Acres**	**9.9**	**9.9**		**Total Acres**	**7.9**

Goal #2-3: Protect and Enhance Globally Rare Northern Metalmark Butterfly Habitat (4.3 acres, Map 19)

- Maintain abundance of required larval food plant (Roundleaf Ragwort) and restore nectar plants
    - Larval Plants - Within Red Cedar woodlands, control woody invasive species such as Autumn Olive and Asiatic Bittersweet
        - Do not thin Red Cedar woodlands unless larval food plant diminishes in future
    - Nectar Plants - Restore nectar plants within existing pollinator strips through control of Wineberry and repeated planting of Black-eyed Susan and Butterfly Milkweed

Brief History

In 2005, David Norris performed a comprehensive review of all of New Jersey's Northern Metalmark Butterfly populations. He found that the population on the Property, specifically the Cabin Glade, was one of the largest populations in the state with a total of 42 observed adults. Norris also provided measures of habitat attributes associated with larger populations (see Appendix C).

The following are field notes taken by M. Bisignano during a 2005 visit from David Norris:
"Contains multiple colonies supported by habitat in various stages of succession. I have called these the Cabin Glade Population, the Route 521 Roadside Population (a.k.a. Maggie's Knoll) and the 521 Northside Population (a.k.a. Fish & Wildlife population). The latter population was not surveyed this year as no metalmarks were observed there in 2004. This population has the densest cedar stand of the three and likely requires considerable management to restore the habitat. The Route 521 Roadside appears to be in good condition. It is a rather small habitat in area but has an open canopy well below the 60% closure threshold. There is a limited, but acceptable number of nectar plants within the habitat in addition to the slope adjacent to the road which has approximately 35-40 *Rudbeckia* and *Chrysanthemum* plants. These plants are well within the 50m average dispersal distance. Removing the invasive shrubs that are found on site should increase habitat value. The Cabin Glades continues to be one of the most, if not the most densely populated habitats known. Canopy could be thinned, but good overall. Nectar plants are sufficient and in close proximity to the ovipositing areas. *Microstegium* and invasive shrubs may pose a problem if not addressed soon."

Important life history facts for Northern Metalmark butterflies include (See Appendix C for additional information):

- Adult flight/reproduction period is late June and July
    - Adults do not make long distance flights and are typically found within 150 feet of caterpillar hatching locations
- Larvae active and moving from April to June and August to September
    - They overwinter as small caterpillars under the leaves of Roundleaf Ragwort. Any invasive species control work should avoid trampling of large patches of ragwort.
- Nectar plants include species flowering during adult presence (i.e., June and July) including Black-eyed Susan, Butterfly Milkweed, Oxeye Daisy (non-native), and Spotted Knapweed (non-native).

Present Information

Map 19 shows previously documented populations of Northern Metalmark Butterflies within and immediately adjacent to the Property. This includes three locations on the Property (Cabin Glade, Maggie's Knoll, and Fen Edge). The Cabin Glade population has been reduced since 2005 but continues to support a small population (less than 10 observed individuals in 2022, S. Wander, personal communication). The other two previously recorded populations no longer support butterflies. Two additional populations are located nearby. The Fish & Wildlife population has received stewardship attention, but the current population status is unknown. The Private Property population located north of the Cabin Glade has been reported to be robust, but the current landowner does not allow access for surveys. If it is robust, it may serve to bolster the Cabin Glade once additional stewardship geared at increasing nectar plants is completed.

Map 19 shows the Cabin Glade habitat area. The primary population center is located on a limestone knoll (0.3 acres) containing both larval and nectar food plants. The main larval food plant areas (cedar forest containing Roundleaf Ragwort) cover 2.1 acres. Currently, the amount of larval food plants is adequate and does not limit the butterfly population size (S. Wander, personal communication). In the recent past there have been efforts to increase the quantity of adult nectar plants (e.g., Black-eyed Susan, Butterfly Milkweed). This work included clearing strips and patches and planting nectar plants covering 0.6 acres. Unfortunately, these areas have become infested with Wineberry. Deer browse and invasive species have combined to significantly hamper these efforts. An additional area received a full meadow restoration (1.3 acres, Patch #162). This area had an abundance of Black-eyed Susan, but they have greatly diminished as the meadow has matured. This pattern is typical in meadow restoration as Black-eyed Susan are quickly outcompeted by other wildflowers.

It is recommended that stewardship include annual introduction of Black-eyed Susan in three 10 square foot patches located within previously created nectar areas immediately adjacent to the population center. This should be accomplished through spraying of broad spectrum herbicide to kill all existing vegetation in early May, followed by raking to expose mineral soil and broadcasting seeds of Black-eyed Susan. Planted areas should receive perimeter fencing to protect them from deer (e.g., 5' tall, galvanized metal fencing using rebar posts). Because this species is transient (i.e., outcompeted within 2-3 years), a constant introduction program is required. Initial seeding should occur along the edges of the population center.

Goal #2-4: Protect and Enhance Additional High Priority Habitat Patches (130 acres, Map 15, Table 13)

- Primary strategy is control of Action Code 2 species in relatively high quality patches
    - Protect mature limestone forest (120 acres)
        - Initial focus on patches with the most diverse wildflowers
    - Protect habitat patches containing state listed rare plants and vernal pools (< 1 acre)
    - Protect priority meadow patches (10 acres)

Limestone Forest

Table 13 provides details on priority limestone forest patches located throughout the Property. It includes target invasive species with their generalized abundance. Notes are provided to assist with decisions on where to begin this important work (e.g., areas with higher amounts of native shrubs and native wildflowers may be the highest priority within this goal). Details on native and invasive species for each patch can be found in Appendix A. Treatment recommendations for individual species can be found in Table 11.

There are approximately 22 acres of forest that had > 50% shrub cover (primarily Spicebush) - mapped patches with higher shrub cover included #26, #27, #28, #104, #120, and #122.

There are approximately 21 acres of forest that had > 25% wildflower cover (includes only 'conservative species' as defined by the Plant Stewardship Index) - mapped patches with higher wildflower cover included #7, #8, #10, #26, #27, and #127.

State Listed Rare Plants and Vernal Pools

Vernal pools are vital to the reproduction of numerous amphibians. There are no current stewardship recommendations for these two habitat patches, but changes in the abundance of any invasive species should be addressed to maintain habitat quality.

During field surveys, American Ginseng was discovered in Patch #24 (0.2 acres). Less than 10 individuals were observed, only one plant had produced fruit in 2022. Invasive species notes are provided in Table 13 and additional details are provided in Appendix A.

Additional searching is critical to determine the true population size and condition for this species, which can be quite inconspicuous when not in flower or fruit. Once this has been conducted, more detailed stewardship recommendations can be formulated, including consideration for subtle canopy thinning to foster healthy plants - research suggests that a canopy cover of 80% is optimal for fruit production. Any canopy thinning should be preceded by invasive species treatments to avoid stimulating new infestations triggered by additional light resources.

Meadow Patches

There are numerous meadow areas on the Property, but the most significant are located at the main Property entrance (ca. 10 acres – See Table 13). These meadows are known for their plant diversity, beauty, and significance to a variety of butterfly species. The southeast portion of the meadow blends into lakeshore limestone fen habitat and features a robust population of gentians.

Stewardship is ongoing to reduce the cover of woody invasive species and native woody species. This should be continued to maintain less than 1% cover of woody plants. Mugwort occurs as small patches (e.g., along dock access road) and large patches (e.g., northwestern areas). This species is highly threatening and requires immediate treatment to prevent future degradation. It is recommended that all observed Mugwort areas be sprayed with Milestone in early October. This herbicide will eliminate all broadleaved species, leaving behind grasses.

Other meadows are either quite young (e.g., less than 2 years since hay field abandonment) or have dense infestations of Mugwort which would require complete restoration to become suitable habitat for pollinators.

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Pitcher Plants in flower within a limestone fen community on the Property