Managing Xeric Habitats for Native Bees, Moths, and other Species of Greatest Conservation Need

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# Executive Summary

A picture containing outdoor, tree, plant

Description automatically generatedThe Northeast Xeric Habitats for Pollinators project involved 20 sites from Maryland to Maine in a joint effort to measure the response of vegetation and bee communities to different habitat treatments. Bee and moth communities were also surveyed to correlate diversity and community composition with site conditions and characteristics. Although xeric sites in the region differ due to environmental factors, all sites share the habitat objective of maintaining lower percent cover of woody plants than most habitats in the northeast. A high-quality xeric habitat in the northeast U.S. typically has well-drained soils and fire-adapted vegetation with open tree canopies, abundant floral resources, and patches of bare soil. Depending on the vegetation, these habitats are referred to as sandplains, barrens, woodlands, and grasslands (Fig. 1).

Figure . Prescribed fire at the Scotia Barrens in Pennsylvania.

Based on the contributed information from all 20 sites (Fig. 2), 279 plant species were identified, 262 species of bees and 1447 species of moths were collected, and we learned several important things about xeric habitats in the Northeastern U.S.:

1. Even among sites that are self-described barrens or woodlands, environmental characteristics were important determinates of vegetation community and structure, and bee and moth communities.
2. Habitat management is effective at restoring and/or maintaining the rare obligate species that were the target of this study. Management treatments including canopy thinning, mowing, and fire resulted in decreases in total, tree, shrub, and woody vegetation and increases in early successional flowering plants, pollinator host plant taxa, and overall plant diversity.
3. Bees and Moths were more diverse in colder, drier sites, but moths were more diverse at sites with higher % cover, while bees were more diverse at sites that were managed for more open conditions.
4. Bees and moths showed a slight increase in species diversity during the timeframe of this project. Reflecting longer term benefits, sites with a history of habitat management and objectives that align with maintaining quality barrens conditions had higher plant and bee species diversity and management was successful in increasing the abundance of plants that are known to be important to pollinators. In contrast long-term management was associated with lower moth richness and abundance.

Map

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Figure . Site locations of xeric sites participating in the project.

Most site managers would prefer to incorporate prescribed fire in management plans to control percent cover of woody plants, but due to the significant constraints in implementing prescribed fire, other treatments such as canopy thinning, mowing, and herbicide are also used to achieve habitat objectives. The project recommends sites follow five steps when determining the best habitat treatments to restore or maintain high quality xeric habitats:

1. Assess the current condition of the site and compare with habitat condition targets (for percent cover of trees, shrubs, and grasses and forbs) and native bee and lepidoptera habitat requirements.
2. Identify the habitat management objectives necessary to achieve the habitat condition(s) targeted. Management objectives may be selected to effect specific changes in habitat structure or composition, as is necessary at pollinator restoration sites, or to preclude such change, as would be employed at site endeavoring to maintain existing, desirable conditions for pollinators.
3. Select and implement specific best management practices that most effectively advance the site’s management objectives. Best management practice selection may be based solely upon efficacy, or may also involve a need to acknowledge and accommodate site constraints.
4. Establish a rotational management strategy that allows units to remain undisturbed to provide unmanaged refugia for rare invertebrates.
5. Monitor site conditions to determine progress toward objectives and revise treatment approaches to continue to improve habitat quality.

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# Introduction

Xeric grassland and shrubland habitats in the northeastern USA are a relatively small and varied habitat type. Notwithstanding, due to their unique vegetative structure, soil conditions and historical fire regimes, they support a disproportionately large assemblage of globally-rare Species of Greatest Conservation Need (SGCN). In particular, many pollinator species depend on the open habitats, bare soils, and canopy gaps characteristic of these habitats, and recent studies suggest that in the Northeast, xeric, fire-influenced grasslands and woodlands support unique pollinator assemblages (Cloudsley-Thompson 1975, Wagner et al. 2003, Droege et al. 2009, Selfridge et al. 2017). A myriad of threats that pose significant risk to these habitats, including habitat fragmentation, losses associated with accelerated habitat succession, and the effects of fire suppression. Due to the rare species xeric sites support, management of these niche habitats has become a considerable focus of state and federal wildlife agencies, non-governmental organizations and academic institutions. However, due to the unique physiographic characteristics and anthropogenic histories, it has been challenging to determine best management practices to restore or maintain habitat quality.

To define how best to begin addressing this need, in 2018, the Northeast Association of Fish and Wildlife Agencies (NEAFWA) through the Northeast Fish and Wildlife Diversity Technical Committee (NEFWDTC), initiated a five-year project with the objective of identifying effective habitat management strategies for Xeric Habitats in the Northeastern U.S. The “Xeric Habitat for Pollinators” project was funded by all 13 states in the Northeast region and the District of Columbia. Each of their State Wildlife Action Plans identified the need to effectively conserve specific, rare species of lepidoptera known to be obligates of barrens and other xeric habitats along with the need to conserve other important native pollinator communities including the solitary, ground-nesting bees for the critical ecosystem services they provide. In particular, many rare, solitary, ground-nesting bees require the sandy soils, nectar resources and open canopies characteristic to high quality remnants of barrens and grassland throughout the northeast region.

To assess how to effectively manage these habitats and better understand their value, the Xerics project plan investigated five primary elements:

1. **Habitat management:** Sites implemented management strategies based on each sites’ unique conditions. Individual site management goals varied, with some locations “maintaining” existing (or previously restored) xeric or barrens conditions, and others working to “restore” habitats to a desired future condition that satisfies ecological goals. Management strategies employed a variety of tools used singularly and in combination including prescribed fire, canopy thinning, mowing/mastication, discing or scarification, herbicide use, and seeding.

Common habitat goals include managing vegetation to:

* 1. Promote native plant species **composition** by reestablishing native herbaceous plant communities, particularly host plants and nectar resources for rare lepidoptera and native bees.
  2. Restore open-canopied **structure** by limiting overstory and understory woody vegetation and exposing mineral soil.
  3. Eradicate invasive plant species.
  4. Reduce wildfire risk and re-establish the effective use of wildlife fire management.

1. **Vegetation monitoring:** A standardized system of vegetation transects were used to describe and evaluate plant species composition and structure before and after habitat management.
2. **Bee monitoring:** Transects of bee bowls were used to sample bee communities before and after habitat management.
3. **Nocturnal Lepidoptera monitoring:** Black light traps were used to evaluate the nocturnal lepidoptera community at most sites.

## The Need for Investigation

All reports and journal articles about this habitat type describe the importance of frequent fire, including the historical use of fire by indigenous peoples to maintain open understories, grassy areas, and pathways (e.g. (Heikens and Robertson 1995, Stewart 2002, Wagner et al. 2003, Droege et al. 2009, Petersen and Drewa 2009, Woodside 2016, Abrams and Nowacki 2021, Hoffman et al. 2021). Frequently referred to as a type of Young Forest habitat, characteristic vegetation endemic to these habitats requires disturbance (Oehler et al. 2006).

Prior to the modern practice of fire suppression (beginning ~1910), habitat conditions in Northeastern grasslands and barrens were maintained by the physical and chemical properties of their xeric soils, site topography, local climate, and relatively frequent fires (<~20 year fire return interval) with variable severity (Forman and Boerner 1981, Sohl 2003). The occurrence of fire in the landscape was historically of both natural (e.g., lightning) *and* anthropogenic (First Nation Peoples) origin (Marye 1955, Abrams and Nowacki 2021). Indigenous Fire Stewardship (IFS) was particularly important to maintaining the high frequency fire regimes necessary to maintain barrens, grassland and savannahs for several thousand years prior to European colonization (Stewart 2002). On some sites, grazing was responsible for maintaining early successional plant communities (Poulos et al. 2020).

With the onset of modern anthropogenic fire management, wildfire suppression and mitigation became the societal priority. Wildfire mitigation relied heavily upon the use of prescribed fires to reduce combustible fuels on the forest floor and lessen the probability of severe and uncontrollable wildfires. When used systematically, prescribed fire can manipulate the composition, structure and function (e.g., reduce woody cover, expose mineral soil, stimulate seed production and germination, etc.) of fire-adapted ecosystems to produce highly diverse and desirable habitats for plant and animal species. However, achieving such results requires a purposeful fire prescription - typically one that differs meaningfully from prescriptions intended solely to mitigate wildfire risk.

Achieving desired habitat conditions at a xeric site after many decades of fire suppression presents unique challenges. In the prolonged absence of wildland fire, many sites are at an increased risk of a high severity crowning fire. If prescribed fires are to be employed to help restore or reset vegetative community or structure, it is typically necessary to burn sites at various times throughout the year (growing season and dormant season) and at various intensities. Such prescribed fires can conflict with concerns regarding other user groups utilizing these habitats and/or the potential risk of fire and smoke affecting adjacent land uses and communities. The northeastern United States are heavily developed and create complex wildland-urban interface issues that complicate the use of fire, even when proposed via low-intensity prescribed burns. While many land managers are still able to employ effective prescribed fire, others have developed alternatives including tree thinning, shrub removal, mowing, herbicides, and direct seeding. While these alternatives cannot achieve all of the beneficial effects of fire, particular with respect to nutrient cycles, they can be used as precursors to prescribed fire by reducing fuel loading and achieving some important plant community compositional and structural changes. Numerous studies have supported the need for prescribed fire to maintain barrens (e.g., (Olson 2011)), but fewer studies are available to assess the opportunities associated with these alternative habitat management approaches.

# What is a xeric habitat?

Xeric habitats are characterized by exceptionally dry, well-drained and nutrient poor soils compared to other habitats (e.g., mesic and hydric habitats). Depending on the composition and structure of the dominate vegetation such habitats are sometimes referred to as “barrens.” Defined by NatureServe, barens are “areas of persisting sparse, low, open, or otherwise distinctive vegetation (when compared with characteristic vegetation of the region), typically on thin, patchy soils or rocky substrates, often with unusual rock or soil chemistry or in special topographic settings.” (NatureServe 2023)

*A high-quality xeric habitat in the northeast U.S. typically has well-drained soils and fire-adapted vegetation with open canopies, abundant floral resources, and patches of bare soil. Depending on the vegetation, these habitats are referred to as sandplains, barrens, woodlands, and grasslands.*

In the Northeast U.S., remnant xeric habitats have well-drained and sometimes deep mineral soils comprised of sand, shale, or other rocky substrate which provide dry conditions despite occurring in an otherwise humid, temperate climate, frequently near lakes, rivers, streams, or wetlands (e.g. (Sohl 2003, Quigley 2020, Corbin and Flatland 2022). These habitats occur throughout the northeastern United States. Given their current distribution, plant species composition and relative sessile rare wildlife populations these habitats were likely larger and more connected in the distant past. However, contemporary xeric habitats supporting remnant SGCN wildlife populations are often small in spatial extent and isolated from other similar habitats. For example, an assessment of deep, sandy soils throughout New York State determined that about 6.7% (9500 km2) of terrestrial habitat meets thresholds to be considered xeric, but due to size, isolation, fire suppression and succession only 353 km2 are currently identified by the New York Natural Heritage Program (Corbin and Flatland 2022).

Well-drained, nutrient poor soils underly these sites and are largely responsible for the characteristic vegetation condition and propensity for fire (Heikens and Robertson 1995, Petersen and Drewa 2009, Quigley 2020). Due to the harsh growing conditions and resultant composition and structure of vegetation, many xeric habitats have been referred to as barrens and have open canopies and a high proportion of forbs that provide good pollen and nectar sources for insects (e.g. Wagner et al. 2003, Shuey et al. 2012, Roberts et al. 2017, Walker et al. 2021, Milam et al. 2022). In the Northeast, these habitats are also referred to as sandplains, sandplain grasslands, sand barrens, pine barrens, heathlands, scrub oak shrubland, dry woodlands, glades, shrubland barrens, pitch pine-oak woodland, and grasslands.

The vegetation communities that root in the well-drained sandy soils are adapted to and reliant on frequent wildland fire which historically maintained an open overstory and understory, as well as patches of bare soil characteristic of the habitat. Common trees include pitch pine (*Pinus ridgida*), red oak (*Quercus rubrum)* and sassafras (*Sassafras albidum*), common shrubs include scrub oak (*Quercus ilicifolia and Q. prinoides*), black huckleberry (*Gaylussacia baccata*), New Jersey Tea (*Ceanothus americanus*), and lowbush blueberry (*Vaccinium angustifolium and V. pallidum*). Common grasses and sedges include little bluestem (*Schizachyrium scoparium*), big bluestem (*Andropogon gerardii*), Indian grass (*Sorghastrum nutans*) and Pennsylvania sedge (*Carex pensylvanica*). Lupine (*Lupinus*) and Loosestrife (*Lysimachia*) are important flowering plants at some sites.

Barrens and other types of xeric habitats are most often relics of precolonial landscapes heavily influenced by post-glacial soil conditions and millennia of indigenous fire stewardship (Abrams and Nowacki 2021, Hoffman et al. 2021). In Connecticut they are believed to have been created by the retreat of the glaciers and associated lakes – about 12,000 years ago (Woodside 2016). Ridgetop barrens are often associated with extremely shallow soils resulting from glacial scouring and/or catastrophic glacial floods (e.g., Altona Sandstone Pavement Barrens, Shawangunk Mountains). Barrens that formed within the mid-Atlantic Coastal Plain, such as New Jersey’s Pine Barrens and Central Long Island Pine Barrens, formed via a longer series of geological processes over time that involved the deposition of marine sand and sediment, their subsequent exposure due to uplifting and retreating sea levels, and the resultant effects of wind scour, alluvial erosion and the further deposition of materials due to inland glaciation (Forman 1979). In Maryland and Albany, NY, evidence suggested barrens have persisted for 4000 to 6000 years before present (Droege et al. 2009) and that Indigenous Fire Stewardship likely secured some large continuous areas in this habitat type (Marye 1955). In some cases, barrens may have been created by intensive use (e.g. Motzkin et al. 1996). Such disturbance maintains critical compositional, structural, and functional aspects of these habitats that cumulatively facilitate many populations of Regional Species of Greatest Conservation Need (Appendix A).

## Historical Land Use

Historic land use at barrens sites has left a range of effects on site’s soil and vegetative conditions. Compared to surrounding landscapes, sandplain and barrens sites featuring flat topography and soils free of rock or bedrock constraints made them ideal for development and certain types of natural resource harvest or agriculture. Many xeric sites in the region have been mined (sand/gravel/clay/ores) or developed for housing or infrastructure and are no longer candidates for restoration. Most sites that have persisted are forested or have a history of agriculture in the past 50 to 100 years. Many forested barrens sites experienced historic timber harvests for charcoal production. Agricultural uses include grazing and pasture, blueberry production, and farming with and without tillage. Understanding the influence of historical land use on current conditions is an important step in customizing a site management plan (e.g. (Lougee 2015)

## Emerging Threats

Management strategies for all habitats must adapt to new threats. In addition to the persistent habitat management challenges in barrens habitats, managers must consider:

* How losses of keystone plant and wildlife species will impact barrens ecosystem health
* Changes in soil chemistry due to pollutant deposition and loss of fire
* Invasive species, including plants and insects, exotic species, native species with competitive advantages, and those with northward shifting ranges
* Changes in adjacent land ownership or use

While climate change may impact when sites can burn, it may not be as significant a threat as it is to other habitats in the Northeast (Butler-Leopold et al. 2018). Barrens are intrinsically resilient to drought and many plants and animals associated with barrens are more common in similar habitats in the southeastern U.S., indicating they can tolerate warmer or drier conditions. In fact, nocturnal moth sampling performed at participating xeric sites produced several records of moth species considered “rare” in our region, but that are relatively common in southern habitats of various types. Barrens with managed fuel loads may also escape an increased risk of fire severity and an increase in fire frequency would help maintain characteristic open conditions. The Northeast also anticipates more severe and frequent extreme precipitation events which could subject barrens near streams to intermittent flooding and high water tables, but the well-drained soils are unlikely to experience long periods of saturation (Dupigny-Giroux et al. 2018).

# Project Findings and Best Management Practices for Xeric Sites

The approach to this project was to recruit sites regionwide that self-identified as “barrens,” implement standard monitoring procedures at the sites, and track change in units that received habitat treatments and those that did not. The Best Management Practices detailed here are derived from the compiled project data, an extensive literature review, and the best professional judgement of site managers.

## Sites Participating in this Study

The study area for this project included 10 states in the Northeast region: Maine, New Hampshire, Vermont, Massachusetts, Rhode Island, New York, New Jersey, Pennsylvania, Delaware and Maryland. Sites from all 14 Northeast region jurisdictions were recruited, but not all sites had the capacity or interest to participate. The required regional scale affected study design and findings. The study area comprises humid temperate ecoregions, and the project data demonstrated that site conditions, inclusive of floral and faunal communities, are influenced by differences in climate and topography. Many sites in this study are located near the coast in the Northeastern Coastal Zone, the Atlantic Coastal Pine Barrens, and the Middle Atlantic Coastal Plain (Fig. 3) (US EPA 2015). Inland from these are the sites in the Northeastern Highlands, Eastern Great Lakes Lowlands, Ridge and Valley, and Blue Ridge ecoregions.

Sites participating in this project range in size from less than 100 acres to more than 3000 acres and include grasslands, heathlands, scrub oak shrublands, and pitch pine-oak woodlands. Sites vary widely in historic land use, recent management effort, current condition, and compatibility with adjacent lands. Two sites involved in this project include airfields, and many were proximate to urbanization or other disparate habitat types. To support statistical analysis, sites were categorized simply as grassland or woodland. Sites with little or no management in the decade leading up to this project were classified as “unmanaged” (Table 1).

Map

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Figure . Site locations with corresponding ecoregions and state boundaries

Table 1. List of participating sites with key habitat characteristics.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Site, state | Land Manager | Habitat Type | Prior Management | Data Contributed |
| EPA Level III Ecoregion: Northeastern Highlands | | | | |
| Ossipee Pine Barrens, New Hampshire | The Nature Conservancy | Woodland | Managed and Unmanaged units | Vegetation, Bee, and Moth |
| EPA Level III Ecoregion: Northeastern Coastal Zone | | | | |
| Kennebunk and Wells Barrens, Maine | The Nature Conservancy | Grassland | Managed | Vegetation, Bee, and Moth |
| Concord Pine Barrens, New Hampshire | New Hampshire Fish & Game | Grassland | Managed | Vegetation, Bee, and Moth |
| Albany Pine Bush Preserve, New York | Albany Pine Bush Preserve Commission | Woodland | Managed | Vegetation, Bee, and Moth |
| Nicholas Farm Wildlife Management Area, Rhode Island | Rhode Island Department of Environmental Management | Grassland | Unmanaged | Vegetation, Bee, and Moth |
| Pratt Farm Wildlife Management Area, Rhode Island | Rhode Island Department of Environmental Management | Woodland | Unmanaged | Vegetation, Bee, and Moth |
| EPA Level III Ecoregion: Atlantic Coastal Pine Barrens | | | | |
| Katama, Massachusetts | The Nature Conservancy | Grassland | Managed | Vegetation, Bee, and Moth |
| Linda Loring Nature Foundation, Massachusetts | Linda Loring Nature Foundation | Grassland | Unmanaged | Vegetation, Bee, and Moth |
| Head of the Plains, Nantucket, Massachusetts | Nantucket Conservation Foundation | Grassland | Managed | Vegetation, Bee, and Moth |
| Rocky Point Pine Barrens State Forest, New York | New York Dept. of Environmental Conservation | Woodland | Managed | Moth |
| Warren Grove, New Jersey | New Jersey Dept. of Environmental Protection Fish and Wildlife | Woodland | Managed and Unmanaged units | Vegetation, Bee, and Moth |
| EPA Level III Ecoregion: Ridge and Valley | | | | |
| Scotia Barrens, Pennsylvania | PA Game Commission and Patton Township | Woodland / Grassland | Managed | Vegetation, Bee, and Moth |
| Sideling Hill, Pennsylvania | Western Pennsylvania Conservancy | Woodland | Unmanaged | Vegetation, Bee, and Moth |
| Green Ridge State Forest, Maryland | Maryland Dept. of Natural Resources | Grassland | Managed | Vegetation, Bee, and Moth |
| EPA Level III Ecoregion: Blue Ridge | | | | |
| Michaux State Forest, Pennsylvania | Pennsylvania Dept. of Conservation & Natural Resources | Woodland | Managed and Unmanaged units | Vegetation, Bee, and Moth |
| EPA Level III Ecoregion: Great Lakes | | | | |
| Presque Isle State Park, Pennsylvania | Pennsylvania Dept. of Conservation & Natural Resources | Grassland | Unmanaged | Bee |
| Sandbar Wildlife Management Area, Vermont | Vermont Fish & Wildlife Department | Grassland | Managed | Bee |
| EPA Level III Ecoregion: Middle Atlantic Coastal Plain | | | | |
| Nanticoke Wildlife Area, Delaware | Delaware Dept. of Natural Resources and Environmental Control | Woodland | Unmanaged | Vegetation, Bee, and Moth |
| Pocomoke State Forest, Maryland | Maryland Dept. of Natural Resources | Woodland | Managed | Vegetation, Bee, and Moth |

Most sites involved in this project have soils with percent sand greater than 70%, though sites in the Ridge and Valley province have lower sand fractions (25-55%). More than 75% of sites have less than 10% organic matter, as is expected in barrens, but some exceptions include Nicholas and Pratt Farms in Rhode Island which have >16% organic matter. Barrens are often characterized as having low soil fertility (e.g. (Quigley 2020). Effective cation exchange coefficients (ECEC) ranged from 1 to 10 meq/100g at sites participating in this study, and sites with over 75% sand had less than 6 meq/100g ECEC. Bulk Density ranged from 1.03 to 1.54 g/cm3 with an inverse relationship to soil organic matter.

Project surveys documented a remarkable abundance and diversity of species:

* 279 plant species were identified in 14 sites.
* Nearly 20,000 bees in 262 species were collected from 20 sites.
* More than 61,000 moths in 1447 species were tallied in 17 preserves.

Plant, bee, and moth communities differed significantly across preserves, among ecoregions, and between grassland and woodland sites (Barton and Poulos 2023). Bee and moth communities exhibited higher species diversity in colder, drier sites and ecoregions. Bees were more abundant and diverse in grasslands, while moths were more abundant and diverse in woodlands. Higher plant cover and diversity and lower percent sand promoted species diversity in moths but not bees. Sites with management over the decade prior to the survey had lower moth abundance and richness compared to unmanaged sites, which may reflect importance of woody vegetation for moths – vegetation that would likely have been reduced by xeric habitat management.

## Best Management Practice Recommendations

The best management practice selection is organized into five steps.

**Step 1 – Assess current condition of site and establish habitat condition targets.**

Xeric sites in the northeast range in ecological community type and vegetation structure from grasslands and heathlands to shrublands and woodlands. Every habitat management plan starts with an assessment of the current habitat condition(s) and clear identification of the site’s habitat management goals or desired future state (i.e., the “habitat condition target").

**Step 2 – Establish habitat management objectives necessary to achieve habitat conditions targeted.**

Management objectives range from those more specific to sites targeting habitat **restoration** goals, such as the need to address canopy density or closure, to those that apply universally to restoration and **maintenance** projects, such as the need to manage invasive or undesirable species.

**Step 3 – Select and implement the most appropriate management practices.**

Once the site’s restorative or maintenance objectives are identified, review the management strategies recommended below to determine those that best address your site needs and/or accommodate site constraints.

**Step 4 – Establish a rotational management strategy.**

Habitat management is by necessity a process of managed disturbance. Design site units so that management strategies can be implemented at smaller scales and in rotation, to minimize adverse effects on fauna and flora.

**Step 5 – Monitor and adaptively manage.**

Monitor results and adaptively respond to management results.

## Step 1: Assessment of Current Site Conditions and Future Habitat Goals

Habitat management planning is rooted in a thorough assessment of existing site conditions. A professional investigation of existing floral and faunal resources contributes to the critical assessment of the site’s present functions and values. Many sites, even those in disturbed or undesirable condition, feature unique habitat functions or conditions that should be understood, and possibly recognized in terms of their own rarity or purpose. Further, existing site conditions may be reflective of geological conditions or past disturbances or land uses that could continue to dictate habitat conditions at the site, regardless of management effort. These are important underlying factors that must be understood.

Once a complete understanding of existing site conditions is established, those functions and values can be assessed and/or compared to the habitat goals for the site. Habitat goals can target historic conditions known to have prevailed at the site, at other sites in the region, and/or may be driven by the habitat requirements of specific flora of fauna established as management priorities. In this study, restoration or maintenance of xeric barrens and grassland habitats for pollinators was the primary management goal. But even when managing for a “generic” habitat type is the goal, the specific quantitative targets against which we might measure success varies by site. For example, the Pennsylvania Game Commission describes healthy barrens as having “early successional structure with abundant ground cover, shrubs, herbaceous pockets, and scattered trees” and set a limit of about 15 trees per acre (BA 10ft2), above which barrens become “savannas” or “woodlands” (Wakefield and Jones 2020). In contrast, a restoration condition in coastal barrens may have large open areas with warm-season grasses and forbs, heath species like lowbush blueberry, cranberry bogs, intermixed with adjacent patches of sparse trees. Ultimately, the specific quantitative objectives will depend on the ecoregion, soils, climate, topography, or previous land use at a site.

The following example habitat condition targets are generally representative for northeast xeric **grasslands** and can be adapted for each site:

* Tree biomass > 5 m tall is < 25 % of canopy cover and clumped with many areas completely open.
* Shrub biomass is limited to small clumps.
* Native grasses and forbs represent >75% of cover.
* Invasive plants are controlled.

The following example habitat condition targets are generally representative for northeast xeric **barrens or woodland** and can be adapted for each site:

* Tree biomass > 5 m tall is 25 - 60% of canopy cover and canopy is discontinuous
* Shrub biomass represents 30-50% of the understory cover.
* Native grasses and forbs represent 30-50% of the understory cover.
* Invasive plants are controlled.

Habitat condition values can also be identified to benefit specific fauna native to xeric habitats. For example, bee and moth diversity and abundance will generally increase as xeric vegetation conditions improve and:

* bee nesting needs are met with bare soil, dead wood, and hollow or pithy stems (e.g. (Antoine and Forrest 2020, Harmon-Threatt 2020);
* native floral resources are available throughout the growing season for bee forage (Scheper et al. 2015);
* host plants are available for moth larvae; and,
* management activities are designed and implemented, both spatially and temporally, such that some meaningful area(s) of refugia are always available for native fauna (Gelles et al. 2021).

The needs of nocturnal moths are not as well understood (but see Coulthard et al. 2019). Many moths overwinter in the leaf litter or in the soil where they are vulnerable to management activities. Project contractors identified moths associated with barrens habitats and common host plants for the larvae of these species include *Quercus spp.* (e.g., scrub oak), *Vaccinium spp.* (e.g. lowbush blueberry), *Ceanothus spp.* (e.g. New Jersey tea), *Ericaceae* and *Myricaceae*. Data from this project showed that overall moth richness and abundance was greater in woodland sites. Reducing tree cover may negatively impact moth communities, while improving conditions for bees.

## Step 2: Identification of Habitat Management Objectives

Sites participating in this study endeavored to achieve the habitat condition targets and values described in Step 1 via four primary habitat management objectives:

* Reduce tree canopy and shrub cover.
* Reduce or eliminate invasive or undesirable species.
* Establish native, desirable vegetation.
* Enhance nesting resources for bees.

Once existing and desired habitat conditions are established, the effort needed to achieve the site’s habitat goals can be determined. Historical barrens in poor present condition, such as those that have transitioned to closed canopy mixed forests, will require significant restoration (Jones 2010). Conversely, sites that approximate barrens vegetation structure and composition in their current state may only require regular maintenance to ensure the continued perpetuation of that condition. “Restoration” projects would reasonably be expected to transition to a “maintenance” project, once they have established the desired habitat condition. It is important to recognize that “restoration” sites are focused on *effecting* meaningful change, while maintenance sites are primarily focused on *precluding* meaningful change. This is commonly a significant determinant in the identification of management objectives. Experience at one of the region’s longest managed sites, the Albany Pine Bush Preserve, illustrates just how different restoration and maintenance strategies can be even within one landscape (Bried et al. 2014). In both cases, identifying the specific, actionable habitat objectives in step 1 is critical to ensure overall project success.

### Restoration Objectives

Intensive habitat management objectives, such as reducing canopy density or closure, are frequently identified at restoration sites. Historical barrens that are being restored after anthropogenic land use or a period absent of fire and other management techniques require more significant habitat management interventions to restore or recover the characteristic vegetation composition and structure (See Table 1 for a list of sites in this condition). The application of prescribed fire to open site canopies and/or eliminate invasive or undesirable woody vegetation at such sites may be ineffective, premature or involve undesirable risks. Intensive logging or canopy thinning may first be needed to lower percent cover of both desirable and undesirable tree species. Sites with established woody invasives and /or overabundant native shrubs are very difficult to recover. Management options range from the application of herbicide to scraping the entire site, but such efforts require sustained expense and effort over multiple years. Where the habitats have been farmed, plowing and establishment of crops will have disturbed or destroyed natural soil profiles and important aspects of the soil microbiome, especially ectomycohrizal fungal communities essential for oaks, pines and heaths. Historic soil disturbances may also have impacted or even eliminated native seed banks. Consequently, reestablishing native plant communities can involve not only preparing an adequate seed bed and securing local genotypes of native plants, but also reestablishing fungal communities. The goal of most restoration activities should be to facilitate transitioning to site maintenance via prescribed fire.

### Maintenance Objectives

Several sites in the Northeast have long-standing management programs that have effectively maintained open canopies and characteristic plant species (See Table 1). Habitat condition at most xeric sites will degrade without continued habitat management effort, so this ongoing work is necessary to maintain the composition, structure and function of suitable SGCN wildlife habitat (Wagner et al. 2003, Poulos et al. 2020). Sites that retained high quality xeric habitat conditions relied primarily on high frequency, low-moderate severity prescribed fire, with other tools only used as needed to rearrange fuels (mowing), to augment established plant communities (invasive control and seeding), or when needed as alternatives to prescribed fire. No sites proposed the use of prescribed grazing as part of this project.

In addition to rare pollinators, most xeric habitat sites will also be home to rare, threatened, or endangered species in other taxonomic groups. The management plan at each site will need to balance habitat requirements of all species and consider avoiding negative impacts to these species from incompatible management activities. (See Appendix A for more information.)

Frequent fire historically maintained the characteristic low biomass, open canopy, and relatively high percentage of bare soil of barrens habitats (Raleigh et al. 2003). The Massachusetts Division of Fisheries and Wildlife recommend prescribed fire every 2-4 years for maintenance of sandplain grasslands, 5-8 years for heathlands, 2-10 years for barrens, and 10-15 years for woodlands (Division of Fisheries and Wildlife 2022). The Pennsylvania Game Commission suggests xeric sites require short fire return intervals (3-5 years) during the restoration phase, and longer fire return intervals (8-15 years) during the maintenance phase (Wakefield and Jones 2020). But, more specifically, they recommend monitoring for indications that fire is needed, such as loss of herbaceous component, increase in fuel load, appearance of invasive shrubs, or presence of fire intolerant trees (Wakefield and Jones 2020). If frosted elfin (*Callophrys irus*) is present, consider longer intervals between fire events (Jue et al. 2022). In any such assessment, both the intensity and timing of prescribed fire application must be purposefully considered, as both will meaningfully effect results on the vegetive community and consequently habitat suitability for SGCN wildlife.

However, site managers participating in this project identified a number of constraints that have precluded the use of fire to effectively maintain habitat conditions over the past 50 years. Conflicting site use and/or adjacent land uses can preclude burning, and the limited availability of trained fire crews combined with narrow windows of allowable weather conditions can make it difficult to burn sites as frequently as desired. Similarly, fire effects within a given site vary with season, with growing season prescriptions generally being most effective (Knapp et al. 2009). However, due to site constraints or regulatory restrictions, burning during the growing and breeding season may be prohibited. Additionally, the presence of rare or endangered species may also limit opportunities to burn. Managing the risks associated with the use of prescribed fire frequently result in fire prescriptions (typically low-intensity back fires) that fail to fully replicate the conditions necessary to achieve desired fire effects. In some cases, fire can encourage invasive species that were not a problem before the fire. While no alternative management strategy can truly replicate fire effects, sites that already approximate the historical conditions of barrens may be able to employ mechanical techniques to remove biomass or treat grasses, shrubs, or trees to maintain the desired vegetation structure (subject to the size of the site and the expense and logistics associated with doing so).

Since 2016, the Sandplain Grassland Network has been collaborating to understand and improve habitat management in coastal New England (Sandplain Grassland Network n.d.). In their experience (representing about 40 years of active management at several sites), they have had “good success at promoting warm season grasses with aggressive mowing and burning, and moderate success at reducing unwanted species with herbicide. However, (they) have had less success with restricting the growth of woody plants and at maintaining plant and animal diversity.” The challenge of suppressing woody vegetation in the absence of fire was a major motivation for this study. Similarly, the North Atlantic Fire Science Exchange (NAFSE) is a hub for fire science information delivery and collaboration between managers and researchers in the northeastern US (https://www.firesciencenorthatlantic.org/). NAFSE is funded by the Joint Fire Science Program as part of their Fire Science Exchange Network; as such NAFSE provides access to resources throughout the other regional exchanges across the country.

Ultimately, site managers should characterize whether their efforts to attain their desired habitat condition targets constitute “restoration” or only “maintenance,” and then identify the primary habitat management objectives necessary to accomplish those goals.

## Step 3: Best Management Practice Selection

To implement the management objectives noted above, sites should identify effective treatment activities. At the beginning of this project, a survey of the 20 participating sites identified the following management practices used by sites performing habitat restoration or maintenance for pollinators:

* Clearing and canopy thinning
* Mowing and brush-hogging
* Prescribed fire
* Herbicide application
* Discing and harrowing
* Seeding and supplemental planting

Each of these activities is outlined here with a description, purpose, and tools and staffing requirements:

* **Clearing/Felling/Canopy thinning (i.e., “Forest Stand Improvement” practices)**

Description: The application of traditional mechanical forest stand improvement (FSI) practices or equivalent management techniques to reduce the extent of canopy closure or biomass, typically in a mature forest community.

Purpose: To reduce canopy density or coverage, so as to increase light penetration to ground-level habitats or vegetation. Canopy thinning is frequently employed to promote native herbaceous and scrub-shrub plant growth. It can also enhance the suitability of terrestrial or below-ground wildlife habitats, such as reptile basking, nesting or hibernacula sites. FSI practices can remove above ground biomass from the site, and potentially remove or expose below-ground root structures to facilitate subsequent management practices. For example, canopy thinning can be an important pretreatment to prescribed fire by reducing dangerous woody fuel loads, improving amounts of fine dead fuels and facilitating air movement that can reduce effective windspeeds needed for safe and effective wildland fire.

Tools and staffing: Traditional FSI practices, such as logging/select felling, girdling or related practices, require specific, specialized forestry tools and materials, and highly trained, skilled, and sometimes licensed workers. Additional, permits may be required.

* **Mowing/Brush-hogging**

Description: Height reduction, consumption and/or rearranging of (typically) herbaceous or early successional vegetation via mechanical cutting.

Purpose: Manage vegetative/habitat structure, stress and/or control undesirable vegetation, particularly woody vegetation, vegetation prep for application of subsequent management practice.

Tools and staffing: A variety of equipment types are available for mowing activities, including but not limited to: rotary-cutting tractors, tractor-mounted brush hogs or drum mowers, agricultural flair mowers and shredders, and the use of forestry-type mulching heads.

* **Prescribed fire (“Rx fire” or “Rx burn”)**

Description: The purposeful and controlled application of fire by a team of fire experts under specified weather conditions to achieve specific goals.

Purpose: The primary purpose for fire in xeric habitat management is to create specific habitat conditions (top kill woody plants, expose mineral soil, reduce litter and duff, stimulate serotinous cones, facilitate germination, recycle nutrients, enable seedling establishment, etc.). Prescribed fire can also be effective at mitigating wildfire danger by reducing or rearranging hazardous fuels. Fire effects are highly variable, depending on site conditions (fuel, weather, topography) and time of year. For example, slow, low-severity prescribed fires can be effective at maintaining some desired fuel /wildfire mitigation goals and maximize factors regarding safety and control, but they can also be limited in their effects on tree/shrub canopy cover, species composition, litter and duff depth and mineral soil exposure. Pairing the timing and severity of prescribed fire with the desired fire effects is always site-specific and requires careful planning and execution by highly trained professional wildland fire personnel. Reversing decades or more of fire suppression can often require mechanical and/or chemical treatments before using fire.

Tools and staffing: To implement a prescription burn, sites need the financial, logistical and administrative support to secure the resources necessary for safe and effective wildland fire. Permits, personnel, equipment, planning, communications and regular training are essential components of a prescribed fire program. Requirements of site level wildland fire prescriptions may vary by state or local jurisdiction. Describing desired fire effects in burn plan can help qualified personnel decide when and how to burn a given site.

* **Herbicide application**

Description: Application of a chemical toxic to plants to destroy unwanted vegetation.

Purpose: To kill or destroy unwanted vegetation or stress vegetation sufficient to accomplish similar results in tandem with other practices.

Tools and staffing: A variety of herbicides are available, many with specific benefits regarding application requirements, suitability in specific application settings (such as wetlands), or effect on target species. Most herbicides require foliar application, but many can be applied to cut stumps, girdled trees, or via injection. Others can be incorporated into the soil or applied via irrigation. Chemical or herbicide use is staff-person efficient, though requires advanced skills and typically state/federal certification or licensing.

* **Discing/Harrowing**

Description: Use of a tractor to pull a disc plow or disc harrower.

Purpose: To apply mechanical disturbance to till the upper 2” – 6” of soil, and to mulch or turn associated cover or vegetation into the uppermost layer of soil. Discing may be employed to passively reset a vegetative community, or in advance of more proactive seeding or planting. Discing is also an effective way to prep management units for application of soil amendments such as lime or to facilitate incorporation of burned materials into the soil.

Tools and staffing: A variety of disc plows or disc harrows are available and must be pulled behind traditional tractor. Discs vary in effective width and can range from 6’ to over 20’.

* **Seeding/Supplemental planting**

Description: Physical introduction of select species seeds or stock to the project site.

Purpose: Introduction of desired plant species, whether to establish the desired plant community or achieve a shorter-term goal such as soil amendment or stabilization.

Tools and staffing: Seeding can be done by hand, hand-held, push or mechanical spreaders, or by tractor via use of a seed drill. Planting is typically done by hand. Staffing needs vary based upon size and scale of project, with seeding being much more efficient than planting.

For each of the four habitat objectives:

* Reduce tree canopy and shrub cover,
* Reduce or eliminate invasive or undesirable species,
* Establish native, desirable vegetation, and
* Enhance nesting resources for bees,

the advantages and disadvantages of each treatment activity are discussed below. Because restoration needs typically precede maintenance needs, the assessments below are loosely organized in that order. The following habitat objectives address the habitat condition targets provided in Step 1:

## Step 3A: Management Objective – Shrub and tree canopy cover reduction

A site featuring a severely closed canopy presents one of the more formidable challenges involved in managing a site for the “xeric barrens” habitat objectives detailed in “Step 1,” above. Project data demonstrated that management treatments are successful at reducing percent cover of trees and shrubs, and partly in consequence increased the percent cover of early successional flowering plants, pollinator host plant taxa, and overall plant diversity (Barton and Poulos 2023).

Sites recognizing the need to reduce site canopy cover are typically considered to be in a “restoration” phase of management, though sites merely “maintaining” xeric conditions may also identify less severe needs to address canopy density or closure. When habitat management objectives included the restoration or maintenance of canopy openings, our data, perhaps unremarkably, demonstrated that the application of more intensive management practices were highly effective and desirable. Project sites also found that application of more than one management practice to achieve canopy density objectives increased effectiveness and/or that certain practices could or should *not* be employed unless preceded by another (examples below).

Available Best Management Techniques/Strategies:

* **Clearing/Felling/Canopy thinning (i.e., “Forest Stand Improvement” (FSI) practices)**
* Highly effective at addressing canopy restoration objectives.
* Equally effective, though less necessary, in addressing canopy maintenance objectives.

**Advantages**:

- FSI projects directly remove non-native or native but undesirable woody canopy vegetation (Pratt Farms), or cause their mortality, such that the canopy does not leaf-out.

- Clearing/canopy thinning can have a dramatic and expeditious effect on habitat structure and function.

- Canopy thinning is an effective practice to initiate the restoration of xeric sites that have succeeded into fully forested conditions and may be effectively used in conjunction with (and typically preceding) other practices such as prescribed burns, where they frequently increase the subsequent practice’s effectiveness and/or lessen its associated risks.

- Killing target vegetation (without tree removal) can achieve desired results, and add wildlife benefits through the retention of snags, cavity trees, or trees featuring exfoliating bark.

- Select FSI practices, such as tree felling, can be surgically implemented to achieve targeted results, such as increasing exposure of a documented basking site.

**Disadvantages**:

- FSI projects can be costly and labor-intensive.

- FSI projects may be subject to seasonal restrictions required to protect wildlife.

- Activities limited to the actual tree canopy are possible, but are inefficient, costly, and labor intensive.

- The larger and/or more mature the vegetation in question, the greater effort may be required.

- Retention of dead/dying trees or shrubs may increase concern regarding treefall hazard(s) and/or increased wildfire risk.

- Clearing activities may produce disturbances and/or create conditions suitable for invasive or non-desirable species introduction.

- Clearing/canopy thinning must be followed up with appropriate maintenance to ensure that target vegetation or habitat conditions develop in the affected area(s).

- Many hardwood stumps will sprout and may require follow-up treatment (herbicide) to cut stumps and new stems.

- Size and scale of FSI projects require critical considerations regarding:

1. equipment access routes
2. soil compaction impacts
3. equipment biosecurity protocols to address weed seeds (power washing equipment, etc.)
4. clearly understandable yet detailed project maps or plans, ensuring that heavy equipment operators have knowledge of what should be removed and what should be left
5. on-site flagging or fencing of important work vs preservation areas

* **Mowing/Brush-hogging**
* Can be highly effective at addressing shrub/scrub canopy restoration objectives.
* Can be highly effective at addressing shrub/scrub canopy maintenance objectives.
* Not at all effective at addressing forest canopy restoration or maintenance objectives.

**Advantages**:

- According to the professional opinion of participating site managers, mowing and brush-hogging can be used to help control the succession of woody stem plants into habitats where they are not desired, precluding development of a closed canopy.

- Mowing is frequently used to reduce the amount of standing vegetation prior to conducting a prescribed burn or herbicide treatment, reducing the risk and/or enhancing the effectiveness of those strategies to reduce canopy closure.

- Mowing is affordable and does not require numerous or highly trained staff.

**Disadvantages**:

- Mowing alone may not remove undesirable vegetation species capable of re-sprouting, nor does it address weed seeds.

- Mowing too frequently or intensively can reduce plant diversity, adversely affect habitat function (nest sites or cover), and may directly harm wildlife.

- Mowing projects may be subject to seasonal restrictions required to protect wildlife.

- The larger, denser and/or more mature the vegetation in question, the less appropriate mowing/rush-hogging will be.

* **Herbicides/Chemical controls**
* Highly effective at addressing shrub/scrub canopy restoration or maintenance objectives.
* Effective at addressing forest canopy maintenance objectives.
* Can be somewhat effective at addressing forest canopy restoration objectives.

**Advantages:**

- Herbicide application provides a targeted, efficient, and effective management practice to reset non-forest-type vegetative communities, or to control or eliminate specific target species.

- Herbicide application provides an equally targeted way to address tree canopy objectives, though due to application constraints, is significantly less efficient and somewhat less effective. Efficiency and effectiveness are increased in “maintenance” scenarios where only select mature trees may present as targets for management.

**Disadvantages:**

- Treatment of mature trees with chemical or herbicides can be challenging and required more specific equipment (trunk or ground injection) or skills.

- Many herbicides are effective across a broad range of vegetative species, posing both a benefit and a risk depending upon the application site and desired effect.

- Herbicides do not typically affect seed sources

- Herbicides may have adverse wildlife considerations.

- Herbicide application is often time- or season-sensitive.

- Herbicide application requires agency-licensed or certified staff.

- Public opinion has turned against herbicide use.

* **Prescribed Fire (“Rx fire” or “Rx burn”)**
* Can be highly effective at addressing shrub/scrub canopy restoration objectives.
* Highly effective at addressing shrub/scrub canopy maintenance objectives.
* Not likely to be effective at addressing forest canopy restoration or maintenance objectives, unless *very* specifically prescribed and implemented.

**Advantages**:

- Prescribed fire best mimics the historic habitat management influences that have formed and *maintained* xeric sites in the Northeast for thousands of years.

- Prescribed fire is particularly effective at *maintaining* existing xeric barrens and grasslands site conditions.

- Prescribed fire is very effective following mowing, which is frequently used to reduce the amount of standing vegetation (fuel) prior to conducting a prescribed burn, reducing the risk and/or enhancing the effectiveness of the burn.

- While requiring highly trained staff and specialized equipment, Rx burns are considered very affordable, particularly as the scale of the management sites increases.

**Disadvantages**:

- Fire prescriptions designed primarily to reduce wildfire risk are generally ineffective at restoring or resetting xeric sites to the target canopy conditions identified in “Step 1” of this document. Rx burns conducted to minimize/mitigate wildfire risk are frequently subjected to regulatory or policy conditions or priorities that preclude burning during the growing season. Further, per the understandably risk-averse prioritization of wildfire-reduction prescriptions, the fires are designed and implemented such that they do not “crown” or directly affect the canopy. Because many tree species native to xeric habitats are (at least in their mature condition) fire-adapted and resistant to fire-induced stress or mortality, these fire prescriptions neither cause mortality-in-place of mature vegetation responsible for canopy closure, nor do they directly consume or combust the canopy itself.

- Use of prescribed fire to restore or reset xeric forest conditions to those of more desirable xeric barrens or savanna would require a deliberate, more intensive, and higher-risk fire prescriptions that might conflict with local jurisdictional requirements.

- Effectiveness in maintaining xeric scrub/shrub canopy conditions in a condition suitable for pollinators is critically dependent upon the timing of burns, with growing season burns being significantly more effective. Use current data at other sites to best inform your decisions but also experiment and monitor your site-specific impacts.

- The application of Rx fire is highly controlled. Application or use restrictions typically present at the site (policy or practice), municipal (ordinance), county or state (laws/regulations) level. In some states, application of prescribed fire is reserved to the jurisdiction of a state fire control agency.

## Step 3B: Management Objective – Reduce or eliminate invasive or undesirable species:

Another challenge faced by site managers is the occurrence of invasive or non-desirable species.

Again, the need to address or eliminate large-scale invasive species as a habitat management objective is commonly considered to represent a “restoration” management scenario. However, even sites with management objectives that more accurately reflect a “maintenance” condition will need to address invasive species, particularly if adjacent properties or site conditions represent a seed source or cause direct encroachment. Projects participating in this study demonstrated that a range of management practices are available and effective.

Available Best Management Techniques/Strategies:

* **Clearing/Felling/Canopy thinning (i.e., “Forest Stand Improvement” (FSI) practices)**
* Highly effective at addressing invasive/undesirable species management objectives for restoration or maintenance sites.

**Advantages**:

- FSI projects directly remove non-native or native but undesirable woody vegetation (Pratt Farms) or cause their mortality.

- Clearing or targeted felling can have a dramatic and expeditious effect on habitat structure and composition.

- Clearing or select felling is an effective practice to initiate the restoration of xeric sites that have succeeded into fully forested conditions and may be effectively used in conjunction with (and typically preceding) other practices such as prescribed burns, where they frequently increase the subsequent practice’s effectiveness and/or lessen its associated risks.

**Disadvantages**:

- FSI projects can be costly and labor-intensive.

- FSI projects may be subject to seasonal restrictions required to protect wildlife.

- The larger and/or more mature the vegetation in question, the greater effort may be required.

- Clearing activities may produce disturbances and/or create conditions suitable for invasive or non-desirable species introduction.

- Clearing/felling must be followed up with appropriate maintenance to ensure that target vegetation or habitat conditions develop in the affected area(s).

- Many hardwood stumps will sprout and may require follow-up treatment (herbicide) to cut stumps and new stems.

- Size and scale of FSI projects require critical considerations regarding:

1. equipment access routes
2. soil compaction impacts
3. equipment biosecurity protocols to address weed seeds (power washing equipment, etc.)
4. clearly understandable yet detailed project maps or plans, ensuring that heavy equipment operators have knowledge of what should be removed and what should be left
5. on-site flagging or fencing of important work vs preservation areas

* **Herbicides/Chemical controls**
* Highly effective at addressing shrub/scrub canopy restoration objectives.
* Can be highly effective at addressing shrub/scrub canopy maintenance objectives.
* Not at all effective at addressing forest canopy restoration or maintenance objectives.

**Advantages:**

- Herbicides can be an efficient, effective way to reset vegetative communities, or to control or eliminate specific target species. Herbicides are generally more effective at controlling herbaceous vegetation, though shrubs and trees can also be treated with good effect. Many herbicides are effective across a broad range of vegetative species, posing both a benefit and a risk depending upon the application site and desired effect. Herbicides do not typically affect seed sources.

**Disadvantages:**

- Treatment of mature trees with chemical or herbicides can be challenging and required more specific equipment (trunk or ground injection) or skills.

- Many herbicides are effective across a broad range of vegetative species, posing both a benefit and a risk depending upon the application site and desired effect.

- Herbicides do not typically affect seed sources

- Herbicides may have adverse wildlife considerations.

- Herbicide application is often time- or season-sensitive.

- Herbicide application requires agency-licensed or certified staff.

- Public opinion has turned against the use of herbicides.

* **Prescribed Fire (Rx Burn or Rx Fire)**
* Can be highly effective at addressing invasive shrub/scrub restoration objectives.
* Not likely to be effective at addressing invasive forest restoration objectives.
* Highly effective at addressing invasive herbaceous, shrub/scrub and forest species maintenance objectives.

**Advantages**:

- Prescribed fire best mimics the historic habitat management influences that have formed and *maintained* xeric sites in the Northeast for thousands of years.

- Prescribed fire is particularly effective at *maintaining* existing xeric barrens and grasslands site conditions.

- May increase nutrient cycling and lead to more robust plants.

- Prescribed fire is very effective following mowing, which is frequently used to reduce the amount of standing vegetation (fuel) prior to conducting a prescribed burn, reducing the risk and/or enhancing the effectiveness of the burn.

- While requiring highly trained staff and specialized equipment, Rx burns are considered very affordable, particularly as the scale of the management sites increases.

**Disadvantages**:

- Fire prescriptions designed primarily to reduce wildfire risk are generally ineffective at restoring or resetting xeric sites to the target vegetative conditions identified in “Step 1” of this document. Rx burns conducted to minimize/mitigate wildfire risk are frequently subjected to regulatory or policy conditions or priorities that preclude burning during the growing season, reducing their effect on larger, woody vegetation. Because many tree species native to xeric habitats are (at least in their mature condition) fire-adapted and resistant to fire-induced stress or mortality, these fire prescriptions neither cause mortality of mature undesirable vegetation.

- Use of prescribed fire to restore or reset xeric forest conditions to those of more desirable xeric barrens or savanna would require a deliberate, more intensive and higher-risk fire prescriptions that might conflict with local jurisdictional requirements.

- Effectiveness in managing invasive or undesirable species at xeric scrub/shrub sites is critically dependent upon the timing of burns, with growing season burns being significantly more effective. However, growing season burns may be less compatible with other land uses including tourism. Use current data at other sites to best inform your decisions but also experiment and monitor your site-specific impacts.

- The application of Rx fire is highly controlled. Application or use restrictions typically present at the site (policy or practice), municipal (ordinance), county or state (laws/regulations) level. In some states, application of prescribed fire is reserved to the jurisdiction of a state fire control agency.

- Prescribed fire is constrained by weather conditions and the window of suitable conditions is often very short.

- Many states have a shortage of trained staff. When prescribed fire is constrained to a narrow time period, it is not possible for the small staff to visit all the sites.

* **Mowing/Brush-hogging –**
* Can be effective at addressing shrub/scrub invasive species restoration objectives.
* Can be highly effective at addressing shrub/scrub invasive species maintenance objectives.
* Not at all effective at addressing forest canopy restoration or maintenance objectives.

**Advantages**:

- According to the professional opinion of participating site managers, mowing and brush-hogging can be used to help control the succession of woody stem plants into habitats where they are not desired.

- Mowing is frequently used to reduce the amount of standing vegetation prior to conducting a prescribed burn or herbicide treatment, reducing the risk and/or enhancing the effectiveness of those strategies to eliminate invasive species.

- Mowing is reasonably affordable, does not require numerous or highly trained staff.

**Disadvantages**:

- Mowing alone may not remove undesirable vegetation species capable of re-sprouting, nor does it address invasive weed seeds.

- Mowing too frequently or intensively can reduce plant diversity, adversely affect habitat function (nest sites or cover) and may directly harm wildlife.

- Mowing projects may be subject to seasonal restrictions required to protect wildlife.

- The larger, denser and/or more mature the vegetation in question, the less appropriate mowing/rush-hogging will be.

- Mowing alters soil chemistry and nutrient cycling, most notably adding carbon which can deplete nitrogen

- Mowing adds litter and duff, which can reduce exposed mineral soil, limiting ground bee nesting habitat and mineral soil seedbed for requisite plant species.

* **Seeding/Supplemental planting**
* Highly effective in helping to achieve maintenance and restoration objectives to reduce or eliminate invasive herbaceous vegetation.
* Less effective at addressing maintenance or restoration objectives regarding invasive shrub/scrub or forest vegetation.

**Advantages:**

- Seeding or supplemental planting can be an efficient, effective way to reset vegetative communities at restoration sites, or to help out-compete undesirable or invasive species at maintenance sites.

- Seeding to establish native herbaceous vegetation species may help shade and therefore preclude the establishment of undesirable woody vegetation.

**Disadvantages:**

- Seeding projects must secure a reliable source of genetically appropriate seeds for the duration of the project.

- Effective seeding or planting plans must first ensure the cause of any declines or failures for desirable vegetation to establish are identified (competition with invasives/herbivores or other pests/shade/poor soil nutrition/lack of management).

- Appropriate seedbed of mineral soil is usually requisite for both germination and seedling establishment.

- For many species soil symbionts are required (e.g. Legumes, Pines, Oaks, and Heaths).

## Step 3C: Management Objective – Establish native desirable vegetation.

The establishment of native, desirable vegetation was a core goal of projects participating in this study. Literature, site managers and the project’s data all recognize the importance and effect that establishment of native, nectar-producing herbaceous vegetation has on pollinator species diversity and abundance. Many barrens-obligate moths require trees as hostplants. The ability to work towards this objective typically indicates that a site is at the end of their “restoration-oriented” management objectives. Once this objective is successfully implemented, the site will likely be able to transition to maintenance objectives.

Available Best Management Techniques/Strategies:

* **Seeding/Supplemental planting**
* Highly effective in helping to achieve maintenance and restoration objectives regarding establishment of native vegetation.

**Advantages:**

- Seeding or supplemental planting is the most direct, efficient, and effective way to reset vegetative communities at restoration sites, or to enhance the species diversity at maintenance sites.

- Seeding to establish native herbaceous vegetation species may help shade and therefore preclude the establishment of undesirable woody vegetation.

**Disadvantages:**

- Seeding projects must secure a reliable source of genetically-appropriate seeds for the duration of the project.

- Effective seeding or planting plans must first ensure the cause of any declines or failures for desirable vegetation to establish are identified (competition with invasives/herbivores or other pests/shade/poor soil nutrition/lack of management).

- Effort needed to understand the role of mycorrhizal fungi and incorporating in planting plans (Duell et al. 2023).

- Need for specialized equipment for cleaning, spreading seed etc. at larger scales.

* **Discing/Harrowing –**
* Effective in contributing to native vegetation establishment objectives at restoration or maintenance sites, especially when used in advance of discing/harrowing and planting or seeding.
* Can be highly effective at addressing shrub/scrub species restoration objectives when used in advance of native shrub species planting.
* Not particularly useful in addressing objectives involving forest restoration or maintenance.

**Advantages**:

- Discing/harrowing is critical to the success of large-scale vegetation restoration projects, particularly in advance of seeding or planting.

- Discing may be used to expose native seed bank materials.

- Discing creates effective fire breaks and can be used to reduce the amount of standing vegetation prior to conducting a prescribed burns, reducing the risk and/or enhancing the effectiveness of those strategies to eliminate invasive species.

- Discing is very effective, efficient, reasonably affordable and does not require numerous or highly trained staff.

**Disadvantages**:

- Discing alone may not remove undesirable vegetation species capable of re-sprouting, nor does it address invasive weed seeds.

- Discing too frequently or intensively can reduce plant diversity, adversely affect habitat function (nest sites or cover) and may directly harm wildlife.

- Discing projects may be subject to seasonal restrictions required to protect wildlife.

- Discing is limited to use on sites with existing, herbaceous community, free of stumps, root wads or severely rocky soils.

* **Clearing/Felling/Canopy thinning (i.e., “Forest Stand Improvement” (FSI) practices)**
* Can be a highly effective strategy to facilitate restoration objectives at forested or scrub-shrub sites.

**Advantages:**

- FSI projects directly remove non-native or native but undesirable woody vegetation, or cause their mortality, opening the canopy to facilitate the growth of native/desirable vegetation on the forest floor.

- Clearing or select felling is an effective practice to initiate the restoration of xeric sites that have succeeded into fully forested conditions and may be effectively used in conjunction with (and typically preceding) other practices such as seeding and planting, prescribed burns, or herbicide application, where FSI practices frequently increase the subsequent practice’s effectiveness and/or lessen its associated risks.

**Challenges:**

- FSI projects can be costly and labor-intensive.

- FSI projects may be subject to seasonal restrictions required to protect wildlife.

- The larger and/or more mature the vegetation in question, the greater effort may be required.

- Clearing activities may produce disturbances and/or create conditions suitable for invasive or non-desirable species introduction.

- Clearing/felling must be followed up with appropriate maintenance to ensure that target vegetation or habitat conditions develop in the affected area(s).

- Many hardwood stumps will sprout and may require follow-up treatment (herbicide) to cut stumps and new stems.

- Size and scale of FSI projects require critical considerations regarding:

1. equipment access routes
2. soil compaction impacts
3. equipment biosecurity protocols to address weed seeds (power washing equipment, etc.)
4. clearly understandable yet detailed project maps or plans, ensuring that heavy equipment operators have knowledge of what should be removed and what should be left
5. on-site flagging or fencing of important work vs preservation areas

* **Mowing/Brush-hogging**
* Thinning is a very effective practice to achieve native vegetation reintroduction objectives.
* Can be effective in assisting with vegetation species restoration objectives.
* Can be highly effective at addressing shrub/scrub invasive species maintenance objectives.
* Not at all effective at addressing forest canopy restoration or maintenance objectives.

**Advantages**:

- According to the professional opinion of participating site managers, mowing and brush-hogging can be used to help control the succession of woody stem plants into habitats where they are not desired.

- Mowing is frequently used to reduce the amount of standing vegetation prior to conducting a prescribed burn or herbicide treatment, reducing the risk and/or enhancing the effectiveness of those strategies to eliminate invasive species.

- Mowing is reasonably affordable, does not require numerous or highly trained staff.

**Disadvantages**:

- Mowing alone may not remove undesirable vegetation species capable of re-sprouting, nor does it address invasive weed seeds.

- Mowing too frequently or intensively can reduce plant diversity, adversely affect habitat function (nest sites or cover) and may directly harm wildlife.

- Mowing projects may be subject to seasonal restrictions required to protect wildlife.

- The larger, denser and/or more mature the vegetation in question, the less appropriate mowing/rush-hogging will be.

* **Prescribed Fire (Rx Burn or Rx Fire)**
* Can be effective at addressing native vegetation establishment maintenance and restoration objectives in fire-adapted communities.
* Not likely to be effective at meeting native vegetation introduction/establishment objectives in vegetative communities not historically managed by fire.

**Advantages**:

- Prescribed fire best mimics the historic habitat management influences that have formed and *maintained* xeric sites in the Northeast for thousands of years.

- Prescribed fire is particularly effective at *maintaining* existing, fire adapted vegetation in xeric barrens and grasslands, particularly for species that require fire for seed (cone) dispersal and/or to enhance germination.

- Use of prescribed fire may increase nutrient cycling and lead to more robust plants.

- While requiring highly trained staff and specialized equipment, Rx burns are considered very affordable, particularly as the scale of the management sites increases.

**Disadvantages**:

- While effective at eliminating invasive/undesirable vegetation (discussed above), the use of prescribed fire alone will not meaningfully assist in the introduction of native herbaceous species.

## Step 3D: Management Objective – Enhance nesting resources for bees.

While not universally identified as a critical habitat management objective for pollinators in the literature, and poorly addressed by this study’s data analysis, exposing bare mud or friable soils was considered to be an important component of site managers and species experts who coordinated on this study. Most bee species are ground-nesters, and many others employ mud for nest creation.

Managing for the exposure of bare soil is something restoration sites should design for and anticipate but is primarily a site maintenance objective. Maintenance activities that encourage the proliferation of bunch grasses or other naturally-sparse vegetation, or in other ways preserve access to the soil, should facilitate pollinator species richness and abundance.

Available Best Management Techniques/Strategies:

* **Seeding/Supplemental planting**
* Highly effective in helping to achieve maintenance and restoration objectives regarding establishment of native vegetation.

**Advantages:**

- Seeding or supplemental planting is the most direct, efficient, and effective way to reset vegetative communities at restoration sites, or to enhance the species diversity at maintenance sites.

- Seeding to establish native herbaceous vegetation species may help shade and therefore preclude the establishment of undesirable woody vegetation.

**Disadvantages:**

- Seeding projects must secure a reliable source of genetically-appropriate seeds for the duration of the project.

- Effective seeding or planting plans must first ensure the cause of any declines or failures for desirable vegetation to establish are identified (competition with invasives/herbivores or other pests/shade/poor soil nutrition/lack of management).

* **Discing/Harrowing –**
* Effective in contributing to native vegetation establishment objectives at restoration or maintenance sites, especially when used in advance of discing/harrowing and planting or seeding.
* Can be highly effective at addressing shrub/scrub species restoration objectives when used in advance of native shrub species planting.
* Not particularly useful in addressing objectives involving forest restoration or maintenance.

**Advantages**:

- Discing/harrowing is critical to the success of large-scale vegetation restoration projects, particularly in advance of seeding or planting.

- Discing may be used to expose native seed bank materials.

- Discing creates effective fire breaks and can be used to reduce the amount of standing vegetation prior to conducting a prescribed burns, reducing the risk and/or enhancing the effectiveness of those strategies to eliminate invasive species.

- Discing is very effective, efficient, reasonably affordable and does not require numerous or highly trained staff.

**Disadvantages**:

- Discing alone may not remove undesirable vegetation species capable of re-sprouting, nor does it address invasive weed seeds.

- Discing too frequently or intensively can reduce plant diversity, adversely affect habitat function (nest sites or cover) and may directly harm wildlife.

- Discing projects may be subject to seasonal restrictions required to protect wildlife.

- Discing is limited to use on sites with existing, herbaceous community, free of stumps, root wads or severely rocky soils.

* **Clearing/Felling/Canopy thinning (i.e., “Forest Stand Improvement” (FSI) practices)**
* Can be a highly effective strategy to facilitate restoration objectives at forested or scrub-shrub sites.

**Advantages:**

- FSI projects directly remove non-native or native but undesirable woody vegetation, or cause their mortality, opening the canopy to facilitate the growth of native/desirable vegetation on the forest floor.

- Clearing or select felling is an effective practice to initiate the restoration of xeric sites that have succeeded into fully forested conditions and may be effectively used in conjunction with (and typically preceding) other practices such as seeding and planting, prescribed burns, or herbicide application, where FSI practices frequently increase the subsequent practice’s effectiveness and/or lessen its associated risks.

**Disadvantages:**

- FSI projects can be costly and labor-intensive.

- FSI projects may be subject to seasonal restrictions required to protect wildlife.

- The larger and/or more mature the vegetation in question, the greater effort may be required.

- Clearing activities may produce disturbances and/or create conditions suitable for invasive or non-desirable species introduction.

- Clearing/felling must be followed up with appropriate maintenance to ensure that target vegetation or habitat conditions develop in the affected area(s).

- Many hardwood stumps will sprout and may require follow-up treatment (herbicide) to cut stumps and new stems.

- Size and scale of FSI projects require critical considerations regarding:

1. equipment access routes
2. soil compaction impacts
3. equipment biosecurity protocols to address weed seeds (power washing equipment, etc.)
4. clearly understandable yet detailed project maps or plans, ensuring that heavy equipment operators have knowledge of what should be removed and what should be left
5. on-site flagging or fencing of important work vs preservation areas

* **Mowing/Brush-hogging**
* Thinning is a very effective practice to achieve native vegetation reintroduction objectives.
* Can be effective in assisting with vegetation species restoration objectives.
* Can be highly effective at addressing shrub/scrub invasive species maintenance objectives.
* Not at all effective at addressing forest canopy restoration or maintenance objectives.

**Advantages**:

- According to the professional opinion of participating site managers, mowing and brush-hogging can be used to help control the succession of woody stem plants into habitats where they are not desired.

- Mowing is frequently used to reduce the amount of standing vegetation prior to conducting a prescribed burn or herbicide treatment, reducing the risk and/or enhancing the effectiveness of those strategies to eliminate invasive species.

- Mowing is reasonably affordable, does not require numerous or highly trained staff.

**Disadvantages**:

- Mowing alone may not remove undesirable vegetation species capable of re-sprouting, nor does it address invasive weed seeds.

- Mowing too frequently or intensively can reduce plant diversity, adversely affect habitat function (nest sites or cover) and may directly harm wildlife.

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* **Prescribed Fire (Rx Burn or Rx Fire)**
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- Prescribed fire is particularly effective at *maintaining* existing, fire adapted vegetation in xeric barrens and grasslands, particularly for species that require fire for seed (cone) dispersal and/or to enhance germination.

- Use of prescribed fire may increase nutrient cycling and lead to more robust plants.

- While requiring highly trained staff and specialized equipment, Rx burns are considered very affordable, particularly as the scale of the management sites increases.

**Disadvantages**:

- While effective at eliminating invasive/undesirable vegetation (discussed above), the use of prescribed fire alone will not meaningfully assist in the introduction of native herbaceous species.

## Step 4: Establish a rotational management strategy.

The management practices recommended in this report are intended to support populations of bees and moths – an important target taxon in these habitats. A patchy mosaic of management units that provides refugia from conservation work is crucial to prevent unintended damage to the populations.

Regardless of initial conditions or habitat objectives, sites should be divided into management units and rotational management strategies should be used to develop a mosaic of habitat conditions that represent the historical range of variability suitable for target SGCN wildlife (Wagner et al. 2003). Multiple management units also facilitate retention of wildlife refugia. Most invertebrates inhabit sites year-round and are unable to escape management activities during critical life stages. Rotational management will maintain constant refugia within the site, protecting populations of rare species from being extirpated by management activities. This is particularly important if adjacent land use is not suitable and does not provide a source population for rare species. A mosaic of treatment units will support the greatest diversity of invertebrates averting the need to take single species actions (Gelles et al. 2021). As an example, to ensure adequate refugia for the endangered Karner blue (*Plebejus melissa samuelis*), the Albany Pine Bush Preserve Commission will not burn more than one third of an occupied subpopulation each year and will not burn adjacent thirds of an occupied subpopulation within consecutive years.

## Step 5: Monitor and Adaptively Manage

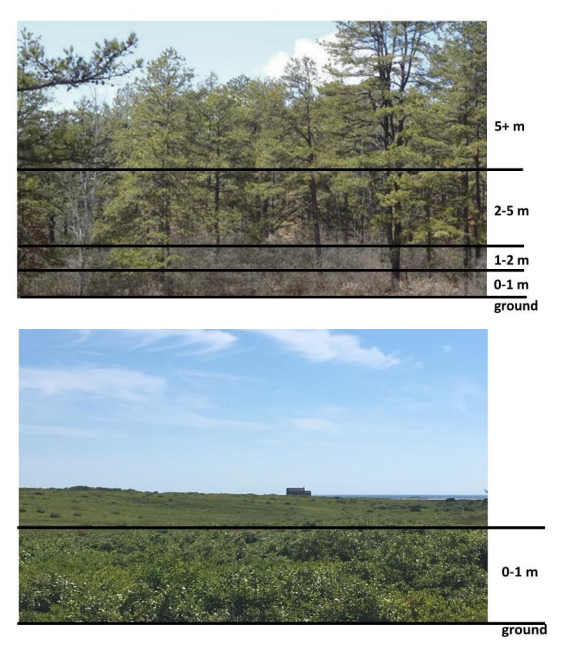
The recommendations provided above are intended to improve habitat conditions for native bees and nocturnal moths, but the first responses to management will be in the vegetation community. This study found that bee diversity was highest in sites with a long history of effective management (Barton and Poulos 2023). Therefore, a commitment to management that will achieve habitat condition targets will benefit pollinators in the long term. Interannual fluctuations in bee populations make it difficult to determine the immediate effects of management on species without extending surveys over multiple years (Selfridge et al. 2017, Turley et al. 2022). Xeric sites in the Northeast are dependent on fire and are successional unless managed – management will need to continue to maintain habitat condition targets.

Habitat objectives outlined above should be determined specifically for each site and monitoring plans should track these objectives quantitatively. Because site conditions are varied, recommendations are imprecise. Monitoring the vegetative response to management activities is the best way to inform future management.

Diagram

Description automatically generatedThe vegetation monitoring protocol used for this study (Appendix B) employs a line-point intercept assessment of vegetation intersecting a vertical line (Figure 4) at the soil surface, 0-1 m, 1-2 m, 2-5 m, and >5 m (Figure 5).

Figure 5: Two examples of line-point intercept hits for ground cover. In point 1, the pin intercepts rock at the ground, and then fescue, bluegrass, and clover in the 1-2 m stratum. In point 2, the pin hits at the ground and at the 1-2 m interval, but no other ground cover or species in the 1-2 m stratum.

Fig. 5. Example of the different sampling strata that would be included in the point-line intercept sampling in a pitch pine oak forest where all strata are present (top) and in a heathland where only the ground and 0-1 m strata are present (bottom).

# Conclusion and Recommendations

The geographic extent of the study area presented both opportunities and challenges. The Xeric Habitat for Pollinators project design did not, in the end, contain enough site replicates to derive data specifically addressing the differences between specific habitat management techniques. Additionally, the 5-year project window (inclusive of pandemic interruptions) did not afford enough time to fully monitor the effects of many project sites’ habitat management efforts. Vegetation responses were more easily detected that those of the highly mobile faunal communities sampled. Notwithstanding, the data collected and analyzed, pooled with literature resources and the real-world experiences of site managers with – in some cases – decades of habitat management experience, did allow the project to make the following broad recommendations for sites considering habitat management for pollinators at xeric sites.

Manage  
Our data emphasize the overall positive impacts that habitat management can have on bee communities. Management treatments were shown to enhance potential bee habitat by decreasing woody cover and showed an increase in early successional flowering plant cover, as well as bee and moth host plant cover, providing a long-term benefit to both taxa. Within the project timeframe, much of this response was driven by two sites, the Albany Pine Bush and Pratt Farm, the former has been actively managed for several decades, and the latter underwent major thinning operations that were more intensive than management activities at other project sites. But differences in sites managed prior to the study vs. sites that were unmanaged prior to the study were not attributable to these two sites.

While it is difficult to tease out the effects of environment, site, etc. on pollinator communities themselves, it is noteworthy that none of the treatments had a negative impact on bee communities, with the exception of a slight depressing effect of prescribed fire on bee species richness. While moth community richness and abundance was lower in sites with a decade of prior management, this result may represent impacts on the moth community as a whole. Xeric habitat associated species may not have been negatively affected by habitat management.

Manage for Habitat Heterogeneity: A Case for Small Units on Rotational Management Schedules Managing different areas of the site (“units”) on a rotational basis creates habitat heterogeneity within a site, and produces a variety of microhabitats that can support or enhance biodiversity. Our data illustrate that bees and moths sort out differently along environmental gradients. While both show an association with flowering plants, bee species richness is correlated with a decrease in canopy cover and an increase in bare ground, while moth species richness is higher in woodlands over grasslands. Managing units for different seral states may maximize diversity (Gelles et al. 2021). It also provides refugia for species that may suffer direct mortality during management activities such as prescribed fire. Managing sites as single, contiguous blocks in the absence of suitable refugia is especially undesirable for maintenance sites that likely already support a suite of rare species.

Manage for Plant Communities: Vegetation Influences Pollinator Communities  
Our results add to a large body of evidence that bee and moth communities are driven in large part by plant communities, and in our project, bee species composition sort out along some environmental gradients in a similar manner to plant species composition. The strongest driver of bee community composition between grassland and woodland sites was canopy cover, with the most diverse bee communities found in grassland sites with minimal tree cover. Conversely, the presence of canopy cover can have a positive impact on moth communities by increasing diversity. Management also increased early successional flowering plant cover and bee and moth host plant cover, changing plant communities in ways that “should matter” to pollinator communities.

Monitor  
Timing, intensity and frequency of management can all influence the resulting habitat. Our results indicate that plant, bee, and moth communities all differed significantly across sites, among ecoregions, and between grassland and woodland habitats (Barton and Poulos 2023). It stands to reason that they will also vary in response to management. It is critical that land mangers monitor plant community response, including responses of both desirable and undesirable vegetation. Even in the absence of invertebrate species data, monitoring the plant community response can serve as an important indicator for invertebrate diversity. Monitoring plant species is also more likely a reasonable expectation of site managers, who may not possess the identification skills necessary to monitor bee or moth community response.

A Note Regarding Carbon Storage and Sequestration

In the face of climate change, wildlife and/or wildlife habitat management strategies have come under a new form of scrutiny – assessing effects on carbon storage or sequestration. Terrestrial carbon is stored both above-ground and within soil and is found in living and dead biomass. Vegetation structure and composition determines the storage pool of above-ground carbon and its sequestration rates, while temperature, soil type, and water holding capacity determine storage and sequestration of below-ground carbon. While increasing efforts to sequester carbon in natural landscapes is a practical and important mitigation response to climate change, wildlife habitat values are not always compatible with maximizing carbon sequestration (Littlefield and D’Amato 2022).

*Managing xeric or barrens habitats, as is necessary to maintain the rare fauna and flora that have co-evolved with dependencies on these unique habitat conditions, would not appreciably alter carbon sequestration or storage rates, either to a positive or negative extent.*

The sandy, well-drained soils characteristic of barrens sites in the northeast U.S. enable aerobic decomposition year-round, and as a result typically feature higher overall rates of decomposition and accumulate less soil organic matter than do sites featuring saturated or seasonally saturated loamy or clay soils. A study of the New Jersey Pine Barrens found that the most xeric portions of the Pinelands Management Area have the least stored carbon and the lowest rate of carbon sequestration in live carbon (leaves/needles, wood, roots), detrital carbon (fine and coarse litter and dead roots), and soil organic carbon compared to other areas within the pine barrens which are expected to modestly increase in carbon storage (Scheller et al. 2011). In fact, most sites involved in this study have less than 10% soil organic matter (or 4.7% carbon) based on data extracted from the web soil survey (Soil Survey Staff, Natural Resources Conservation Service, United States Department of Agriculture n.d.). In general, carbon storage provided by forest growth exceeds carbon released by habitat management according to a study of upland forests in Massachusetts (<https://www.mass.gov/service-details/carbon-storage-on-masswildlife-lands>). Furthermore, habitat management to improve forest health can increase carbon sequestration rates and help preclude catastrophic carbon releases due to unmitigated wildfires or the effects of insect damage/disease.

# Contacts

If you would like to discuss your management plans with an experienced barrens or xeric habitat manager, you can contact:

The Albany Pine Bush Preserve Commission, Albany, NY, 518.456.0655

Linda Loring Nature Foundation, P.O. Box 149, Nantucket, MA 02554 [www.llnf.org](http://www.llnf.org)

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# Appendix A: Regional Species of Greatest Conservation Need in Xeric Habitats in the Northeast US

Northeast Regional Species of Greatest Conservation Need are regularly reviewed and include species from a wide range of taxonomic groups. Species are categorized according to the portion of the species’ range that overlaps the Northeast Region (Regional Responsibility) and the level of conservation concern. Some species that cannot be categorized but experts have some concern for are categorized on a Watchlist as Assessment Priorities. You can learn more about the RSGCN review process in the 2023 Northeast Synthesis (Terwilliger Consulting Inc. and Northeast Fish and Wildlife Diversity Technical Committee in prep.). Here, RSGCN are listed based on their association with the closest habitat category – Glades, Barrens, and Savannas (Terwilliger Consulting Inc. and Northeast Fish and Wildlife Diversity Technical Committee 2023).

Table A.1 Species that may not occur in habitats other than Glades, Barrens, and Savannas. These species have greater than 50% Northeast responsibility. They are all considered to be on the “Watchlist” and some are not currently SGCN in Northeastern states.

|  |  |  |
| --- | --- | --- |
| Taxonomic Group | Scientific Name | Responsibility |
| Solitary Bees | *Hylaeus saniculae* | 50-75% |
|  | *Lasioglossum izawsum* | 100% (NEAFWA endemic) |
|  | *Osmia felti* | 50-75% |
|  | *Colletes bradleyi* | 100% (NEAFWA endemic) |
|  | *Andrena braccata* | 100% (NEAFWA endemic) |
|  | *Lasioglossum arantium* | 50-75% |
| Moths | *Acleris comandrana* | 100% (NEAFWA endemic) |

Table A.2 Species that occur in Glades, Barrens, and Savannas and only one other habitat type and have greater than 50% Northeast responsibility.

|  |  |  |  |
| --- | --- | --- | --- |
| Taxonomic Group | Scientific Name | RSGCN Status | Northeast Regional Responsibility |
| Solitary Bees | *Nomada electa* | Watchlist [Assessment Priority] | 100% (NEAFWA endemic) |
| Butterflies and Skippers | *Callophrys lanoraieensis* | Moderate Concern | 100% (NEAFWA endemic) |
| Moths | *Papaipema sp. 1* | Very High Concern | 100% (NEAFWA endemic) |
| Terrestrial Snails | *Anguispira stihleri* | Very High Concern | 100% (NEAFWA endemic) |
| Terrestrial Snails | *Helicodiscus triodus* | High Concern | 100% (NEAFWA endemic) |
| Moths | *Agrotis buchholzi* | Very High Concern | 50-75% |
| Terrestrial Snails | *Striatura exigua* | Watchlist [Assessment Priority] | 50-75% |

Table A.3 Additional species that occur in Glades, Barrens, and Savannas but may occur in other habitats as well. These species have greater than 50% Northeast responsibility.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Taxon | Subtaxon | Scientific Name | Concern Level | Responsibility |
| Amphibian | Salamanders | *Plethodon shenandoah* | Very High | 100% (NEAFWA Endemic) |
| Amphibian | Salamanders | *Plethodon virginia* | Very High | 100% (NEAFWA Endemic) |
| Amphibian | Salamanders | *Ambystoma jeffersonianum* | Watchlist [Assessment Priority] | 50-75% |
| Bird | Landbirds | *Catharus bicknelli* | High | 75-100% |
| Bird | Landbirds | *Euphagus carolinus* | Moderate | 50-75% |
| Bird | Raptors | *Aquila chrysaetos* | Moderate | 50-75% |
| Insect:Coleoptera | Fireflies | *Pyractomena similis* | Watchlist [Assessment Priority] | 50-75% |
| Insect:Coleoptera | Tiger Beetles | *Cicindela patruela consentanea* | High | 100% (NEAFWA Endemic) |
| Insect:Coleoptera | Tiger Beetles | *Cicindela patruela patruela* | High | 50-75% |
| Insect:Lepidoptera | Butterflies and Skippers | *Atrytone arogos arogos* | High | 50-75% |
| Insect:Lepidoptera | Butterflies and Skippers | *Calephelis borealis* | High | 50-75% |
| Insect:Lepidoptera | Butterflies and Skippers | *Callophrys irus* | Very High | 50-75% |
| Insect:Lepidoptera | Butterflies and Skippers | *Erynnis persius persius* | Very High | 50-75% |
| Insect:Lepidoptera | Butterflies and Skippers | *Colias interior* | Watchlist [Assessment Priority] | 100% (NEAFWA Endemic) |
| Insect:Lepidoptera | Moths | *Metarranthis pilosaria* | High | 100% (NEAFWA Endemic) |
| Insect:Lepidoptera | Moths | *Abagrotis benjamini* | High | 75-100% |
| Insect:Lepidoptera | Moths | *Apodrepanulatrix liberaria* | High | 50-75% |
| Insect:Lepidoptera | Moths | *Catocala herodias gerhardi* | High | 75-100% |
| Insect:Lepidoptera | Moths | *Papaipema duplicatus* | Moderate | 50-75% |
| Insect:Lepidoptera | Moths | *Drasteria occulta* | Very High | 100% (NEAFWA Endemic) |
| Insect:Lepidoptera | Moths | *Macaria exonerata* | Very High | 100% (NEAFWA Endemic) |
| Insect:Lepidoptera | Moths | *Crambus daeckellus* | Very High | 100% (NEAFWA Endemic) |
| Insect:Lepidoptera | Moths | *Eucoptocnemis fimbriaris* | Watchlist [Assessment Priority] | 50-75% |
| Insect:Lepidoptera | Moths | *Papaipema appassionata* | Watchlist [Assessment Priority] | 50-75% |
| Insect:Lepidoptera | Moths | *Cerma cora* | Watchlist [Assessment Priority] | 50-75% |
| Insect:Lepidoptera | Moths | *Cyclophora culicaria* | Watchlist [Assessment Priority] | 50-75% |
| Insect:Lepidoptera | Moths | *Schizura apicalis* | Watchlist [Assessment Priority] | 50-75% |
| Insect:Lepidoptera | Moths | *Hemaris gracilis* | Watchlist [Assessment Priority] | 50-75% |
| Insect:Lepidoptera | Moths | *Zanclognatha martha* | Watchlist [Assessment Priority] | 50-75% |
| Mammal | Bats | *Myotis leibii* | High | 50-75% |
| Mammal | Rabbits and Hares | *Sylvilagus obscurus* | Moderate | 50-75% |
| Mammal | Small Mammals:Rodentia | *Microtus chrotorrhinus* | High | 75-100% |
| Mammal | Small Mammals:Rodentia | *Microtus chrotorrhinus carolinensis* | High | 75-100% |
| Mammal | Small Mammals:Rodentia | *Neotoma magister* | Very High | 50-75% |
| Mollusc | Terrestrial Snails | *Paravitrea pontis* | Moderate | 100% (NEAFWA Endemic) |
| Mollusc | Terrestrial Snails | *Novisuccinea chittenangoensis* | Very High | 100% (NEAFWA Endemic) |
| Reptile | Snakes | *Coluber constrictor constrictor* | Watchlist [Assessment Priority] | 50-75% |
| Reptile | Snakes | *Opheodrys vernalis* | Watchlist [Assessment Priority] | 50-75% |
| Reptile | Turtles | *Glyptemys insculpta* | High | 75-100% |
| Reptile | Turtles | *Clemmys guttata* | High | 50-75% |

Though not listed above, Box Turtles (Terrapene Carolina Carolina) are a moderate concern RSGCN and Stewardship priority. They are known to occur in barrens habitats. Best management practices for box turtles were recently prepared (Erb and Roberts 2023).

# Appendix B: Vegetation monitoring protocol used for this project