The Trustees of Reservations

Sand Barrens Habitat Management

A Toolbox For Managers

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Executive Summary

- The guiding principles for this document are as follows:
    1. To emphasize the importance of land-use history.
    2. To maximize the understanding of how a site fits into the surrounding landscape.
    3. To achieve a balance between the constraints of cost and the frequency of applying a management tool.
    4. To emphasize the need for monitoring rare species and habitat change.
    5. To fully investigate all risks to rare species when managing.
    6. To provide for flexibility in using combinations of tools for habitat management.
    7. To emphasize the importance of using this toolbox in a dynamic manner.
    8. To emphasize the need for information sharing and continued research.

- In the northeastern United States, sand barrens are a subset of barrens ecosystems occurring on various substrates—shale, conglomerate, serpentine—and in harsh landscapes such as dry ridge tops. Sand barrens occur in dry sandy areas such as outwash plains and ancient lake deltas. Poor quality soils such as coarse sand or ridge top soils form a foundation for barrens, creating difficult growing conditions for most plants.

- Sand barrens community types (Section 2) can be broadly classified into several categories: grasslands and heathlands, shrublands, dwarf pine plains, barrens, woodlands, and forests. For each category, habitat variability can be found. All community types are inherently defined by human activities.

- The barrens habitats throughout the Northeast (Section 3 overview) are all similar to one another in that Scrub Oak, Pitch Pine, tree oaks, Black Huckleberry, and other heath species dominate. Each site exhibits slightly different characteristics. The southern sites in the region have dwarf pine plains. The northern sites have species more typical of boreal ecosystems, such as spruce and fir. The coastal outwash plain sites have exemplary occurrences of earlier successional habitats such as heathlands, grasslands, and shrublands.

- As a whole, these sand barrens communities are among the most imperiled habitats in the world. Sand barrens habitats are in dire need of management, as they support rare and uncommon assemblages of plants and animals.

- Following the first human settlements in the northeastern United States, thousands of years ago, human-related disturbances drastically changed the structure and diversity of vegetation around highly populated areas—primarily through large-scale burning and girdling.

- As European settlements were increasingly established in the United States in the 1600s, land clearing for agriculture and livestock grazing became widespread. The English settlers adopted practices of the Native Americans for maintaining open landscapes, such as burning and girdling.

- By the late 1800s, scores of agricultural fields and pastures in the Northeast were abandoned. Because of the subsequent abandonment of these farms, traditional land-use practices of burning, clearing, mowing, and grazing consequently collapsed. This, combined with fire suppression activities and the increased development of open space, led to a decline in disturbance-dependent habitats throughout the Northeast.

- Described in this toolbox are the practical issues involving the use of prescribed fire (Section 4), prescribed grazing (Section 5), mowing (Section 6), clearing (Section 7), and herbicides (Section 8) to manage sand barrens habitat.

- In Section 9, using the sand barrens of Martha's Vineyard as a case study, these methods are tied together, looking at ways to use the tools holistically to achieve habitat management objectives. The costs, benefits, and risk to rare species for each method are also described.

- Currently, most sand barrens sites in the Northeast are in the early to mid stages of their ecological management programs, focusing primarily on restoring early- to mid-successional habitats. Long-term management effects are not well known due to the infancy of many programs, although ecological research on barrens sites is significant.

- Prescribed fire is a necessary part of managing sand barrens in the northeastern United States. Although many issues and logistics need to be addressed and costs may be high, the ecological benefits of fire, when applied correctly, are great. The ecological effects and the ability of prescribed fire to achieve ecological goals, especially given its historical significance are the greatest benefits of burning.

- Burning presently offers many disadvantages as well. These disadvantages should be weighed with other management tools. Prescribed burning is potentially dangerous, labor and equipment intensive, is limited in its seasonality, and is highly regulated in many states.

- Using grazing as a tool may have numerous benefits to a management unit. Livestock grazing can be used to target vegetation that other tools may not be able to target, can control growth in areas that other tools cannot, can reduce woody growth and increase species diversity, and may prove to be highly flexible in terms of season and frequency. If not properly conducted, however, a grazing scheme may destroy resident herbaceous species and allow for the introduction of invasive and exotic species.

- Mechanical mowing is a relatively flexible tool, and can essentially be performed anytime of the year. The initial financial costs of mowing may be high—if one was to purchase a mower, or tractor equipped with a mower—but tend to become much lower over time. Targeting—or avoiding—specific areas through mowing may increase indigenous species while reducing the number of invasive or exotic species. Consequently, mowing may increase duff build-up, crush sensitive species, and may reduce species diversity in some cases.

- Clearing is an intense disturbance that will have a tremendous effect on habitat structure. Several factors—such as timing, season, clearing method, clearing technique, target species, and adjacent habitats—will determine the success of a land-clearing project. For this reason, its use should be considered carefully as a restoration tool. Meeting management objectives, however, may be greatly facilitated when clearing is combined with other management tools, such as burning (Section 4) or using herbicides (Section 8.)

- Although the use of herbicides may serve as an effective management tool, its use should not serve as a long-term solution. Selectively applying herbicides will allow managers to avoid the use of excessive mowing or grazing treatments in the future to remove any resprouting vegetation.

Section 1: Introduction

In the northeastern United States, sand barrens are harsh landscapes that are home to disturbance-dependent rare habitats and a wide variety of rare species. Sand barrens are dominated by tree oak species, Scrub Oak (*Quercus ilicifolia*), Pitch Pine (*Pinus rigida*), heath species (Ericaceae) such as Black Huckleberry (*Gaylussacia baccata*) and blueberries, other shrubs, and a diverse assortment of grasses and herbs. This document presents a management toolbox for the application of disturbances to restore and manage rare sand barrens habitats. Although rare sand barrens communities are the focus of this report, the restoration and maintenance of sand barrens habitats may be similar to those found in other rare barrens types or managed habitats in general (e.g. old field maintenance). Described in this toolbox are the practical issues involving the use of prescribed fire (Section 4), prescribed grazing (Section 5), mowing (Section 6), clearing (Section 7), and herbicides (Section 8) to restore and maintain various habitats. In Section 9, using Martha's Vineyard as a case study, these methods are tied together, looking at ways to use the tools holistically to achieve habitat management objectives. Section 9 also summarizes the costs, benefits, and risk to rare species for each method. Because many of these habitat management tools have not been used over the long term (or for some, not at all) on Martha's Vineyard for habitat restoration, this section describes our best estimate of species and habitat response to various treatments based on direct experience and information reported in the literature. As our information improves, through increased applied and basic research, this document will evolve.

Barrens areas are all united by a common theme of restricted growth of trees and other vegetation due to soils and disturbances.[1] Poor quality soils such as coarse sand or ridgetop soils form a foundation for barrens, creating harsh conditions for most plants. Various human-caused disturbances have also historically maintained a diverse assortment of habitats. These disturbances—clearing, mowing, grazing, and burning—when applied in various regimes[2] and combinations, created different community types. A continuum of grasslands, heathlands, savannas, shrublands, and woodlands[3] across the landscape was the result (Section 2). Lack of disturbances can also affect these habitats: development, fire suppression, and a reduction of traditional agriculture-based land uses such as grazing, woodcutting, and burning have decreased the extent of rare barrens habitats, grasslands, and other disturbance-dependent habitats significantly throughout the eastern United States.[4]

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[1] Olsvig, L. S. 1980. *A Comparative Study of Northeastern Pine Barrens Vegetation*. M.S. Dissertation, Cornell University: Ithaca, NY. It can be surmised from this study that soils and disturbances can be linked, i.e., that sandy soils create conditions suitable for shrubby vegetation, in turn creating a landscape that is more fire-prone. As fires sweep across these landscapes, vegetation will survive selectively according to its tolerance to fire and its adaptability to sandy soils and other such disturbances.

[2] A disturbance regime includes all disturbances affecting a habitat and takes into account season, extent, type, intensity, duration, severity, and frequency of each disturbance over a long time period. Disturbances include fire, salt spray, wind, grazing, mowing, clearing, and storm events.

[3] Woodlands are more open than forests, with tree canopy cover ranging from between 25% to 75%, approximately, depending on the source. Anderson, R. C, J. S. Fralish, and J. M. Baskin, eds. 1999. *Savannas, Barrens, and Rock Outcrop Plant Communities of North America*. Cambridge University Press: Cambridge, UK. p. 2.

[4] Finton, A. D. 1998. *Succession and Plant Community Development*. M. S. Dissertation, Univ. of Mass, Amherst.

Anderson, R. C, J. S. Fralish, and J. M. Baskin, eds. 1999.

Motzkin, G., W. A. Patterson, and D. R. Foster. 1999. A Historical Perspective on Pitch Pine-Scrub Oak Communities in the Connecticut Valley of Massachusetts. *Ecosystems*. 2: 255-273.

Barrens habitats are scattered throughout the eastern United States and are highly diverse in terms of their geology, plants, and animals.[5] In inland areas are dry ridges, plateaus, and mountaintops (e.g., the Pocono barrens, the Shawangunk-Kittatinny Ridge in New York and New Jersey,[6] and various ridgetops in the Berkshires: Mt. Tekoa, Mt. Race, Monument Mountain, and Mt. Everett, for example). Barrens areas also occur sporadically throughout the East on various substrates (e.g., serpentine barrens in Maryland, Pennsylvania, New York, and North Carolina; heathland barrens on ridgetops in Shenandoah National Park; and barrens on sandstone, conglomerate, shale, and other hardpan surfaces in the Appalachian Mountains). In addition, barrens sites occur in the Midwest (oak barrens) and Southeast (Longleaf Pine barrens) on substrates ranging from sand to rock (chert, limestone, granite) and in other areas prone to fire. The sand barrens of the northeastern United States are simply one subset of these many barrens types.

Through prescribed burning, manual clearing, mowing, and herbicide application, in various combinations, managers have started to restore sand barrens habitats, ranging from Pitch Pine-Scrub Oak barrens to grasslands. Prescribed burning is commonly practiced and used extensively for managing barrens habitat and minimizing the occurrence of uncontrollable wildfires (see Section 4). Livestock grazing, on the other hand, is used infrequently in the United States for habitat management. According to extensive research in the United Kingdom, however, the use of livestock grazing may be an effective management tool (see Section 5). Mowing, clearing, and the use of herbicides have also gained high recognition as tools for barrens management in the United States, and will be discussed in Sections 6, 7, and 8, respectively.

Through analyzing the combined effects of each tool, and incorporating the known results of monitoring efforts, we are able to construct an ecological matrix. This matrix will assist managers in determining the most effective tool, or combination of tools, to manage barrens habitat (as explained in Section 9).

[5] For an excellent overview of barrens as an ecological term, see Michael Homoya's report: http://www.epa.gov/grtlakes/oak/Proceedings/Homoya.html

[6] For more information on the Shawangunk-Kittatinny Ridge, see: http://training.fws.gov/library/pubs5/web_link/text/skr_form.htm.

Section 2—Sand Barrens Plant Communities

2.1 Introduction

Sand barrens community types can be broadly classified into several categories: grasslands and heathlands, shrublands, dwarf pine plains, barrens, woodlands, and forests. For each category, examples describing habitat variability can be found. All community types are inherently human-imposed definitions. In nature, these habitats are all interconnected and grade into one another. Taking into account the dynamic and variable nature of these communities can only make management activities more successful. Defining community types, however, is important in determining management objectives as described in this toolbox (Section 9). Without having defined objectives, determining the success of a project can be difficult or impossible. With this in mind, sand barrens plant communities are described in this section. These community definitions will be used throughout the document.

Figure 2.1*: A transition zone between heathlands (left) and Scrub Oak-heath shrublands (right). To the left, the grass, herbaceous, and heath (red shrubs) components increase whereas to the right, Scrub Oak (brown and green shrubs) dominates. Martha's Vineyard, MA.*

2.2 Grasslands and heathlands

Grasslands and heathlands occur in areas that have a history of a high level of disturbances. Grasslands and heathlands often occur together in a mosaic pattern, although either grass or heath may dominate depending on the disturbance regime of an area. Little Bluestem and other grasses, such as Poverty Grass (*Danthonia spicata*) and Red Fescue (*Festuca rubra*) dominate the grassland component of this mosaic. A high diversity of herbaceous species—asters (*Aster*), goldenrods (*Solidago* and *Euthamia* spp.), and wild indigo (*Baptisia tinctora*), for example—are interspersed within the grasses. Heathland species are Black Huckleberry, Late Lowbush Blueberry (*Vaccinium angustifolium*), and Bearberry (*Arctostaphylos uva-ursi*) with other shrubs such as roses (*Rosa* spp.), Northern Bayberry (*Myrica pensylvanica*), and Nantucket Shadbush (*Amelanchier nantucketensis*), which only occurs on the islands of Massachusetts. Bearberry typically exists in dense patches with sparse grasses, herbs, and lichens. Scrub Oak also occurs as a component of this community, mainly in transition zones (Figure 2.1). This grouping of community types is highly diverse between sites, ranging from the Hempstead Plains grasslands, which include more tallgrass prairie species, to the grasslands and heathlands of Martha's Vineyard and Nantucket.

2.3 Scrub Oak-heath shrublands and dwarf pine plains

Scrub Oak shrublands and dwarf pine plains occur in areas with frequent historical disturbances—fire, salt spray, or frost, for example. Examples of this habitat are found on former pasture land, now regrown following abandonment and fire suppression, or are found in frost-prone bottoms or in areas with high frequency of fire and coarse soils.

Scrub Oak (*Quercus ilicifolia*, with *Q. marilandica* in southern sites) and heath species dominate Scrub Oak-heath shrublands. Heath species include lowbush blueberries and Black Huckleberry. Black Huckleberry tends to form a mid-shrub layer in between Scrub Oak, with blueberries growing underneath. The Scrub Oak forms the upper-shrub layer, which varies in height depending on disturbances, soils, and other factors. Little Bluestem and other grasses occur within patches with herbs such as Canadian Rockrose (*Helianthemum canadense*). Although tree oak and Pitch Pine also occur within this shrubland, they are, in general, in shrub or sapling form.

Figure 2.2*: A woodlands-barrens-shrublands transition on Martha's Vineyard, MA. The shrublands are in the top right corner of this aerial photograph.*

Figure 2.3*: A transition zone between an oak woodland (background) and a tree oak-Scrub Oak-heath barrens (foreground). Trees, such as the Post Oak in the upper right of this photograph, become denser towards the background of this photograph. Martha's Vineyard, MA.*

Quaking Aspen (*Populus tremuloides*), Big-toothed Aspen (*Populus grandidentata*), and Black Cherry (*Prunus serotina*) also occur within this habitat. With disturbances such as fire or frost, grasses and herbaceous species may become more abundant, creating a grassy shrubland.

Dwarf pine plains occur only in highly disturbed areas of the New Jersey Pine Barrens and the Central Pine Barrens of Long Island. A low-growing form of Pitch Pine (*Pinus rigida*) dominates this community type.[7] Presently, most of this community type is composed of dense thickets of Pitch Pine and Scrub Oak, with Black Huckleberry also a part of the shrub layer. Historically, these areas were more open due to frequent disturbances such as fire, with greater species diversity resulting. Within these open patches were species such as Stiff Aster (*Aster linariifolius*) and Broom Crowberry (*Corema conradii*) and were named "coremal" after the genus of the latter species.[8]

2.4 Barrens

This is a structurally diverse habitat type described in its myriad forms throughout the northeastern United States sand barrens. In this case, the term barrens refers to the sparse density of the tree canopy and the habitat itself as opposed to the poor soils characteristic of the broader term "sand barrens." Once trees have become sparsely established within a Scrub Oak-heath shrubland, the community begins to change as leaf litter develops and some areas become shaded (Figure 2.2). Pitch Pines and tree oaks occur in different patterns within barrens habitats. Barrens managed through fire, grazing, or mowing may become more savanna-like in character, with grass and herbs as an important understory component.

Tree Oaks within these habitats are Post, Black, White, and Scarlet. Pitch Pine is also a dominant species. Tree species composition varies by site: fir, spruce, and birch occur in more boreal sites (Maine and New Hampshire), Martha's Vineyard has large areas of tree oak barrens, and New

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[7] This form may be a result of frequent disturbances creating a selective pressure on these populations of Pitch Pine. The form could be either genetically- or physiologically-based; data are inconclusive.

[8] Windisch, A. 1999. *Fire Ecology of the New Jersey Pine Plains and Vicinity*. Dissertation, Rutgers University.

Jersey has large areas of Pitch Pine-dominated barrens, for example. Tree composition also varies within sites, creating a mosaic both within and between sites.

2.5 Woodlands

As canopy density increases, sand barrens habitats become more dominated by the overstory of oaks and Pitch Pine (Figure 2.3). Although most sand barrens woodlands today have an understory of Scrub Oak and heath, with a long-term disturbance regime, woodlands may develop oak openings and have a higher understory diversity. Oak openings are characterized by sparse open-grown trees within a grassy understory composed of Indian Grass (*Sorghastrum nutans*), Little Bluestem, goldenrods, asters, and Butterfly Weed (*Asclepias tuberosa*), for example.

2.6 Forests

Forested areas, defined by a closed canopy of oak and pine, occur throughout the northeastern United States sand barrens.[9] These sand barrens forests typically have a heath-dominated understory, although other species such as scrub oaks or Arrow-wood (*Viburnum dentatum*) may occur. Areas dominated by forests are reflective of areas that, relative to other community types, have experienced infrequent disturbances or disturbances of low severity or intensity. These areas may also exist in areas with better soils or lower incidences of frost or salt spray. Management tools can convert these habitats to woodlands, savannas, barrens, or even grasslands, shrublands, and heathlands, if properly applied.

When tree canopies close, Scrub Oak is still present in dry forests yet typically declines in cover, as it is shade-intolerant.[10] Black Huckleberry remains, however, as a significant component of the shrub layer. Most trees are over five meters tall and lower boles become free of limbs as the canopy shade eventually removes the lower branches. Still, dry forests may have relatively sparse canopies, with much light still reaching the understory. Sedges and grasses such as Little Bluestem and Common Hairgrass in addition to Round-leaved Pyrola (*Pyrola rotundifolia*), Striped Wintergreen (*Chimaphila maculata*), Bracken Fern (*Pteridium aquilinum*), and dewberry exist in the understory.

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[9] Forests are typically classified as having tree cover greater than approximately 75%. Tree cover between 25% and 75% may be classified as woodland, depending on the source. Anderson, R. C, J. S. Fralish, and J. M. Baskin, eds. p. 2. For this report, the delineation between forests and woodlands is at the point when the tree canopy closes, at a basal area of greater than 50 square feet per acre, approximately (data from Martha's Vineyard; may vary by site).

[10] The decrease in Scrub Oak may also be an interaction between shading and deer browse. Deer favor oak over heath species.

Section 3: Regional Context of Northeastern Sand Barrens Habitats

Figure 3.1*: Map showing the northeastern United States sand barrens sites discussed in this text.*

3.1 Introduction

Between New Jersey and Maine, three core sand barrens areas exist: the New Jersey Pine Barrens; the Central Pine Barrens (Long Island); and the Cape, Islands, and Plymouth complex. Several other sites of over 1,000 acres, ranging from the Waterboro barrens in Maine to the Albany Pine Bush, exist throughout the Northeast, generally found on ancient deltas entering into glacial lakes and their subsequent aeolean drift (Figure 3.1).[11] In addition, many smaller sites exist within outwash and moraine sites.[12] In this section, we ask the following questions. How do these sand barrens habitats in the northeastern United States compare to one another? What factors make sand barrens habitats similar and different throughout this broad region? What management is taking place region-wide? Regional issues are discussed below: exotic species, a decline in human-caused disturbances, pesticide use, and rapid growth and development. Finally, a table provides for direct comparison between sites (table 3.1).

3.2 Rapid Growth and Development

The recent (Post WWII) expansion of human settlements has dramatically reduced the area of barrens habitats.[13] In addition to the direct loss of habitat to industrial, commercial, and residential buildings and related infrastructure, habitat is lost indirectly through succession and degraded through the introduction of exotic species such as feral cats. Within developed landscapes, making effective use of management tools such as prescribed fire and grazing is much more difficult both logistically and politically than using prescribed fire in less densely settled areas, leading to smaller burn units, more limited burn windows, and increased

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[11] Albany Pine Barrens occur, to a large extent, on wind-blown dune deposits.

[12] An excellent list of barrens-related websites can be found at http://pb.state.ny.us/chart_master_links.htm

[13] This contrasts with historical settlements, which often increased the incidence of fire and fire-associated habitats. Examples of this would be the prevalent use of "slash and burn" shifting agriculture, railroad induced fires (sparks and embers from the train commonly started fires), and charcoal kilns for use in bog iron production. The bog iron industry increased the incidence of fire dramatically in surrounding habitats (Plymouth, MA, is one example) Patterson, W. A. and A. E. Backman. 1988. Fire and Disease History of Forests *In Vegetation History*. Huntley, B. and Webb, T. (eds.). pp. 603-632.

regulations. Albany and Concord barrens, on one extreme, have been over 30% developed,[14] and the Hempstead Plains have been virtually eliminated. In contrast with these sites, the New Jersey Pine Barrens are well protected from development. Nantucket, Plymouth, Long Island, and a large section of Falmouth on Cape Cod contain large contiguous areas of barrens habitats that are also well protected. Martha's Vineyard has a large amount of open space, but this open space is threatened by fragmentation from development, which is rapidly encroaching on natural areas. The boreal barrens sites in Maine and New Hampshire are small and have been reduced considerably in size due to development and succession. As a whole, barrens sites are well protected, but sites such as Martha's Vineyard and Ossipee, New Hampshire, appear most at risk with regards to future habitat fragmentation from development.

3.3 Pesticide Spraying

DDT spraying, which was banned in the United States in 1972, and Gypsy Moth spraying using Bt have heavily affected invertebrate species in the Northeast, specifically Lepidoptera, which comprise a significant proportion of the rare species in barrens areas. Vast areas of the Northeast were sprayed for mosquito control and to control Gypsy Moth outbreaks. The islands of Martha's Vineyard and Nantucket, however, were spared to a large degree. For example, Martha's Vineyard was only sprayed once with DDT in 1956, with 17,000 acres covered.[15] By contrast with this one-time spraying, mainland counties of Massachusetts were repeatedly sprayed, with much larger areas covered.[16]

3.4 Decline in Human-Caused Disturbances

In the Northeast, vast areas of the landscape have changed considerably as agriculture has declined and fire suppression has reduced the magnitude of wildfires and the fire return interval.[17] All barrens sites have shown a decline in early and mid-successional habitats, which are often dominated by Scrub Oak.[18] These habitats, without disturbances, eventually turn into forests, which have a closed tree canopy. When the tree canopy closes in barrens habitats, species richness, specifically rare species richness, decreases. In addition to a change in vegetation structure, a decline in disturbances has reduced the cover of plants that depend on or respond positively to disturbances. These species include Sandplain Gerardia (*Agalinis acuta*), Smooth False Foxglove (*Gerardia flava*), Small White Snakeroot (*Eupatorium aromaticum*), and Chaffseed (*Schwalbea americana*), which disappeared in Massachusetts one year following a ban

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[14] Finton, A. D. 1998. *Succession and Plant Community Development*. M. S. Dissertation, Univ. of Mass, Amherst.

[15] For an interesting article on the politics behind the limited DDT spraying on Martha's Vineyard see: Dean, C. Island Insect Trove Could Spur Revival of Mainland Populations, *New York Times* 12 September, 2000, Science Times, p. 2.

[16] Anonymously authored report to Governor King's office, 1979.

[17] Whitney, G. G. 1994. *From Coastal Wilderness to Fruited Plain: A History of Environmental Change in Temperate North America from 1500 to the Present*. Cambridge: Cambridge University Press.
Foster, D. R. and G. Motzkin. 1999. *Historical Influences on the Landscape of Martha's Vineyard: Perspectives on the Management of the Manuel F. Correllus State Forest*. Harvard Forest Paper No. 23.
Pyne, S. J. 1997. *Fire in America: A Cultural History of Wildland and Rural* Fire. Seattle: University of Washington Press.
Raleigh, E. L. 2000a. *Land-use History of Long Point*. Vineyard Haven, MA: The Trustees of Reservations, white paper.

[18] Finton, A. D. 1998; Jordan 1999. *Conceptual Ecological Model for the Long Island, NY Dwarf Pine Barrens*; Windisch, A. 1999. Historical aerial photographs also show significant changes in habitat on Martha's Vineyard and Nantucket.

on wildland fires in 1963.[19] Animal species dependent on more open barrens habitats also declined: Barrens Metarranthis (*Metarranthis apiciaria*), Barrens Buck Moth (*Hemileuca maia maia*), and Melsheimer's Sack-bearer (*Cicinnus melsheimeri*), for example.[20] Grassland birds declined as well due to agricultural abandonment.[21]

The reintroduction of a historical disturbance regime is key to protecting barrens habitats. In larger barrens sites, the wildland fire infrastructure and culture is more developed as human settlements in these areas have coped with wildfires for many years. In the New Jersey Pine Barrens, 20,000 acres is burned every year, mainly using winter backfires to reduce fuel loads. This may not accomplish ecological goals, however.[22] By contrast with this site, Martha's Vineyard has a more transient population with less exposure to wildland fires.

3.5 Exotic and Nuisance Species

Exotic and nuisance species of plants and animals affect uncommon native species and rare habitats in sand barrens habitats and are considered a national threat to biodiversity by many conservation organizations and government agencies.[23] Some exotic plant species are or may become threats in barrens habitats. Mammalian predators are a threat to breeding birds such as the Upland Sandpiper (*Bartramia longicauda*). Exotic parasitoid flies and exotic moths are a potential threat to rare Lepidoptera.

Compsilura concinnata, a parasitoid tachinid fly, was introduced to the United States in 1906 to control Gypsy Moths. *Compsilura* is a generalist parasitoid, with over 200 species of Lepidoptera recorded as its hosts. Where this species exists, entire moth populations disappear or are reduced considerably, especially the silkworm moths. *Compsilura* is present throughout the Northeast, yet does not appear to be driving moth population dynamics as much in coastal areas.[24] *Compsilura* also reduces or extirpates native tachinid populations where it occurs in high densities.[25] Unlike many other areas in New England, Martha's Vineyard has large populations of silkworm moths, such as the Imperial Moth (*Eacles imperialis*), possibly due to low numbers of *Compsilura*.

An exotic moth, *Noctua pronuba*, is a potential invasive species that has spread rapidly around the United States. Although no research currently shows the effect of *Noctua pronuba* on native Lepidoptera, its abundance in sites with rare moth species is cause for concern. More research is needed to ascertain the effects this moth may have on rare moth species.

Domestic dogs and cats, feral cats, rats, skunks, and other animals associated with human habitations can also significantly affect wildlife, specifically breeding birds. These species can

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[19] This was a result of the Clean Air Act enforcement in Massachusetts. The loss of this species in Massachusetts showed the dramatic relationship between fire and this species. Tim Simmons, personal communication. During the peak of agriculture in New England, many of these currently rare plants and grassland birds were described as common, their populations elevated due to vast areas of open habitats.

[20] Further south, the latter two species occur in more closed forest situations.

[21] See Raleigh, E. L. 2000b. *Rare Species of Long Point Wildlife Refuge*. Vineyard Haven, MA: The Trustees of Reservations, white paper.

[22] Windisch, A. 1999.

[23] For an in-depth guide to invasive species, see: http://www.invasivespecies.gov/. For a toolkit of best practices to control invasive species, see: http://www.cabi-bioscience.ch/wwwgisp/gt1goto.htm.

[24] Jeff Boettner, personal communication. Little is known about the abundance of *Compsilura* on Martha's Vineyard.

[25] Jeff Boettner, personal communication. Native tachinid populations may be of interest on Martha's Vineyard.

directly kill wildlife or indirectly harass key wildlife species, potentially reducing their productivity. These species may have a significant impact on rare breeding bird species in barrens habitats.[26]

Barrens sites do not appear to have major region-wide problems with invasive exotic plant species. Many exotic species occur in barrens sites, although most are not currently invasive in sand barrens. Albany Pine Bush is the only site for which exotic species such as Garlic Mustard and Black Locust are a major concern and management goal. Albany Pine Bush is one of the most fragmented sites, and its problem with exotic plants may be a result of this fragmentation. Other sites such as Ossippee have identified species ranging from Autumn Olive (*Elaeagnus umbellata*) to Field Thistle (*Cirsium discolor*) as potential problems. On Martha's Vineyard, exotic plant species are not a major problem at most barrens sites, although as development continues to fragment habitats, it may become more of an issue.[27] Monitoring and early control will likely prevent major problems from happening in the future.

***Table 3.1**: Significant sand barrens sites[28] within the northeastern U. S.*

Area Name	Early Successional Acres[29]	Total Site Acres[30]	Selected Distinctive Habitats and Characteristics of Area	General Management Goals[31]
New Jersey Pine Barrens	100,000[32]	1.1 million[33]	By far the largest site in the northeastern U.S. Pitch Pines have serotinous cones[34] within Dwarf Pine Plains, which cover 15,000 acres (G1G2). Pine plains were burned every 6-8 years historically, with more grasses and forbs described.[35] Blackjack Oak (*Quercus marilandica*) is a scrub oak component found here and on Long Island.[36]	Fuel reduction using winter backfires covering 20,000 acres per year is conducted by the state. Another goal besides fuel management is to maintain a fire regime mosaic maximizing the diversity of rare and characteristic species.[37]

[26] The National Audubon Society has much science-based information on this matter, specifically cats. http://www.audubon.org/local/cn/98march/cats.html.

[27] Most but not all invasive exotic species problems on Martha's Vineyard exist at morainal sites, agriculture or old field sites, and along roadsides, not within barrens habitats of the outwash plain.

[28] Early successional habitats include grasslands, heathlands, grassy shrublands, Scrub Oak shrublands, Pitch Pine-Scrub Oak barrens, pine-oak woodlands, and savannas.

[29] Acreages are estimates based on the best available knowledge of early successional habitats. These habitats are generally found within a matrix of Pitch Pine and oak forest and woodlands. This matrix is part of the functioning barrens ecosystem, although it typically does not support the suite of rare species that may depend solely on rare early successional habitats. Early successional habitats include sandplain grasslands and heathlands, dwarf pine plains, Scrub Oak-heath shrublands, and habitats with a sparse canopy (savannas, Post Oak-Scrub Oak-heath barrens).

[30] This figure includes the total acres within a site. In many cases, this is this historical extent of barrens habitats, including the woodlands and forests that form or formed the matrix. In many cases, significant areas of the site have been developed.

[31] As of 2001. Management goals will shift over time.

[32] This is the world's largest occurrence of barrens communities. Windisch, A. 1999.

[33] Windisch, A. 1999.

[34] Serotinous cones open when exposed to fires. Serotinous cones are indicative of areas having high incidences of fire. Long Island and New Jersey are the only known barrens with serotinous cones on Pitch

Area Name	Early Successional Acres[29]	Total Site Acres[30]	Selected Distinctive Habitats and Characteristics of Area	General Management Goals[31]
Central Pine Barrens, Long Island, NY	7,000+[38]	100,000+[39]	Dwarf Pine Plains cover only 1,000 acres (Pitch Pines have serotinous cones). Frost bottom communities here tend to be grassy with a heath component; few Pitch Pines and Scrub Oaks exist in bottoms. Hempstead Plains tall grasslands covered 38,000 acres, with less than 30 acres remaining today following extensive development.[40]	Goals are to maintain and/or restore natural processes, maintain a shifting mosaic of natural communities and successional stages, increase the acreage of target communities (e.g., dwarf Pitch Pine plains), maintain viable populations of rare Lepidoptera, and increase populations of native herbaceous species. Fire will be the principal tool, with acreage targets set at 500 acres, increasing to 1,500 acres by 2015.[41]
Albany Pine Bush, NY	2,600[42]	16,000+[43]	Pitch Pine and Scrub Oak community covers sand dunes averaging 20-30 feet high, up to 60 feet tall. Sand was historically mined for glass.[44]	The overall goal is to expand the barrens community, reduce fuels, and remove invasives such as Black Locust (400 ac.), aspen, honeysuckle, Garlic Mustard, and barberry. Karner Blue butterfly exists here.
Montague Plains, MA	165+[45]	2,000[46]	This is the largest area of barrens habitat along the CT River Valley.[47] This site was 80% plowed historically, one of the most intensively used large barrens sites in the northeast. Plowed areas have regenerated as Pitch Pine stands.[48]	Some prescribed fire is presently occurring. Wildfire hazard reduction, maintenance of aquifer quality, and rare species habitat protection within Scrub Oak areas are future goals of importance.[49]

Pines, although Emily Russell is studying serotiny in Shawangunks, NY (Glenn Motzkin, personal communication).

[35] Windisch, A. 1999.

[36] For more information, see: http://training.fws.gov/library/pubs5/web_link/text/nj_pine.htm

[37] Example is from the Warren Grove Range, provides a case study for more ecologically beneficial fire management. September and October burns are also recommended for duff reduction and stimulation of grasses and forbs. Windisch, A. 1999.

[38] The oak woodland matrix for these habitats is 34,000 acres. Myers, R. et al. *Long Island Pine Barrens DRAFT Goals from 1995 TNC plan*, revised 1998.

[39] This is the area under the authority of the Central Pine Barrens Joint Planning and Policy Commission http://pb.state.ny.us/. Historically, pine barrens and associated habitats likely covered more area (e.g., Hempstead Plains), but Long Island has been heavily developed. For more information, see: http://training.fws.gov/library/pubs5/web_link/text/li_pine.htm.

[40] Reschke, C. 1990. *Ecological Communities of New York State*. New York Natural Heritage Program.

[41] Myers, R. et al. 1998.

[42] Finton, A. D. 1998.

[43] The historical extent of barrens is estimated at 16,188 acres, most of which has been developed. Rittner, 1976, in Finton, A. D. 1998.

[44] http://training.fws.gov/library/pubs5/web_link/text/apb_form.htm

[45] Glenn Motzkin, personal communication. Scrub Oak dominates this area.

[46] Glenn Motzkin, personal communication. Most of the area is forested. 2,000+ other acres of historical habitat have been developed in the plains.

Area Name	Early Successional Acres[29]	Total Site Acres[30]	Selected Distinctive Habitats and Characteristics of Area	General Management Goals[31]
Plymouth-Carver, MA	6,300[50]	85,000[51]	A large, core protected area of 18,000 acres (DEM) protects knob and kettle topography and moraine habitat. High levels of spraying for Gypsy Moth up to 1972 led to low diversity of rare moths. White Pine and other softwoods are a large component of this area.[52]	Increased research and fire management are needed. Looking at small-scale prescribed burning and other management on an experimental basis; public safety is a priority.[53]
Cape Cod, MA	5,300+[54]	200,000+[55]	Stunted Pitch Pine and oak define heavily disturbed areas on the Outer Cape (National Seashore); large portions of developed areas fragment much of the habitat, except for the Massachusetts Military Reservation and Crane WMA (18,000+ ac.). Large areas of tree oak and Pitch Pine with interspersed Scrub Oak bottoms and grasslands cover the landscape. A large area of Scrub Oak shrubland occurs in the ordinance impact area Camp Edwards and a large area of grassland occurs around Otis Air National Guard Base.	A biological management plan at Camp Edwards is designed to protect a full spectrum of habitats. One goal of the draft plan is to increase the area of Scrub Oak shrublands and barrens. Another goal is to maintain grasslands through burning and mowing. Public safety is an issue as the Cape is highly developed.[56]

[47] The next largest site in the valley is at Westfield (approximately two hundred acres of habitat). Glenn Motzkin, personal communication.
[48] Other smaller sites along the Connecticut River Valley have similar land-use histories. Pitch Pine stands have little ericaceous understory. Glenn Motzkin, personal communication.
[49] Glenn Motzkin, personal communication.
[50] L. Raleigh analysis of J. Stone Plymouth Pitch Pine data, August 2000 revision.
[51] L. Raleigh analysis of J. Stone Plymouth Pitch Pine data, August 2000 revision.
[52] Historically, White Pine communities likely dominated this area, with post-settlement disturbances significantly altering community composition and structure.
[53] Austin Mason, personal communication.
[54] Based on information from the Camp Edwards Integrated Natural Resources Management Plan February 2001, courtesy of Mike Ciaranca. and 1991 data for Cape Cod National Seashore, courtesy of Glenn Motzkin.
[55] Includes both outwash plain and sandy moraine area. Harvard Forest digitized map of Oldale and Barlow (1986).
[56] Camp Edwards Integrated Natural Resources Management Plan.

Area Name	Early Successional Acres[29]	Total Site Acres[30]	Selected Distinctive Habitats and Characteristics of Area	General Management Goals[31]
Martha's Vineyard, MA	3,500+[57]	40,000+ [58]	Scrub Oak shrublands and associated barrens host a large density of rare invertebrate species. Sandplain grasslands and heathlands exist along the south shore, recently maintained by oceanic processes such as salt spray. These grasslands and heathlands are some of the most diverse areas within the sand barrens examined in this document.[59] Conservation sites are generally fragmented, with core areas being the state forest and the Long Point site. Large areas of the state forest were never plowed.	700 acres are being actively managed within the sandplains for habitat reasons, using fire, clearing, and other techniques. Creation of savanna and maintenance of heathlands or grasslands are principal goals. Reduction of fuels is a management concern. The acres under active management are expected to increase in the near future.
Elizabeth Islands, MA	2,000+[60]	2,000+[61]	Although not outwash substrate, the morainal soils of the Elizabeth Islands support grassland and heathland communities. The Elizabeth Islands are home to one of the largest populations of Grasshopper Sparrows in New England.	Grazing is the primary management tool, although small-scale fires are currently used. Catbriar is a native, but highly invasive, species within the open habitats that can turn heathland and grassland habitat into dense thickets.
Nantucket, MA	11,000+[62]	20,000+	Nantucket has the highest density of rare species in MA.[63] The largest remaining area of early-successional heathlands and grasslands (3,400+ acres total[64]) occur on Nantucket due in large part to historic grazing and oceanic effects. Rare moth species are slowly colonizing the island.[65]	The goal is to maintain grasslands and heathlands, avoiding further invasion by Scrub Oak through regular mowing and burning (500 acres). An additional 600 acres was mowed three times during the growing season to remove shrubs, with a goal of restoring grasslands and heathlands.[66] Because Scrub Oak is prohibitively expensive to remove and an integral part of the ecosystem, managers are broadening their goals to include more Scrub Oak cover.

[57] A larger protected area exists (8,000+ acres). Most of this acreage is part of the oak woodland and forest matrix, which can be restored to a target habitat type, however. The 3,500+-acre figure includes protected sites with target habitats as well as unprotected and undeveloped sites and is an approximation.
[58] Includes outwash and some moraine.
[59] Olsvig, L. S. 1980. *A Comparative Study of Northeastern Pine Barrens Vegetation*. M.S. Dissertation, Cornell University: Ithaca, NY.
[60] This area mostly includes grassland areas on Nashawena, but also Pasque and Naushon.
[61] Since these habitats have primarily been maintained through grazing, the plant species composition is not classified as barrens habitat. Examples are Red Maple swamps, greenbriar thickets, and beech forests.

Area Name	Early Successional Acres[29]	Total Site Acres[30]	Selected Distinctive Habitats and Characteristics of Area	General Management Goals[31]
Ossipee Pine Barrens, NH	2,000+[67]	7,000[68]	This site is primarily composed of Pitch Pine-Scrub Oak-heath habitats; the barrens landscape is threatened by development, logging, gravel mining, and fire suppression, with large areas of private ownership. The largest contiguous area of barrens is 900 acres.[69]	The primary site goal is maintaining, enhancing, and restoring ecosystem processes and dynamics to preserve an "exemplary occurrence of the Pitch Pine/Scrub Oak barrens natural community."[70]
Concord Pine Barrens, NH	560+[71]	4,500[72]	The largest assemblage of rare Lepidoptera (37) in New Hampshire occurs here, 14 of which are found in grassy opening habitats.	Restoration of Karner Blue butterfly (federally endangered) within grassy openings primarily through summer mowing, but also using spring fire and August clearing with herbicide application is a priority.[73]
Kennebunk Plains, ME	700+[74]	1,000+[75]	This site is primarily sandplain grassland containing exemplary populations of Grasshopper Sparrow and Northern Blazing Star. The grasslands are surrounded by 300+ acres of Scrub Oak and Pitch Pine habitats.	Maintain 500 acres of sandplain grassland community using fire, annually burning at least 10% of the area and no more than 30% to accommodate birds and invertebrates.[76]

[62] Photo-interpretation by J. Stone. 1999. Mass GIS. Includes Tuckernuck.
[63] Barbour, H., T. Simmons, P. Swain, and H. Woolsey. 1998. *Our Irreplaceable Heritage: Protecting Biodiversity in Massachusetts*. MNHESP and TNC.
[64] Photo-interpretation by J. Stone. 1999. Mass GIS. Includes Tuckernuck.
[65] Paul Goldstein, personal communication.
[66] Karen Combs-Beatty, personal communication.
[67] 4,500 acres of conservation target. *Site Design—Ossipee Pine Barrens*. 1994. TNC White Paper.
[68] *Site Design—Ossipee Pine Barrens*. 1994.
[69] *Site Design—Ossipee Pine Barrens*. 1994.
[70] *Site Design—Ossipee Pine Barrens*. 1994, p. A-3.
[71] 563 acres of fire-suppressed Pitch Pine-Scrub Oak barrens, a remnant of a chain of historic barrens along the Merrimack River. Proposed management on 400 acres. VanLuven, D. E. 1994. *Site Design: Concord Pine Barrens*. Concord, NH: TNC.
[72] VanLuven, D. E. 1994.
[73] VanLuven, D. E. 1994.
[74] 500 acres of sandplain grassland plus more areas of Pitch Pine-Scrub Oak habitats; the state owns over 1,000 acres. Henderson, J. S. 1994. *Fire Management Plan, Kennebunk Plains, Maine*. TNC.
[75] This area also includes forested areas immediately surrounding the plains: Pitch Pine with lowbush blueberry, primarily.
[76] Henderson, J. S. 1994.

Area Name	Early Successional Acres[29]	Total Site Acres[30]	Selected Distinctive Habitats and Characteristics of Area	General Management Goals[31]
Shapleigh and Waterboro Barrens, ME	2,000+[77]	3,500+[78]	These sites are one of the best examples of a boreal variant of barrens, which includes tree species such as Gray Birch, spruce, and fir. Very little plowing or cutting of the site occurred historically. The 1947 fire was a major factor affecting the current vegetation patterns.[79]	Short-term burns will focus on fuel reduction by clearing followed by fire, with a concentration on growing season burns. Management goals generally focus at the community level. Timber harvesting for wildlife management and income is also used, however.[80]
Killick Pond (Hollis), ME	600+[81]	1,000+[82]	The Killick site is a boreal variant of barrens, with less dense Pitch Pines than Waterboro and Shapleigh and more heath and grassy openings.[83]	Small summer burns were conducted to manage for barrens community.[84] 600 acres of potato field is being restored to pine barrens habitat.[85]

3.6 Conclusions

The barrens habitats throughout the Northeast are all similar to one another in that Scrub Oak, Pitch Pine, tree oaks, Black Huckleberry, and other heath species dominate. Each site is slightly different, however. The southern sites in the region have dwarf pine plains. The northern sites have more northern species, such as spruce and fir. The coastal outwash plain sites have exemplary occurrences of earlier successional habitats such as heathlands, grasslands, and shrublands. Sites with similar edaphic factors also possess different species compositions. The species found in frost pockets, for example, vary by site: in general, they are grassier on Long Island and shrubbier on Martha's Vineyard. Many of these differences are likely due to land-use and disturbance histories for each area.[86] In addition, these differences are also likely due to thousands of years of plant dispersal patterns and fire regimes. For example, both the dwarf pine plains of Long Island and New Jersey and the Scrub Oak-heath shrublands of Martha's Vineyard likely arose from a high incidence of fire within a broad fireshed.[87] These sites, however, are very different in terms of their vegetation structure, plant species composition, and animal

[77] Finton, A. D. 1998.
[78] Andy Cutko, personal communication.
[79] Nancy Sferra, personal communication.
[80] Nancy Sferra, personal communication.
[81] In the mid-term, the potato field restoration will approximate early-successional habitat, albeit significantly degraded in terms of flora and fauna, initially. Other early successional habitat also exists, with approximately 50 acres of heathland and grassland openings. Nancy Sferra, personal communication.
[82] Andy Cutko, personal communication.
[83] Andy Cutko, personal communication.
[84] Nancy Sferra, personal communication. Burns have only been conducted on the Maine Army National Guard property.
[85] Poland Springs Bottling Company is restoring this habitat.
[86] Site variation in the incidence and timing of frost events may also play a large role in vegetation within frost pockets. Glenn Motzkin, personal communication.
[87] A fireshed is a fire-prone landscape with various fire regimes based on local landscape influences. Because fires are able to significantly alter landscape structure and species composition, the subsequent fire regime will vary accordingly. Large, xeric areas with minimal barriers to fire (lakes, rivers, wetlands) generally have the highest fire frequencies on a landscape. For more details, see: Windisch, A. G. 1999.

communities. It is these differences that create diversity on a landscape scale that should be an integral part of regional biodiversity protection.

Management region-wide currently focuses on maintaining and increasing the size of various early- to mid-successional habitats. Key habitats are dwarf pine plains, sandplain grasslands, maritime heathlands, and Scrub Oak-heath shrublands. These are all part of a mosaic of habitats found within a woodland and forest matrix. These habitats are targeted for management due to their greater concentration of rare species. Region-wide, most ecological management programs are in their initial or middle stages. Currently completed management plans focus on increasing the acreage under management and maintaining existing habitats,[88] typically with fire (Section 4). Clearing is also heavily used and can be an effective management tool (Section 7), but not at the larger southern sites, where fire has traditionally been used. Grazing is only heavily used on the Elizabeth Islands, yet grazing could be a more widespread management tool, depending on management goals (Section 5). Currently there are no larger sites that have mature ecological management programs.[89] Long-term management effects are not well known due to the infancy of many programs, although ecological research on barrens sites is significant.[90]

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[88] Examples of management plans are:
Myers, R. et al. 1998; Woodall, C. A. and W. A. Patterson. 1997. *Fire Management Plan, Washburn Island State Forest, Falmouth, MA*, white paper; Henderson, J. S. 1994; VanLuven, D. E. and K. M. Helmboldt. 1995. *Fire Management Plan for the Concord Pine Barrens, Concord, NH*, white paper; Raleigh, L., L. Vernegaard, and R. Hopping. 1998. *Wasque Reservation, Heathlands and Grasslands Management Plan*. Vineyard Haven, MA: The Trustees of Reservations, white paper; and Vernegaard, L., R. Hopping, and E. Trisch. 1998. *Nashawena Management Plan*. Beverly, MA: The Trustees of Reservations, white paper.

[89] A mature ecological management program would be one in which acres managed per year had reached a steady state and goals were more focused on habitat maintenance activities. Several smaller sites such as the Kennebunk Plains have mature ecological management programs.

[90] Examples of research includes:

- successional and community-level research (Finton, A. D. 1998; Reschke, C. 1990; Sneddon, L., M. Anderson, and K. Metzler. 1994. *A Classification of Terrestrial Community Alliances in The Nature Conservancy's Eastern Region.* First Approximation Draft),
- community dynamics and modeling research (Windisch, A. 1999*;* Simmons, T. no date. *Islands Bioregional Plan*. TNC; Jordon, M. 1999. *Conceptual Ecological Model for the Long Island, NY Dwarf Pine Barrens*. White paper; Young, R. 1993. *Waterboro Pine Barrens of Maine, ecological model*. White paper; Latham, R. 1993. *Alternate Steady States Model, Pocono Till Barrens and Serpentine Barrens*. White paper.),
- ecosystem- and landscape-level research and reports (Schweitzer, D. F. and T. J. Rawinski. 1988. *Element Stewardship Abstract, Northeastern Pitch Pine/Scrub Oak Barrens*. TNC white paper; Foster and Motzkin. 1999; Motzkin, G., et al. 1996; Patterson, W. A. 1994. *The Waterboro Barrens: Fire and Vegetation History as a basis for the Ecological Management of Maine's Unique Scrub Oak-Pitch Pine Barrens Ecosystem*, white paper; and other land-use history research sited in Raleigh 2000a), and
- management's effects on populations (Vickery, P. 1996; Dunwiddie, P. and C. Caljouw. 1990. Prescribed Burning and Mowing of Coastal Heathlands and Grasslands in Massachusetts. *Ecosystem Management: Rare Species and Significant Habitats.* New York State Museum Bull. 471: 271-275; and McCartney, D. J. 1988. *A Comparison of Responses of a Martha's Vineyard Heath-Shrub Community to Controlled Burning and Mowing*. M.S. Dissertation, Univ. of Mass, Amherst.).

Section 4: Prescribed Fire

4.1 Introduction

Prescribed fire is an important land management tool to reduce fuel loads, to restore and maintain ecologically important habitats, and to improve public safety (Figure 4.1). Prescribed fire can also improve scenic vistas and restore historic features such as overgrown stone walls. In order to carry out prescribed fires, the following should be considered: notification and education programs, partnerships, equipment, personnel, wildfire response, ecological burning, prescriptions, insurance, safety, smoke management, fire regulation, costs, fire effects, current uses of prescribed fire, and fire history.[91] These are summarized below.

Figure 4.1*: A prescribed burn in heavy fuels produces flames higher than a mature oak tree. In a wildfire situation, such fire behavior may be difficult to control. Once fuels are reduced, the flames would be much lower.*

4.2 Fire History

What were the historical fire regimes[92] in sand barrens sites and how do they compare region-wide? This question, unfortunately, will never be answered fully. Even so, historical accounts, known land-use practices by Native Americans and European settlers, charcoal analysis of pond and bog sediment layers, and the present composition of communities can give us a good idea of the history of fire.

The prevailing theme when analyzing fire history is change. Changes in fire regimes occur in both time and space. Different sites and areas within sites have unique historical fire regimes. These fire regimes have changed over time as well, shaping the present vegetation at each site. In the northeastern United States, lightning fires are uncommon.[93] Humans, therefore, are, and have been, the primary ignition source for fires.[94] With this in mind, we must look at the land-use history of our sites.[95]

The foundation of fire history is based on the soil and climate. Coarse sandy soils, such as those found in most sand barrens create dry, low-moisture environments favorable for widespread

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[91] For a detailed look at any of these subjects, see: Pyne, S. J., P. L. Andrews, and R. D. Laven. 1996. *Introduction to Wildland Fire*. New York: Wiley and Sons and Wade, D. D. 1989. *A Guide For Prescribed Fire in Southern Forests*. USDA Forest Service Technical Publication R8-TP 11. USDA Forest Service, Southern Region. The Nature Conservancy's Fire Management Manual provides detailed information about many of these issues: http://tncfire.org/manual/sitemap.htm

[92] For a description of fire regimes, see: Whelan, R. J. 1995. *The Ecology of Fire*. Cambridge, UK: Cambridge University Press, pp. 45-56.

[93] Pyne, S. J. 1997, pp. 9-19.

[94] 95% of all fires in New England are human-set. W. A. Patterson and K. E. Sassaman. 1988. Indian Fires in the Prehistory of New England. Pages 107-135 in*: Holocene Human Ecology in Northeastern North America*. Ed. George P. Nicholas. Plenum Publishing Co.

[95] Raleigh, E. L. 1999. *Land-use History of Long Point Wildlife Refuge*. Vineyard Haven, MA: The Trustees of Reservations, white paper.
Capece, J. A. 2001. *Land-use History of Cape Poge and Wasque*. Vineyard Haven, MA: The Trustees of Reservations, white paper.

fire.[96] These dry soils typically support vegetation more adapted to drought conditions: Little Bluestem (*Schizachyrium scoparium*), Black Huckleberry (*Gaylussacia baccata*), Scrub Oak (*Quercus ilicifolia*), and Pitch Pine (*Pinus rigida*), for example. This vegetation is highly flammable, providing a good ignition source.[97] The climate of the northeastern United States is typified by a relatively equal amount of rainfall every month of the year, with the summer months being the driest. Low fuel moisture conditions occur predominately during the spring and fall, when vegetation is dormant and extended dry periods can occur. The highest incidence of drought, however, occurs during the summer, when evapotranspiration is highest. Finally, the prevailing westerly winds influence the direction of fire spread. Most fires in the Northeast will therefore travel from west to east, facilitating burning downwind from potential ignition sources. These factors all lay the groundwork for human-caused historical fires.

Both Native Americans and European settlers ignited fires historically. Settlement patterns on the landscape, timing of burns, frequency of burns, and reasons for burning are all documented.[98] Results of these studies show us many clues towards understanding a historical fire regime. When European settlers arrived, Native American populations ranged in density throughout the Northeast, with the highest densities along major rivers and along coastal areas.[99] Throughout New England, many other areas ranging from Narragansett Bay to Salem were described as vast open fields, due to intensive Native American land-use.[100] When European settlers arrived, they also used fire for clearing the landscape and improving the productivity of their fields.[101] Throughout historical times, accidental fires were also prevalent.[102] As the population and uses of the land increased after colonial settlement, most areas of New England experienced higher

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[96] Chandler, C. Cheney, P., Thomas, P., Trabaud, L. and Williams, D. 1983. *Fire and Forestry*. Vols. 1 and 2. New York: Wiley and Sons. Land-use, however, can dramatically alter flammability as in the case of hemlock forests being cleared, followed by wildfire. The resulting community was more of a scrubby barrens. Whitney, G. G. 1994. Also note that in other habitats, more mesic (moist) sites often burn more frequently as xeric (dry) sites do not accumulate fuels rapidly due to low primary productivity (e.g. Carolina sandhills).

[97] Pitch, resins, and other volatile organics, as well as the vegetation structure (ladder fuels) and moisture content all affect flammability. For more details see: Whelan, 1995.

[98] Patterson, W. A. and K. E. Sassaman. 1988; Russell, H. S. 1980. *Indian New England Before the Mayflower*. Hanover, NH: University Press of New England. 284 pp; Whitney, G. G. 1994.; Raleigh 2000a; Foster and Motzkin 1999; Cook, S. F. 1976. The Indian population of New England in the seventeenth century. *Publications in Anthropology*, no. 12: 1-91. Berkeley: University of California; Ritchie, W. A. 1969. *The Archaeology of Martha's Vineyard: A Framework for the Prehistory of Southern New England, A Study in Coastal Ecology and Adaptation*. Garden City, NY: The Natural History Press.

[99] Cook, 1976. 35 people per square mile on Martha's Vineyard, 4 per square mile in Southeast Massachusetts, 50 on Nantucket, 0.5 in Maine, and 10 in the Connecticut River Valley. In: Patterson, W. A. and K.E. Sassaman, 1988.

[100] Patterson and Sassaman 1988. Conflicting historical accounts of the presettlement landscape exist, however.

[101] A description of the fire history of the northeastern United States can be found in Pyne, S. J. 1997, pp. 46-70. Land clearing was an important contributor to fires: trees were cut in the autumn or early spring and after drying were set fire, providing potash for enriching the soil. In: Dwight, *Travels*, Vol. 2, Letter 13, pp. 321-322. The general practice of burning was adopted from the Native Americans. Cronon, W. 1983. *Changes in the Land: Indians, Colonists, and the Ecology of New England*. New York: Hill and Wang Press. 240 pp.

[102] Whitney, G. G. 1994. Laws were passed restricting burning to "the dampest spring months." Colonists were liable for fires that crossed property boundaries and were required to notify their neighbors when they were planning to burn. Cronon, W. 1983. Fire codes in Massachusetts date back to 1631 (Pyne, S. J. 1997).

fire frequencies than pre-settlement.[103] This high level of fire was seen throughout the coastal plain of New England.[104] Fire suppression in the twentieth century, however, reduced the frequency of fires throughout the Northeast, considerably changing again the ecology and fire regimes for the region (Section 3.4).

4.3 Current Uses of Prescribed Fire

In the Northeast, prescribed fire is used on a limited basis, with some areas under more fire management than others are. When compared with other regions in the United States, the Northeast has the lowest acreage under fire management. The southeast, for example, burns approximately eight million of acres every year. [105] In the New Jersey Pine Barrens, approximately 20,000 acres are burned using backfires every winter, predominately for public safety reasons—decreasing the risk of catastrophic wildfire (Section 4.8) by reducing fuel loads and minimizing smoke (Section 4.7). These winter backfires have a low ecological value and may not be achieving the desired reduction of catastrophic fire risk.[106] In the northeastern sand barrens, less than 2,000 acres are burned for ecological reasons every year (see table one in Section 3), primarily on Martha's Vineyard, on Long Island, in southern Maine, and in the New Jersey Pine Barrens. This is a very small fraction of the almost 1.6 million acres of sand barrens sites in the northeast.

4.4 Fire Effects

Fire can have a dramatic effect on barrens habitats, affecting soils, vegetation, and animals both long- and short-term. Fire, however, is dynamic, and its effects depend on many factors: weather conditions during, before, and after burning, ignition techniques, fuel conditions, species composition before a burn, seasonality, and the species composition of adjacent units.[107] The fire behavior ultimately determines the short-term effects of a burn on plants and animals within a unit. The fire regime[108] ultimately determines the long-term composition of species—the habitats—present within a site and the manner in which habitats transform themselves from one to another.[109] This section will take a very simplified approach to fire effects based on our current knowledge and monitoring.

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[103] Patterson, W. A. and A. E. Backman. 1988. Fire and Disease History of Forests. *Vegetation History*, Huntley, B. and Webb, T., eds. Kluwer Academic Publishers.

[104] Pyne, S. J. 1997.

[105] Wade, D. D. 1989. and Pyne, S. J., P. L. Andrews, and R. D. Laven. 1996.

[106] "There are also many negative ecological effects of using such a narrow, artificial fire regime (Whelan and Muston 1991, Robbins and Myers 1992, Whelan 1995), particularly if used at short intervals over many decades to the exclusion of other fire regimes. Prescribed burning programs in New Jersey have not widely entered the realm of ecological fire management." In: Windisch, A. G. 1999.

[107] Robbins, L. E. and R. L. Myers. 1992. *Seasonal Effects of Prescribed Burning: A Review*. Tall Timbers Research Miscellaneous Publication No. 8. Drought, storms, and insects after a burn may further affect recently burned units. Wade, D. D. 1989. *A Guide for Prescribed Fire in Southern Forests*. USDA Forest Service Technical Publication R8-TP 11. USDA Forest Service, Southern Region; Keetch, J. J. and G. M. Byram. 1968. *A Drought Index for Forest Fire Control*. USDA Forest Service Research Paper SE-38. USDA Forest Service, SE Forest Experiment Station. Asheville, NC.
Fire Effects Information Service website at http://www.fs.fed.us/database/feis/index.html

[108] A fire regime includes, season, extent, type, intensity, severity, and frequency over a long time period. Fire regimes, however, are highly dynamic and shift depending on human, habitat, and climatic factors. For more details see Whelan, R. J. 1995.

[109] Our ability to describe habitats and their complexities are very basic. Add to that spatial and temporal dynamics over hundreds of years and even more complexities arise. For this reason, we still have many questions left to answer regarding fire regime research in sand barrens and other fire-prone habitats.

What are the effects of fire? The current research in fire effects is documented in the literature.[110] Following a burn, we are specifically interested in observing how fire affects the diversity and structure of plants, the abundance and presence of animals, and the effects on soils.

4.4.1 Soils

Duff reduction and the release of nutrients become important factors when considering fire effects. Species diversity and rare species of plants are typically associated with reduced duff and exposed mineral soil conditions.[111] Ants, tiger beetles, sand wasps, and other insects may also benefit from exposed mineral soils.[112] Duff reduction through prescribed burning is determined primarily through moisture levels. The Keetch-Byram Drought Index (KBDI) is one method of measuring drought and therefore, indirectly, duff moisture.[113] In general, a KBDI of over 300 is needed to consume significant amounts of organic matter and to expose mineral soil.[114] In the Northeast, this level of KBDI is primarily reached in the summer months, when fires can significantly reduce duff. Duff, however, may be reduced over the long-term through spring burns and other treatments—such as mulching, see Section 7, table 7.1—if decomposition rates exceed biomass accretion rates. Prescribed fire also releases nutrients into the soil and may increase pH values in the highly acidic sandy soils. This has the effect of stimulating vegetation.[115]

Figure 4.2*: Unlike other heath species, Bearberry resists flames.*

4.4.2 Vegetation

The effect of fire on vegetation depends on the species, fire behavior, and seasonality (Figure 4.2). For woody species, the location of the roots, bark thickness, resprouting ability, and carbohydrate reserves are important and vary by season and fire regime. Black Huckleberry growing in duff will have most of its roots in the duff layer; high

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[110] In addition to other citations in this section, fire effects are summarized at the Fire Effects Information Service website, in Raleigh et al 1998; Smith, J. K., ed. 2000. *Wildland Fire in Ecosystems: Effects of Fire on Fauna*. Gen. Tech. Rep. RMRS-GTR-42-vol. 1. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 83 p., and in Brown, J. K.; Smith, J. K., eds. 2000. *Wildland Fire in Ecosystems: Effects of Fire on Flora.* Gen. Tech. Rep. RMRS-GTR-42-vol. 2. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 257 p. These publications can be ordered or downloaded through: http://www.fs.fed.us/rm.

[111] Frey, S. N. and L. Raleigh. 1998. *Analysis of State-listed Plants growing in Heathlands and Grasslands at Long Point and Wasque*. Vineyard Haven, MA: The Trustees of Reservations, white paper.

[112] Dr. David Wagner and his researchers have documented over 300 invertebrate species using open sandy areas in patches of sand barrens along the Connecticut River. Invertebrate Symposium presentation, March 28, 2003.

[113] Keetch, J. J. and G. M. Byram. 1968.

[114] KBDI ranges from 0 to 800. The value refers to the amount of rainfall in hundredths of an inch necessary to reduce the index to zero. KBDI of over 500 would consume most organic matter.

[115] Dudley, J. L. 1993. The Effects of Prescribed Burning on Nutrient Availability and Primary Productivity in Sandplain Grasslands. *American Midland Naturalist* 130 (2): 286-98. Seed germination and flower stalk abundance can also be greatly increased, although the species that benefit will depend on seasonality.
http://www.fs.fed.us/database/feis/plants/graminoid/schsco/index.html
The effect of summer fires on huckleberry can also be seen in Dr. William Patterson's Truro burn plots. Also high woody mortality in the summer is reported in Phipps, R. G. 1998. *Report on International Conference on Lowland Heaths*. Phipps, R. G., Ed. Nantucket, MA.

mortality can occur if duff is consumed.[116] Carbohydrate reserves in the rootstocks can also influence resprouting and mortality. For hardwoods, root reserves are lowest during leaf-out and highest during leaf-drop. For evergreen species, reserves peak in the spring and reach a minimum in the mid- to late-summer.[117] In general, woody species are more susceptible during the growing season.[118] In addition, dormant season burns favor warm season grasses whereas growing season burns favor cool season grasses.[119] Dormant season burns (spring) appear to have the following results: an increase in Little Bluestem, Pennsylvania Sedge, Northern Blazing Star,[120] and bare ground percent cover; a decrease in shrub, lichen, and Black Huckleberry cover and tree oak density.[121] Fall blooming species in the composite family also benefit from spring burns. Pitch Pines are typically top-killed, but resprout readily from rootstock and branches. Golden Heather, on the other hand, suffers almost complete mortality when burned, yet germinates profusely following burns.[122] Plant species, therefore, tend to respond to fire based upon their life history characteristics.[123]

4.4.3 Animals

The direct effects of a single burn on animals are generally considered harmful, yet the effects of a long-term fire regime are often necessary for the survival of certain species and their habitats. Invertebrates and birds, for example, are both documented as harmed by fires, with complete mortality assumed in many cases due to a lack of information.[124] The effect on a particular

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[116] On the other hand, huckleberry roots will occur in mineral soil (where it is more protected) in areas where the duff has previously been consumed through a long-term fire regime. http://www.fs.fed.us/database/feis/plants/shrub/gaybac/index.html

[117] Sablon, L. du. 1904. Recherches physiologiques sur les matieres de reserves des arbres I. *Revue General de Botanique* 16:341-368, 386-401. Sablon, L. du. 1904. Recherches physiologiques sur les matieres de reserves des arbres II. *Revue General de Botanique* 18:5-25, 82-96. In Robbins, L. E. and R. L. Myers. 1992. *Seasonal Effects of Prescribed Burning: A Review*. Tall Timbers Research Miscellaneous Publication No. 8.

[118] Dunwiddie, P.W. and C. Caljouw. 1990. *Prescribed Burning and Mowing of Coastal Heathlands and Grasslands in Massachusetts*. N.Y. State Mus. Bull. 471, pp. 271-275

Patterson, W. A. 1988. *The role of fire in the origin and maintenance of prehistoric coastal New England heaths. International Conference on Lowland Heaths*. R. G. Phipps, Ed. Nantucket, MA; McCartney, D.J. 1988.

[119] http://www.fs.fed.us/database/feis/plants/graminoid/schsco/index.html
http://www.fs.fed.us/database/feis/plants/graminoid/carpen/index.html

[120] Our Wasque and Long Point Wildlife Refuge monitoring data shows these trends. Other researchers have noted an increase in this species as well: Vickery, P.D. 1996.

[121] McCartney (1988) found that Golden Heather, Trailing Arbutus, rockrose, and lichen species were often eliminated from plots following a disturbance. Our four years of data, although inconclusive for a long-term fire regime, shows, however, that these species do survive (save for lichen in heavily managed areas).

[122] Monitoring data from Long Point Wildlife Refuge and Wasque Reservation, Martha's Vineyard, 1997-2000.

[123] See Section 9, Table 2. These species characteristics may have evolved, in part, to the effects of a long-term fire regime. Also see: Bond, W. J. and B. W. van Wilgen. 1996. *Fire and Plants*. London, Chapman and Hall.

[124] Discussed in Vernegaard, L., R. Hopping, and D. Reid. 1998. *Ecological Management of Grasslands: Guidelines for Managers*. Beverly, MA: The Trustees of Reservations, white paper.

Ells, S. F. 1995. Bobolink Protection and Mortality on Suburban Conservation Lands. *Bird Observer*. 23(2):98-112.

Swengel, A.B. 1996. Effects of Fire and Hay Management on Abundance of Prairie Butterflies. *Biological Conservation* Vol. 76. pp. 73-85

Goldstein, P. Z. 1997. *A Preliminary Inventory of Rare Insect Occurrences on Nashawena Island: Life History Requirements and Recommendations for Ecological Management Priorities*. Beverly, MA: Report

species, however, depends on the species life history characteristic, the timing of the burn, size of the burn and patchiness of the burn. For example, the Coastal Heathland Cutworm (*Abagrotis nefascia*) larvae feed underground; a surface fire would not harm them during their larval stage. During their adult egg laying stage, on the other hand, this moth species is likely more vulnerable. Unburned patches that occur in burns would also provide refugia and adjacent areas could provide colonizing populations. Section 9 describes the risks associated with fire in habitats where rare species are present.

4.5 Costs

Current average costs are estimated at $250 an acre.[125] Costs include an extensive amount of equipment and personnel—engines with slip-on units, tools, backpack pumps, hose, and radios, for example. Initial costs associated with the creation of a burn program—purchase of equipment, staffing, and training—are high, however. As burn programs mature and total burned area per year increases, costs per acre will naturally decline. Likewise, as unit size increases and fuel loads decrease, costs per acre will decrease. Finally, by collaborating with other organizations, the synergy of operations can reduce costs significantly for all partners, as redundancy is avoided.

4.6 The Current Status of Fire Regulation

Fire has been regulated in Massachusetts and the Northeast for hundreds of years.[126] Regulations occur at a number of levels: local, state, and national. All regulations and permitting revolve around public health and safety. Nationally, the EPA administers the Clean Air Act, which has the potential to affect the extent and success of prescribed burning. The EPA has issued guidelines specifically relating to wildland fires. The goals of these guidelines are to "allow fire to function, as nearly as possible, in its natural role in maintaining healthy wildland ecosystems, and to protect public health and welfare by mitigating the impacts of air pollutant emissions on air quality and visibility."[127] Two important aspects of the document are one, that partnerships are stressed, and two, to reduce smoke, means of habitat management other than prescribed burning should be considered and used, if appropriate. Currently, the Commonwealth of Massachusetts, which must comply with the Clean Air Act,[128] is in compliance for all particulate matter—the main pollutant arising from prescribed burns.[129] Much is in limbo in 2003, however, as only an

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to The Trustees of Reservations, white paper; Simmons, T., R. Meyer, P. Seamon, and J. Selby. 1995. Bugs in your burn? *Rx fire Notes* 4(1):1-5.

[125] NRCS estimate based on TNC dollar amounts (Henry Barbour), Don Liptack, personal communication.

[126] Pyne, S. J. 1997.

[127] http://fire.r9.fws.gov/ifcc

[128] States are required to attain and maintain the National Ambient Air Quality Standards (NAAQS), established on July 18, 1997 (reviewed every 5 years).

[129] NAAQS: Standards for maximum acceptable concentrations of pollutants in the ambient air to protect public health with an adequate margin of safety, and to protect public welfare from any known or anticipated adverse effects of such pollutants (e.g., visibility impairment, soiling, materials damage, etc.) in the ambient air. The new NAAQS levels for PM2.5 are set at a daily concentration less than or equal to 65 $\mu g/m^3$, and an annual mean concentration of less than or equal to 15 $\mu g/m^3$. The daily standard is violated when the 98th percentile of the distribution of the 24-hour concentrations for a period of 1 year (averaged over 3 calendar years) exceeds 65 $\mu g/m^3$ at any monitor within an area. The annual standard is violated when the annual arithmetic mean of the 24-hour concentrations from a network of one or more population-oriented monitors (averaged over 3 calendar years) exceeds 15 $\mu g/m^3$. Compliance with the annual PM2.5 NAAQS is based on population-oriented monitors because the health information, upon which the standard is based, relates area-wide health statistics to area-wide air quality as measured by one or more monitors. http://fire.r9.fws.gov/ifcc/

interim policy exists[130] and the Clean Air Act is currently being discussed with respect to smaller-sized particles and its impact on the health of Americans and compliance for these smaller sized particles (PM2.5 and PM10[131]) is being tested in zones for the first time throughout the state.[132] At this time, prescribed burns are not monitored for their air quality standards or their assessed fees, as they are in some western states.[133] Some areas in the northeastern United States may have difficulties with air quality permitting due to a high density of settlement and winds that may send smoke in the direction of densely settled areas. At a local level, the fire chiefs permit individual prescribed burns the day of the burn. Safety is the primary concern when considering a permit; the fire chief may order a burn to cease at any time.

4.7 Smoke Management

Reducing the risk of health effects and other public safety issues should be the top priority when conducting a prescribed burn. Prescribed burning techniques and burning during favorable atmospheric conditions can significantly reduce these risks, while still allowing for other prescribed fire goals—such as fuel reduction and ecological management—to be met. Creating prescriptions with a range of desirable conditions and selecting burn dates with desired conditions is one method to manage smoke. Wind dispersing smoke rapidly away from population centers and vertical transport of smoke particles are two of these conditions. Burning in the dormant season also reduces smoke, for duff is not consumed as effectively[134] and less live biomass and fuel moisture is typically available. Ignition patterns can also control smoke management. Certain techniques such as "ringing a unit"[135] can create a convective column, effectively pushing smoke vertically and reducing the time a burn is conducted. Backfires can take much longer to conduct, but will also consume less fuel and therefore will generate less smoke, especially during winter months.[136]

Smoke Management Planning (SMP) is a method to manage smoke from prescribed burns to ensure that air quality standards are met. Currently, many northeastern states, including the Commonwealth of Massachusetts, are not required to create SMPs, as measuring of potential NAAQS violations has not yet occurred. State governments, however, do have the option of requiring SMPs, which are specifically established to "mitigate the nuisance and public safety

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[130] Interim Air Quality Policy on Wildland and Prescribed Fires, May 1998. http://www.epa.gov/ttn/oarpg/t1/fact_sheets/firefl.pdf

[131] Units are in micrometers. Tests indicate that, on average, 90 percent of smoke particles from wildland and prescribed fires are smaller than PM10, and 70 percent are smaller than PM 2.5. The EPA's data shows that these small particles may cause many health problems, due to their ability to penetrate deeply into the lungs. http://fire.r9.fws.gov/ifcc

[132] Previously the Clean Air Act focused on particles of larger size.

[133] Fees are charged based on the pollution emitted by each burn. Joel Carlson, personal communication. "As for any source, emissions from fires can be estimated by multiplying the estimated level of activity by an emission factor. The level of activity for fire is the mass of biomass (fuel) consumed, usually expressed in tons. Emission factors expressed in pounds per ton of fuel consumed are available in EPA's publication AP-42 (which is scheduled to be updated). Emission factors are derived from an estimate of overall combustion efficiency (i.e. stoichiometric ratio). The mass of fuel consumed is the product of fire size (acres), pre-burn fuel loading (tons per acre), and fuel consumption (percent of pre-burn loading). An emission inventory can be compiled by the affected air agency for an individual fire, a statistical class of fires, a burn program, or a population of fires in a given area over a period of time based on this information." From: http://fire.r9.fws.gov/ifcc

[134] Duff can contribute to over 50% of particulate emissions. Pyne et al. 1996, p. 566.

[135] Ringing a unit is an ignition pattern that involves encircling a secured part of a unit with fire. The fire then draws air inwards then upwards. This creates an intense burn with generally good smoke dispersal.

[136] Windisch, A. G. 1999.

hazards (e.g., on roadways and at airports) posed by smoke intrusions into populated areas; to avoid significant deterioration of air quality and potential NAAQS violations; and to avoid visibility impacts in Class I areas."[137] SMPs can be implemented at a state level or be in effect only for parts of a state. The plan should include sections on minimizing smoke emissions, public notification, air quality monitoring, public education and awareness, surveillance and enforcement, and program evaluation.[138]

4.8 Safety

Prescribed burning is inherently a potentially dangerous and life-threatening activity. With that in mind, vigorous safety procedures and monitoring can reduce the risk of injury, death, or property damage significantly. Safety also ensures the long-term integrity of a fire program; one incident can end a fire program immediately. Prescribed burning involves the risk of smoke inhalation, minor burns and cuts, major burns, dismemberment, death, damage to equipment, damage or destruction of homes, damage to forest resources and damage or destruction of other personal property. These can occur during an escape, within a unit, or outside the unit. For example, lingering smoke can cause car accidents on roads well outside a prescribed burn unit. Poison Ivy can be a major safety issue as well, especially following burns during post-burn clean up, when ash may contain toxins.

Precautions are many. Fire weather staff can alert the burn boss to changing conditions. Adequate number of properly-trained, experienced, and reliable staff can help with smoke monitoring and patrolling for spot fires. Adequate and well-maintained equipment can help should an emergency arise. The proper safety gear—goggles, fire shelter, helmet, gloves, boots, and Nomex—is also important. Notification of abutters and nearby residents as well as education can also help raise awareness in terms of smoke safety. Finally, a good prescription allows for burns to be carried out only under safe weather conditions.

Over the long-term, prescribed fire and other management tools such as grazing (Section 5), mowing (Section 6), and clearing (Section 7) can increase public safety by reducing fuel loads and reducing the chance of catastrophic wildfires. Burning areas adjacent to recently managed units can also increase the safety of prescribed burns even further, as these units contain reduced fuels.

4.9 Insurance Policy

Safety concerns also raise issues of liability. For this reason, insurance is needed at two levels, described below. With this liability insurance also comes the need to demonstrate standards in training, safety, and protocol. The best example of an insurance policy that covers prescribed burns for a private non-profit organization is the one that covers The Nature Conservancy (TNC). This liability insurance occurs at three levels. First, TNC has a standard general liability insurance that covers damage that may occur during any burn. This includes injury to people as well as property. TNC has been able to receive coverage without increased payments due to their Fire Management Program, which has established training requirements for burn boss certification, protocols, and an organizational fire manual.[139] These items provide enough evidence that prescribed burning, when carried out under a well-organized program, is inherently not as dangerous as other activities. Hence, TNC does not pay additional premiums. Second, TNC carries smoke liability insurance, which is expensive, at a national level. State programs

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[137] http://fire.r9.fws.gov/ifcc

[138] For a detailed guide, see: Prescribed Fire and Fire Effects Working Team. 1985. *Prescribed Fire: Smoke Management Guide.* National Wildfire Coordinating Group, PMS 420-2.

[139] http://www.tncfire.org

then pay the national office on a per acre basis. This type of insurance covers smoke damage to any property as well as death and dismemberment due to accidents, such as car accidents. Third, TNC requires partners and volunteers to sign liability waivers, and, for each non-TNC property, the owner must sign a waiver. This system works well for TNC.

4.10 Prescriptions, Ecological Burning, and Wildfires

For any burn unit a prescription is needed. The prescription lays out all issues relating to fire management including:

- The objectives to be accomplished by a particular burn
- An acceptable range of fire weather, fuel moisture, and fire behavior parameters to safely achieve desired effects[140]
- Burn-specific information on hazards, smoke sensitive areas, contingencies, escape routes and safety zones
- Details of pre-burn site preparation, probable ignition patterns, crew assignments, holding positions, and post-burn clean up activities
- Lists of equipment needed for the burn
- Sources of emergency assistance
- A series of high-quality maps showing the site/preserve, burn unit, smoke sensitive areas, ecologically sensitive areas, proposed ignition pattern, and escape routes, safety zones and secondary control lines
- A checklist for burn preparation and crew briefing[141]

Ecological issues should be taken into account when determining the acceptable range of fire conditions. The historical fire regime, life history information of target species, and habitat characteristics—structure, diversity, soils—are important when determining a prescription. Time of year, fuel moisture, fuel structure and composition, temperature, wind, solar radiation, and ignition patterns control the ecological effects, which should ultimately reflect the long-term goals of a unit. Management plans should provide managers with specific, achievable goals for particular units. These goals should be achievable and measurable, through monitoring.

Wildfire response is another key issue.[142] In the case of a wildfire, personnel should determine how they plan to respond in order to increase safety, avoid ecological or other damage, and to reduce its liability. In all cases, a wildfire is reported directly to fire control officers. The reduction of wildfire risk and ecological management often go hand-in-hand.

4.11 Personnel, Equipment, and Partnerships

In Massachusetts, for example, some organizations have proper staffing for prescribed burns, while others have fire prevention equipment.[143] This scenario makes partnerships extremely important. In Massachusetts, staffing for prescribed burns is limited. Between 1997 and 2000, most prescribed burns were conducted on Martha's Vineyard, where TNC has an ambitious fire

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[140] These parameters can be established with the aid of modeling of fire behavior through *BehavePlus*, which can be downloaded at: http://fire.org/cgi-bin/nav.cgi?pages=behave&mode=1

[141] From TNC's National Fire Management Program Fire Management Manual: http://tncfire.org/manual/sitemap.htm

[142] From TNC's National Fire Management Program Fire Management Manual: http://tncfire.org/manual/sitemap.htm

[143] Equipment includes engines, ATVs, bladder bags, radios, PPE, First Aid kits, weather kit, weather radio, drip torches, fuel cans, fusees, backpack pumps, council rakes, pulaskis, chain saws, rakes, fire swatters, shovels, nozzles, hoses, pumps, and smaller accessories. In addition, fuel—both for vehicles and drip torches—is needed.

management program that works with The Trustees and other organizations. Only a small number of trained burn bosses are in Massachusetts, with one of them being full-time.[144] This leaves, as of 2003, one full-time burn boss to carry out the majority of burns within the state. Certified burn-bosses, whether through TNC or other organizations, are necessary to ensure the proper application of fire statewide. Clearly additional training of personnel is necessary. Any organizational burn boss certification program should take into account national standards set by the National Wildfire Coordinating Group.[145] Partnerships at a local level should be encouraged to ensure a better use of resources, better coordination with respect to public safety, and additional coordinated management goals.

4.12 Notification and Education

For a long-term burn program to succeed, residents of areas near prescribed burn sites must be supportive of the fire program. If they are not in favor of burning, a fire program is not likely to succeed. Prescribed fire, therefore, needs to be seen in a positive light. For this reason, a strong notification and education program is needed. Abutters and other neighbors who may be affected by a prescribed burn (i.e. smoke effects) should be notified months in advance of conducting prescribed burns. Notification should include information on reasons for burning, the dates of the burn season, that safety is the primary concern, who is involved in the burns, and who the contacts are for further questions.

Education involves building knowledge of and confidence in a prescribed burn program. The most important educational tool is the media. Local radio stations should announce as a public service announcement that a prescribed burn is being conducted at a particular location, with relevant information included. This is important because emergency communications centers can become overwhelmed with misguided phone calls concerning a burn. These calls mean that fire departments and police are notified and may need to respond. A press release to this effect should be sent to local radio stations the morning of the burn. In addition, relationships should be established with the media, including newspapers and magazines. Where appropriate they should be invited to attend a burn. On properties where burning is conducted, guided walks and the placement of interpretive signs, will offer excellent opportunities for interpreting prescribed burning. Wherever possible, an interpretive program should be developed around prescribed burning, in conjunction with other habitat management tools.

4.13 Conclusions

Prescribed fire is a necessary part of managing sand barrens in the northeastern United States. Although many issues and logistics need to be addressed and costs may be high, the ecological benefits of fire, when applied correctly, are great. In addition, prescribed fire can reduce fuel loads for public safety and improve scenic vistas. Prescribed burning also offers certain practical advantages over other tools. Mowing, grazing and clearing, however, may be more advantageous in other cases (see Sections 5-7 and 9). Burning has the following practical advantages:

- Ability to manage large areas, potentially on the scale of hundreds of acres.
- Flexibility in terms of ecological effects, depending on the fire regime and burn conditions (see Section 4.4).
- Ability to burn into wetlands and create ecotones.
- Ability to burn in areas with downed woody debris, stones, and steep slopes (not feasible for mowing).

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[144] Joel Carlson is Fire Manager for The Nature Conservancy. Other burn bosses are not full-time and focus on other areas—research, program administration, or property-specific work.

[145] http://www.nwcg.gov

- Ability to reduce leaf litter and duff over the long-term.

The ecological effects and the ability of prescribed fire to achieve ecological goals, especially given its historical significance are the greatest benefits of burning.

Burning presently offers many disadvantages as well. These disadvantages should be weighed with other management tools. The disadvantages of prescribed burning include:

- Limited seasonality. Most burns will likely be conducted during the dormant season. Due to smoke and public health concerns, burning during the growing season is likely not a large-scale viable option.
- Potentially dangerous. Smoke and escaped fires are potentially life threatening and can damage property (see Section 4.8). Public perception is also highly important.
- Labor and equipment intensive. Equipment and personnel costs are high, but with partnerships and burning larger areas, these costs can be reduced in the long-term. A properly trained, experienced, and available crew is needed to conduct prescribed burns.

Section 5: Prescribed Grazing

5.1 Introduction

With nearly one quarter of the earth's land surface grazed by domestic animals, [146] livestock grazing has created significant changes to today's terrestrial ecosystems worldwide.[147] Although the effect of grazing animals on the environment is oftentimes thought of negatively, grazing animals can be beneficial and may be used as tools to benefit the environment and promote ecosystem health. Land managers have used livestock grazing to reduce habitat fragmentation, increase species diversity, and alter forms of habitat structure and composition to suit their management needs. [148] Managers have also used grazing and browsing animals not only to convert woodlands into more open systems, but also to maintain existing open systems, such as grasslands and savannas.[149] Because different breeds and species of grazing animals have a wide variety of foraging behaviors,[150] managers can select from different genetic types to meet management objectives.[151] Managers can also select the number of grazing animals to meet specific management objectives. This section is intended to serve as a resource for making decisions about prescribed grazing.

Although prescribed grazing has been used extensively in the United Kingdom with great success to managers, its use in the northeastern United States must be considered carefully. The success of using animals as management tools depends on several complicated factors, such as: location of the site, season, weather, topography, ability to acquire and transport animals, and more importantly, the labor, financial, and time costs to implement a grazing project. For this reason, several questions must be addressed before considering the use of grazing as a management tool:

1. What are the management objectives and what are the future desired conditions?
2. What, if any, grazing prescription can be used to attain these objectives?
3. Is grazing a practical tool for habitat management at this site?
4. How effective is grazing at controlling woody growth to create or maintain early- to mid-successional habitat?
5. What effects from grazing will result on rare species or sensitive resources?
6. Can grazing be implemented to correspond with seasonality and plant phenology? [152]
7. What will be the short and long-term costs of grazing?

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[146] The word "graze" is used in this document to describe the act of consuming forage by animals.

[147] West, N.E. 1993. Biodiversity and Land Use. Pages 21-26 *in* W.W. Covington and L.F. DeBano (Technical Coordinators) 1994. *Sustainable Ecological Systems: Implementing an Ecological Approach to Land Management*. 1993 July 12-15; Flagstaff, Arizona. Gen. Tech. Rep. RM-247. Fort Collins, CO: U.S.D.A. Forest Service, Rocky Mountain Forest and Range Experiment Station. 363 pp.

[148] In order to properly interpret the terminology used in this report, grazing terms as described by The Forage and Grazing Terminology Committee (originally published in 1991 by Pocahontas Press, Post Office Drawer F, Blacksburg, VA 24063) are presented in footnotes.

[149] McPherson, Guy R. and J.F. Weltzin. 2000. *Disturbance and Climate Change in United States/Mexico Borderland Plant Communities: A State-of-the-Knowledge Review*. Gen. Tech. Rep. RMRS-GTR-50. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 24 pp.

[150] *Forage (noun); The edible parts of plants, other than separated grain, that can provide feed for grazing animals, or that can be harvested for feeding. Includes browse, herbage, and mast; (verb), To search for, or to consume forage.*

[151] For example, goat grazing may be most effective at eliminating existing trees and shrubs, whereas cattle and sheep grazing may be the most effective at controlling the spread of future trees and shrubs through seedling grazing.

[152] The word "phenology" is used to define the relationship between a regularly recurring biological phenomenon, such as plant budding, and the climatic or environmental factors that may influence it.

8. Will grazing be a viable, cost-effective tool for sustainable long-term habitat management?
9. Can grazing be used with other tools to create a sustainable long-term habitat management plan?

This section will address these questions in general terms and will look at the history of grazing in the northeastern United States, the present use of grazing, stocking rates and grazing systems, livestock types and their effects, and the costs and benefits of grazing.

5.2 Grazing History

The history of grazing in the northeastern United States dates back to the first settlement of the American colonies. Livestock were first imported from England to the American colonies in the early 1600s for subsistence while the settlers established permanent communities. Cattle, goats and sheep provided settlers with valuable products, such as wool, milk, cheese, and meat. As land was cleared to provide for agriculture, large tracts were set aside as pasture for these animals.

Throughout most of the northeastern United States, land was often cleared using livestock to graze the forest undergrowth.[153] As trees were cut, stumps were removed from the fields with large animals, such as oxen. Livestock were then released again to browse back any regrowth. [154] Old woodlots were often transformed into pastures by allowing livestock to graze the resprouts of cut trees. When grass[155] and hay became scarce, trees were cut specifically to provide fodder for livestock.[156] As vast tracts of land became treeless, local governments began to pass legislations that regulated the number and density of grazing animals on common lands.

Throughout colonial New England, sheep grazing became an integral component of farming. Along with goats and cattle, sheep were able to use land unsuitable for cultivation or forestry. As a result, livestock populations increased dramatically, as did the demand for wool. The demand grew so quickly that by the end of the 1700s, sheep farming had secured a firm foothold in the American colonies.[157] Laws during this time were frequently passed to increase the number of sheep flocks in the colonies.

During the late 1800s, both farming and grazing declined substantially because of industrialization, changes in wool tariffs, and immigration of the American people to more fertile soils in the Midwest. Farmlands and pastures in the northeastern United States were increasingly abandoned; and in due course, subdivided. As a result, fragmentation of open land occurred as abandoned pastures progressed into shrublands, woodlands, and forests.

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[153] Whitney 1994. A density of one cow for every two acres of land was sufficient to eliminate most of the trees less than 6 inches in diameter, and to create an obvious browse line in the first five to ten years of grazing. A few seasons sufficed for the total elimination of forest underbrush, including the young trees the forest depended upon for reproduction.

[154] The term "browse" is used in this document to define the leaf and twig growth of shrubs, woody vines, trees, and other non-herbaceous vegetation available for animal consumption. The verb form of this word is used to describe the act of consuming such vegetation by animals.

[155] Grass (noun), members of the plant family Poaceae.

[156] Whitney 1994.

[157] Wright, C.W. 1910. *Wool-Growing and the Tariff: A Study in the Economic History of the United States*. Vol. V. Cambridge: Harvard University Press.

5.3 The Present Use of Livestock Grazing as a Habitat Management Tool

Although grazing research in barrens sites in the northeastern United States is limited,[158] grazing may be an effective management tool to increase habitat heterogeneity, remove brush, and promote the growth of perennial grasses.[159] Grazing studies conducted on United Kingdom barrens, where heathlands and moors have existed for thousands of years, [160] may provide useful information for managing barrens sites in the northeastern U.S. The U.K.-based Grazing Animals Project (GAP)[161] determined that livestock grazing is better fitted for achieving their conservation objectives over other management tools that they have experimented with, such as herbicides (Section 8) and mowing (Section 6). Their research has determined that grazing is especially useful for controlling scrub and trees, maintaining or improving vegetation structure, and developing a diverse mosaic of vegetation. Because a number of heathlands in England were neglected, the North East Hampshire Heathlands Project was formed to promote and coordinate regional heathland management. The English heaths are threatened primarily by forest and scrub invasion. Following hand clearing of invading scrub, grazing has shown to be the most effective tool to prevent the recurrence of scrub invasion.[162] Because of this project's grazing management plan, young birch stumps have been killed within a single season. In the Dorset Heaths, heathland is also being lost to birch, pine, rhododendron, and other trees and shrubs. To counter this loss and to maintain heathland diversity, five of Dorset's heathland National Nature Reserves are being returned to traditional grazing through partnerships with adjacent landowners.[163]

5.4 The Costs of Prescriptive Livestock Grazing

Creating and implementing a grazing prescription for habitat management can be a difficult and time-consuming process. The following section will outline the costs—such as the costs of fencing, labor, and animals—involved in designing a grazing prescription. Fencing and labor costs are the major financial factors involved in implementing a grazing prescription.[164] In addition, liability regarding leased animals may result in costly legal matters and adverse public reaction, if death or sickness occurs to the animals. It is also important to keep in mind that, in addition to financial costs, livestock grazing may present several ecological costs that may outweigh or negate the potential benefits. For this reason, the sensitivity levels of each plant

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[158] Severson, K. E. 1990. Summary: Livestock Grazing as a Wildlife Habitat Management Tool. Pages 3-6 *in* K.E. Severson. 1990. *Can Livestock Be Used as a Tool to Enhance Wildlife Habitat?* USDA Forest Service. General Technical Report RM-194. Reno, NV: Proceedings of the 43rd Annual Meeting of the Society for Range Management.

[159] http://www.bluegoose.arw.fws.gov. Although grazing animals are typically used to promote species diversity, they may also be used to create areas of homogeneous habitat.

[160] http://www.hans.kampf.org

[161] English Nature and its partner organizations support the GAP, which aims to uncover a greater understanding of the use of domestic livestock for the conservation and management of wildlife habitats. English Nature is a statutory body that achieves, enables, and promotes nature conservation in England. English Nature works in partnership with individuals and a wide range of organizations including government agencies and volunteer organizations. For more information, visit the English Nature website at: http://www.english-nature.org.uk/. Small, R.W., C. Poulter, D.A. Jeffreys, J.C. Bacon. 1999. *Towards Sustainable Grazing for Biodiversity: An Analysis of Conservation Grazing Projects and their Constraints*. No. 316. English Nature, Northminster House, Peterborough PE1 1UA. 257 pp.

[162] Edgar, P. 1993. Contracting Out Heathland Management. *Enact: Managing Land for Wildlife*. 1.2: 11-16.

[163] Graham, S., I. Alexander, A. Nicholson. 1997. Return of the heathcroppers. *Enact: managing land for wildlife*. 5.2: 4-7.

[164] Financial costs are typically greatest during the initial stages of assigning a prescription as equipment and animals may need to be purchased or leased and staff hired. Employing qualified staff and consulting livestock veterinarians may be relatively costly. Costs may also increase significantly as contracts, waivers, and liability/insurance forms become necessary.

species to grazing must be known before assigning a prescription. Livestock grazing may severely alter native plant species composition and potentially introduce exotic and invasive species that could be difficult to control. Such exotic and invasive species may threaten rare species. Many these costs, however, can be mitigated through proper grazing management.

5.4.1 Fencing

Fencing is typically required in most grazing prescriptions for two main reasons: first, to retain livestock within a given management unit, and second, to keep predators out. Temporary fencing is typically used for rotational grazing schemes, while permanent fences are used for continuous grazing.[165] For example, *ElectroNet*™ is likely the most reasonable product offered to employ a rotational grazing system for sheep and goats.[166] These fences may also be used to protect sensitive resources, such as rare species, from any damage that may be incurred from the grazing animal.

5.4.2 Labor

A livestock caretaker would need to be hired to monitor the grazing animals at all times during grazing activity. The caretaker would have to possess emergency livestock medicine on-site and be knowledgeable of the medication and its administration in the event an animal requires emergency care.[167] The caretaker would also be responsible for quarantining livestock for up to two days prior to releasing the animals into any grazing unit. By doing so, the threat of introducing exotic plants would be essentially eliminated. This process involves setting up a holding pen where animals would be supplied feed that has no potential of exotic introduction, such as grain.

In the occasion that animals attempt an escape, such as when the forage has been entirely consumed, electric fencing may become damaged, animals may be harmed, and livestock may escape. In the event of an escape, the caretaker may be responsible for gathering and securing stray animals to an enclosed area. A sheep dog may be necessary to facilitate this process and may serve to protect livestock from domestic animal harassment.

5.4.3 Animal Costs

For long-term management objectives, it may be worthwhile to purchase the animals outright. In this case, the costs associated with raising, housing, and caring for the animals must be considered carefully. Leasing the animals, on the other hand, may be a more cost-effective approach. Many times, animals may be obtained from local farmers or livestock owners, typically at little to no cost. With this option, a contract or a waiver must establish which party is

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[165] Permanent structures, typically intended for continuous grazing schemes, will require much more time, labor, and money to install and maintain. Volunteers should be solicited to minimize the costs of labor to construct permanent fences. Either type of fencing can be ordered through Wellscroft Farm Fence Systems. 167 Sunset Hill-Chesham. Harrisville, New Hampshire 03450. (603) 827-3464.

[166] Composed of eight energized electroplastic wires, *ElectroNet*™ will prevent domestic dogs and other predators from entering the grazing unit. Plastic posts must be spaced every 12 feet, using PowerPosts™ for corners. Energizers will be required for every three nets. Gates are not needed; fencing may be opened easily at any end or connection. For every 150-foot roll of fencing, 5 minutes are needed for installation. No tools are required. The fencing is supported every 12 inches by built in plastic mini-posts that rest on the soil surface, allowing easy installation around obstacles, hills, and ditches. At a cost of $0.67 per foot, this product is very inexpensive.

[167] Plant toxicity is a significant concern. Vegetative toxicity can fluctuate in a given species throughout the year, being highly toxic in one season and non-toxic in another. In many cases, the effects of animal intoxication may be reversed if the animal is treated within the hour. Using local livestock accustomed to barrens vegetation should lower or eliminate this risk, however.

responsible for the supervision, health, and care of livestock. A livestock veterinarian, prior to establishing an agreement, should be hired to examine overall animal health and fitness. In the event of animal sickness or death, expensive and time-consuming legal matters may be involved.

Livestock grazing may also be contracted through a livestock grazing management company. The contractor should be made aware of the specific management objectives for each site and be responsible for best using livestock to achieve the objectives. The contractor should be responsible for any injuries incurred upon livestock during the contract period along with the care, health, and supervision of the animals.

5.5 The Benefits of Prescriptive Livestock Grazing

Prescriptive grazing may have many benefits to land managers seeking to control ecological succession. Livestock grazing may serve as a low-cost tool to restore and maintain ecosystem health. Livestock grazing can provide managers with the opportunity to avoid using toxic chemicals and unaesthetic mechanical equipment to inhibit invasive plant growth. Grazing may allow a relatively immediate return of nutrients into the soil and not add biomass to the duff layer.[168] In barrens habitats, the effects of livestock trampling may actually assist in reducing the duff layer and exposing the mineral soil that many invertebrates and rare plant species depend upon for survival.[169] Because livestock concentrate nutrients and seed in sporadically placed dung piles, the best approach to increasing species diversity in grasslands and heath may be treatments of grazing followed by a rest period.[170] Through this method, dung piles will provide a microenvironment for seedling establishment and the rest period would allow for new plants to germinate and grow.

5.6 Selection of the Grazing Animal

Several factors will dictate the success of prescriptive grazing as a habitat management tool. The animal breed and its foraging behavior and physiological condition, the available forage, combined effects of grazers and timing of grazing are but a few of the factors.

To reduce woody vegetation effectively, target plants should have the maximum number of carbohydrates stored in aboveground plant parts, which generally occurs when leaf size is at its maximum. If grazing is allowed at this time, the maximum number of carbohydrates allowable is removed at each grazing interval.

Various combinations of livestock type and breed may be used in combination to achieve management objectives. For example, one particular type and breed of animal may be used to prepare a management area for another animal, such as using goats to reduce woody growth, and sheep to increase herbaceous heterogeneity.[171] The palatability of forage to the animals will play a substantial role in determining which animal to use, and the season to use it. Under high

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[168] Duff is a layer of partially decomposed organic matter. This duff layer prohibits the growth of many plant species and generally develops over time with increasing tree and shrub cover.

[169] Conversations with local livestock owners and grazing experts support the claim that ungulate hooves perform a scissor-like action in ordinary locomotion, and will aid in breaking up duff. In Northeast Hampshire, England, livestock have been very effective in disturbing leaf litter and promoting the germination of heathland species. For more information see: Edgar, Paul. Contracting Out Heathland Management. *Enact: Managing Land for Wildlife*. 1.2 (1993): 11-16.

[170] Luken, J. O. 1990. *Directing Ecological Succession*. New York: Chapman & Hall.

[171] For more on this topic, see: Breymeyer, A.I. and G..M. Van Dyne (eds). 1980. *Grasslands, Systems Analysis and Man*. New York: Cambridge University Press. 950 pp.

grazing pressure, however, animals will compete for forage material causing palatability to become less important and plant selectivity to decrease.

Various physiological states may also affect an animal's desire to forage, including stage of breeding, pregnancy, lactation, fatness, fear, and excitement.[172] Similarly, various studies have reported up to three times the amount of food intake in sheep following shearing, likely as a means of maintaining body temperature.[173] In addition to the physiological condition of a grazing animal, environmental factors—such as temperature—may also influence the amount of food intake. For example, many large herbivores crave salt or other minerals, and may consume plants in locations with mineral-rich soils, while that animal would not consume the same plants in more mineral-poor areas. [174] The most commonly available grazing animals are described below.

5.6.1 Domestic Cattle

The original habitats of wild aurochs, ancestors to domestic cattle, were open forests and meadows and included grass, leaves and acorns in their diet. [175] Domestic cattle may be used to forage grasses and shrubs. A number of studies suggest that shrub invasion of heathland and grassland is accelerated by cattle grazing, although other variables, such as the season of grazing and stocking levels, will have a significant influence on invasion rates.[176] The decline of woody vegetation will consequently allow herbaceous plants to recover more quickly in the future.[177] Figure 5.1 illustrates highland cattle being used to maintain a European grassland.[178]

Figure 5.1*: Highland cattle being used to graze European grasslands.*

5.6.2 Domestic Goats

There are many breeds of domestic goats that in the U.S., each with a unique foraging strategy. Goats are very agile and are able to forage in areas other animals are unable to access. Goats tend to prefer the leaves, twigs, and bark of woody plants to that of grass and herbaceous plants. Even at low stocking rates, goats have been known to forage more on woody material and are able to consume vegetation that may be unpalatable to other grazing animals.[179]

5.6.3 Domestic Sheep

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[172] Breymeyer and Van Dyne 1980.
[173] Breymeyer and Van Dyne 1980.
[174] Breymeyer and Van Dyne 1980.
[175] Nowak, R.M. 1991. *Walker's Mammals of the World*. 5th edition. Baltimore: John Hopkins University Press. 2 vols.
[176] See page 172 in: Luken 1990. Multiple authors are cited for this reference. These studies also suggest that the fastest rate of shrub invasion is when heavy grazing is followed by an absence of grazing.
[177] To effectively reduce woody vegetation, target plants should have the maximum number of carbohydrates stored in above-ground plant parts, which generally occurs when leaf size is at its maximum. If grazing is allowed at this time, the maximum number of carbohydrates allowable is removed at each grazing interval.
[178] Photograph excerpted from http://www.home.zonnet.nl/hanskampf/index3.html
[179] Breymeyer and Van Dyne 1980.

Sheep may be useful tools for managers to control undergrowth in forests and other wooded areas.[180] The diet of the domestic sheep consists mainly of grasses, sedges, and forbs.[181] In Figure 5.3, sheep are being used to graze European heath vegetation.[182] Sheep have also been used to browse shrubs and tree sprouts, such as in the Great Smokey Mountains National Park where sheep had been found to consume oak sprouts, hawthorn, and blueberry.[183] Domestic sheep also tend to find Poison Ivy (*Toxicodendron radicans*) quite palatable. If managers are restoring habitat grass and heath habitat, sheep grazing may be the best approach to increasing species diversity through periodic grazing following by rest.

5.7 Selection of a Grazing System and Stocking Rates

The selection of a grazing system and subsequent stocking rates are site-specific and are dependent on several factors; such as: management objectives, the number of animals available for use, costs, available time and labor, and qualified personnel.[184] This section will outline the pros and cons of continuous grazing, rotational grazing, and environmental protective grazing; and will discuss their relation to stocking rates.

5.7.1 Continuous Grazing

Figure 5.3*: Sheep grazing a European heathland.*

Continuous grazing is a method in which livestock occupying a unit are left to graze at will. The animals are generally left to graze until the supply of forage supply[185] is depleted. Stocking rates, however, may be adjusted to allow livestock to graze target species. Continuous grazing is generally the easiest grazing prescription to implement, requires less fencing than other methods, and requires the least amount of management. Continuously grazing animals tend to graze selectively. This "spot grazing" leads to more grazing pressure on the palatable plants than unpalatable plants. Over time, this can reduce the survival rate of palatable plants. If these plants are a desired part of the habitat, then this grazing prescription should not be used. If, on the other hand, management goals call for reducing palatable species, then this grazing method may be used to achieve management goals.[186]

5.7.2 Rotational Grazing

Rotational grazing is a system in which two or more grazing units are alternately grazed and rested.[187] Generally, rotational grazing may be useful to maintain plant diversity and structure

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[180] http://www.sheepusa.org/news/ffpdf/Ffshepecology.html
[181] *Forb (noun), any herbaceous broadleaf plant that is not a grass and is not grass-like.*
[182] Photograph excerpted from http://www.home.zonnet.nl/hanskampf/index1.html
[183] Luken 1990.
[184] Securing the proper breed of livestock at the proper time, and in sufficient numbers, may be the largest logistical setback.
[185] "forage supply" refers to the amount of vegetation available for livestock to graze.
[186] An example of this would be targeting poison ivy with sheep.
[187] Emmick, D.L. and D.G. Fox. 1993. *Prescribed grazing management to improve pasture productivity in New York.* USDA Soil Conservation Service and Cornell University Department of Animal Science. 44 pages.

while continuous grazing typically reduces plant diversity and structure.[188] Through rotational grazing, the manager has greater control over the amount of forage that is to be grazed in each unit.

5.7.3 Environmental Protective Grazing

In order to protect fragile environments from overuse or overgrazing, Environmental Protective Grazing (EPG) may be prescribed.[189] Environmental Protective Grazing includes using either continuous or rotational grazing, or both. The grazing units must be allowed adequate rest from grazing and be carefully timed around wildlife cycles and sensitive developmental stages of resident plants and animals. Fencing may be set up to exclude livestock from ecologically sensitive areas.

5.7.4 Stocking Rates

Animal stocking rates may severely influence vegetative responses to grazing, and involve three pivotal factors: frequency of grazing, intensity of grazing, and the season in which grazing takes place.[190] As the intensity of grazing increases, overall vegetative productivity typically declines. Generally, plants that are grazed intensely during early growth stages and given a deferment throughout the remainder of the growing season may produce additional growth and be more vigorous than plants that receive less intense defoliation throughout the growing season.[191] In addition, plants typically produce more leaves than woody tissue in the early growing season. Grazing following the growing season, typically autumn and winter, will remove older and dead plant material that is of relatively little value to the plant or shrub. Fall and winter grazing may have the least detrimental effect on grasses, but some negative impacts may occur if grazing intensity is high, such as trampling or severe shifts in nutrient quantities and concentrations.[192]

5.8 Conclusions

In order to evaluate the success of implementing a grazing plan, all potential costs and benefits should be determined beforehand. Although this document presents a strong case for the use of prescriptive grazing, when all aspects are considered, grazing could be risky and costly. Costs and risks, however, can be significantly reduced depending on the availability of livestock, labor, community support, and legal agreements or contracts. In the occasion that a grazing prescription may actually adhere to management guidelines, unforeseen setbacks may inevitably occur, such as inclement weather or climatic conditions; animal sickness, escape, or death; or the pursuit of unforeseen, but necessary, legal matters.[193] With these factors in mind, grazing has several benefits as well. Grazing can target vegetation that other tools may not specifically target, can control growth in areas that other tools cannot, can reduce woody growth and increase species diversity, and is highly flexible in terms of season and frequency.

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[188] Vernegaard, L., R. Hopping, and D. Reid. 1998. Ecological Management of Grasslands *in* Ecological Management at The Trustees of Reservations: Guidelines for Managers, white paper.

[189] Payne, N.F. and F.C. Bryant. 1994. Techniques for Wildlife Habitat Management of Uplands. New York: McGraw Hill. Pp. 347-412.

[190] In addition, weather can severely affect the foraging behavior and selectivity of individual animals. For more on this see Edgar 1993.

[191] Trlica, M.J. Grass Growth and Response to Grazing. Placed on the World Wide Web November 15, 1999 under a copyright of the Colorado State University Cooperative Extension. See http://www.ext.colostate.edu/pubs/natres/06108.html

[192] Trlica 1999.

[193] For example, although electric fencing is effective, it is not guaranteed to be 100% successful at detaining livestock. If animals escape, they may enter roadways and cause severe traffic accidents. Escaped animals may also be attacked by domestic animals. In either case, liability issues become a significant concern.

Section 6: Mechanical Mowing

6.1 Introduction

Mechanical mowing is one of the simplest forms of management for controlling landscape structure and managing plant community composition. Similar to grazing, the use of mowing in modifying a landscape typically functions more as a habitat maintenance tool than as a restoration tool.[194] Mowing may be appropriate for managing grasslands, heathlands, oak openings, savannas, and other areas in sand barrens habitats requiring low-lying vegetation structure. When performed regularly, mowing may allow for the reduction of woody growth and a subsequent increase in herbaceous cover.[195] Land managers use mowing machines throughout the northeastern United States not only to control invasive woody vegetation, but also to create more open and diverse ecosystems. The following sections outline the history of mowing in the U.S., the present use of mowing, the effects of mowing on a landscape, and the associated benefits and costs of mowing.

6.2 Mowing History

Mowing has been practiced in the northeastern United States since the time of the earliest settlements. During colonial times, farmers and laborers collectively harvested hay, using hand scythes.[196] Figure 6.1 illustrates the typical two-handed scythe of colonial times.[197] Through seeding European grasses, hayfields—or English meadows—were created that supplied livestock with winter fodder. Hayfields became scarce, however, as land was subdued to suit other agricultural needs.

Figure 6.1*: An historic two-handed scythe.*

Harvesting adequate hay to support livestock for the winter, therefore, was a major challenge.[198] During the four to five months of the non-growing season, the typical cow would consume approximately two tons of hay, approximately the product of one or two acres of meadow or mowing land.[199] In the mid 1800s, mowing machines were invented and introduced to the

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[194] For more information on the use of mowing as a restoration tool to remove dense stands of brush or whole trees, see Section 7.

[195] Dunwiddie, P.W., W.A. Patterson III, J.L. Rudnicky, and R.E. Zaremba. 1997. Vegetation Management in Coastal Grasslands on Nantucket Island, Massachusetts: Effects of Burning and Mowing from 1982 to 1993. Pages 85-97 *in* P.D. Vickery and P.W. Dunwiddie, eds. *Grasslands of Northeastern North America: Ecology and Conservation of Native and Agricultural Landscapes*. Lincoln, MA: Massachusetts Audubon Society. The 11-year study examining the effects of burning and mowing in coastal grasslands on Nantucket supports this case. Plots mowed in August resulted in an 83% increase in herbaceous species. Herbaceous species richness increased, the numbers of rare species were maintained or enhanced, and many shrubs were reduced in cover and frequency.

[196] Up until the 19th century, the average farmer of the Northeast relied chiefly upon his own labor and that of his family. Bidwell, P. W. and J.I. Falconer. [1925] 1941. *History of Agriculture in the Northern United States 1620-1860.* Baltimore: The Lord Baltimore Press and the Carnegie Institution of Washington.

[197] Photograph excerpted from http://www.informallearning.com/archive/1999-0506-b.htm

[198] Whitney 1994.

[199] Whitney 1994; with several references to others.

Northeast.[200] Today, brush-cutting machines are typically used to mow fields, meadows, and heathlands, and range in size from manual cutters with blades under ten inches wide to tractor-mounted machines with blades several feet wide and large industrial-sized machines that crush vegetation, thereby reducing the height of fuels and decreasing potential fire behavior.

6.3 The Use of Mowing in Succession Management

Mechanical or manual cutting of vegetation is the oldest and most common form of succession management today.[201] Frequent mowing can change species dominance in grasslands, can reduce populations of unwanted species in heathlands and elsewhere, and can stimulate regeneration of non-target species from seed.[202] Typically, mowing is not used in heavily forested areas, yet can be used for openings or other smaller applications. Mowing may be enticing to managers as it offers some advantages over other management tools. Mowing may be performed more than once in a given season (as opposed to burning), can be performed any time of the year, can be completed on units of nearly any size or shape, can be used to target—or avoid—specific areas, and is able to adjust vegetation structure to various levels. This section will outline the overall ecological effects that mowing may have on barrens habitat and will discuss the costs and benefits associated with mechanical mowing.

6.4 Mowing Effects

Mowing affects plant species composition, woody plant growth, the accumulation of plant litter, and vegetation structure. The particular ecological effect that mowing will ultimately hold, however, depends on the mowing regime—the timing, frequency, extent (percent of unit mowed), and intensity (number of passes and blade height)—used for a particular unit. In addition to the effects on vegetation, mowing also affects animals through direct mortality, changes in habitat structure, and removal of food sources. Mowing can be timed, however, to reduce the risk to rare or uncommon plant or animal species.

The first noticeable effect that mowing will have on a landscape is the reduction of vegetative structure. A mosaic pattern, however, can be achieved by mowing only parts of a management unit, leaving structural diversity as dictated by site-specific management goals. The effects of mowing on individual plant species and plant parts, however, vary by species. Mowing has a unique form of selection on plants, in comparison to other disturbances such as fire or grazing. For example, mower blades do not usually cut low-lying vegetation, yet the mower and tractor may actually crush and kill these species. Timing may also affect species differently. For example, most blazing stars, asters, goldenrods, and other composites are less susceptible to mowing in the early growing season, when most of the biomass is in short basal rosettes and underground. Mowing in the late growing season, on the other hand, would affect these species considerably—at that time, they are typically tall and flowering. In addition, mowing may lead to an increase in plant species diversity, although species richness may decline, depending on how mowing fits into a site's overall management.[203]

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[200] Bidwell, P.W. and J.I. Falconer. [1925] 1941. The invention of American horse-power mowing and reaping machines dates from patents issued as early as 1803, but were not introduced to New England until after 1850.

[201] Luken 1990.

[202] Luken 1990.

[203] Dunwiddie, P.W. and C. Caljouw. 1990. *Prescribed Burning and Mowing of Coastal Heathlands and Grasslands in Massachusetts.* N.Y. State Mus. Bull. 471: pp. 271-275. Our monitoring efforts on Wasque have also illustrated an increase in overall species richness, although one investigator noted a decrease in species richness as a result of mowing; see: McCartney, D. 1988.

Due to the acidity of sand barrens soils, decomposition of plant litter is typically slow, and accumulation of litter may eventually form a layer of partially decomposed organic matter—called duff—on top of the mineral soil. A duff layer may inhibit the germination of uncommon and rare plants, which often require exposed mineral soil. Unfortunately, duff accumulation can be increased through mowing, which leaves mowed debris on-site.[204] In some cases, such as when the mower blades inadvertently scrape the ground, mineral soil may be exposed and allow for the establishment of grass and plant seedlings.

6.4.1 Timing and Frequency of Mowing Applications

One of the greatest benefits of mowing is that managers have a wide degree of control over timing and frequency. Control over timing can allow managers to target specific plants or avoid vulnerable times for key species of plants and animals. Mowing during the growing season, for example, can significantly reduce woody species, yet can also affect rare plants and animals, specifically those that are breeding or flowering at the time of mowing (see Section 9 for risk management).[205] For several barrens habitats, some reduction of woody vegetation may be a management objective—for example, tree oak and pine removal in coastal heathlands. The effect of mowing using different timings and frequencies on oaks, pines, and other woody species may be due, in large part, to where the plant carbohydrate stores are located. We hypothesize that oak resprouts would experience more mortality during the early growing season, whereas pine resprouts would be reduced more during the late growing season, when root reserves were lowest.[206] For the control of woody species, therefore, mowing applications should be timed to remove target species when carbohydrate reserves are the lowest in below-ground storage organs.

Plant species all respond to mowing differently, depending on their life histories. Also with fall mowing, Black Huckleberry and Scrub Oak typically display a reduction in overall percent cover, but not frequency.[207] Herbaceous species, however, such as jointweed (*Polygonella articulata*), rockrose (*Helianthemum* spp.), and pinweed (*Lechea* spp.) typically increase, with a significant increase in the prevalence of grasses.[208] The most marked increase has been illustrated by the low-lying cool season Pensylvania Sedge (*Carex pensylvanica*), which drastically increases in percent cover and frequency following mowing.

Frequency of mowing also becomes important when determining effects on plants and wildlife. Frequent mowing over time may remove more sensitive animal species from a site, whereas mowing one site twice during the growing season may allow a habitat a rest period and would cost significantly less. Mowing during the breeding season, although it may achieve desired

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Dunwiddie, P.W. 1994b. *Some thoughts on past and future vegetation monitoring at Katama.* Report to the attendees of the Katama Monitoring Meeting, white paper.

[204] In order to reduce duff accumulation, however, prescribed burning may be an effective tool, or more drastically, a mulching machine to break up duff and expose mineral soil (see Section 7).

[205] Several research and monitoring programs show that summer mowing can reduce woody growth. Monitoring at Wasque Reservation on Chappaquiddick supports this hypothesis. In addition, see Dunwiddie and Caljouw 1990. Dr. William Patterson's summer mowing plots at Truro showed a sharp reduction of shrubs.

[206] Our monitoring data shows that this is likely the case. Other unpublished research in Massachusetts may show similar conclusions. More mortality would occur because plants, on average, would have less energy available to resprout.

[207] This reflects a reduction in shrub density within a patch, although the patch survives through resprouting.

[208] Both in terms of frequency and percent cover. Others, however, did not see an increase in rockrose cover, showing how short-term studies may be misleading. McCartney 1988.

effects on the vegetation, may adversely affect animals. Monitoring prior to a breeding season mowing, however, would give site specific information about species that may be impacted. If the ecological costs to these animals outweighs the ecological benefits, a mow should be postponed to a less sensitive time. Allowing mowed units to recover following a treatment may allow some plants and animals to return to the unit, to increase in numbers, or to regrow through seeds or sprouts. For this reason, some species that may have been reduced by mowing[209] may actually still recover or benefit over the long-term.[210] The frequency and timing of mowing applications can therefore be tailored to create a desired community composition.

6.5 The Benefits of Mechanical Mowing

Mowing is simple, efficient, requires minimal labor, is highly effective at targeting many forms of woody growth, and is a relatively flexible tool in that it can be performed at anytime during the day, during any season, and under a wide range of weather conditions. Mechanical mowing has been used on Martha's Vineyard to target Pitch Pine growth of up to five feet high and up to 3.5 inches in diameter. Oak sprouts taller than three feet in height are typically difficult to mow. However, mowers may be used to target "problem" areas, irrelevant of their size, and are typically able to maneuver around obstacles such as trees, houses, and other structures. The size of the mower will typically determine its ability at maneuvering around obstacles and between management units.

Mechanical mowing can also be a very inexpensive tool for habitat management that has many logistical benefits associated with it. For example, no regulatory framework is necessary for the use of mowing, such as the permits that are typically required for prescribed burning or the use of herbicides.[211] In addition, a single staff member will typically suffice to perform most mowing operations, and may be hired and easily trained to operate machinery.

6.6 The Costs of Mechanical Mowing

The costs of mechanical mowing depend on several factors. Contracting may be the most cost-effective for short-term applications, while long-term projects may require the purchase of a tractor and mower.[212] In this case, initial costs are typically the greatest, as equipment is purchased, staff members are hired, and the necessary preparations made. In restoring open communities, initial management is also typically the most intense. The need for frequent mowing generally declines as carbohydrate reserves of target species are depleted and as management goals are met.

Routine maintenance costs are necessary, and involve, to name a few, the purchase of grease, fuel, hydraulic oil, and other fluids. Non-routine maintenance costs will depend upon several factors, including the frequency and duration of equipment use. The presence of stones and other such obstacles will also reflect the need for mower maintenance and repair. The potential for unexpected equipment failure and emergency repair is a possibility, and the potential for such a situation must not be neglected. Labor costs will also typically increase as vegetation density, diameter, height, and vegetation rigidity increases. In general, summer mowing of hardwoods may require daily sharpening of mower blades. The use of dull blades while cutting such material may cause the vegetation to tangle around mower blades, potentially damage equipment, and decrease mowing effectiveness. Mower blade sharpness becomes less important in the fall

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[209] Lichens and Golden Heather, for example.
[210] Through our monitoring data, older plants had all died, but new seedlings of Golden Heather were apparent the year after a mowing treatment.
[211] Unless mowing occurs within regulated areas such as wetland buffer zones, for example.
[212] The N.R.C.S. budgets $45 per acre for the cost of mowing on Martha's Vineyard.

and winter when plant material is generally more brittle and will break from the point of contact.[213]

Mowing is only possible in areas relatively free from obstacles and hazards—such as stones, stumps, snags, and ditches. Removing such obstacles to allow for mowing may also be very cost prohibitive. Due to their geological histories, however, many sand barrens in the Northeast are relatively flat and generally free from rocks, facilitating management through mowing.

In addition to financial and logistical costs, mechanical mowing may exhibit ecological costs as well. Mowing creates a uniform habitat structure, may require repeated applications to be effective, may reduce the cover of certain species, and increases litter within the mowed area.[214] Through the accumulation of litter, mowing may also shade individual plants from the sun and inhibit the proper conditions necessary for successful seed germination. The tractor and mower may require numerous passes over a single area and may harm rare or uncommon species.[215] Exotic seed introduction should also be a significant concern when operating a mower that is used on multiple sites. Care must be taken in ecologically sensitive areas as mowing equipment can destroy microhabitats that support rare plant species, vertebrates and invertebrates, fungi, and lichens.[216] Mowing patterns and timing of the mowing may mitigate ecological costs, however. For example, mowing from the inside of a unit towards the periphery, will avoid herding small mammals into the center of the unit, where they may be more at risk from mowing operations. See Section 9 for risk assessment and target species.

6.7 Conclusions

Mechanical mowing is a relatively flexible tool, and can essentially be performed anytime throughout the year. As in any habitat management tool, initial costs are high. In general, however, mowing costs are low. Mowing may increase duff build-up, crush sensitive species, and may reduce species diversity in some cases. Contrarily, mowing may also reduce invasive species and can be highly specific in terms of timing, frequency, and avoiding or targeting specific areas. Care must be taken, however, to consider all impacts on sensitive vegetation, rare species, and other wildlife.

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[213] Due to the pliable nature of growing plants, especially oak resprouts, growing season mows often require several passes, beginning with the mowing deck fully raised, followed by a lowered deck for each subsequent mow. Although labor costs are greater with this technique, expensive damages to the mower and equipment may be avoided.

[214] Removing biomass is possible, but often cost prohibitive.

[215] McCartney 1988.

[216] Our monitoring efforts on Martha's Vineyard have shown a decline in percent cover of lichen species due to mowing and burning.

Section 7: Clearing as a Restoration Tool

7.1 Introduction

In many sand barrens of the northeastern United States, areas that were historically cultivated were also likely affected by other practices—such as clearing, burning, mowing, or grazing—and tended to exhibit more structurally open conditions than we see today. One method to recreate these historically open habitats—and set a foundation for the use of other management tools—is clearing.

Several methods exist for clearing land, each with their own respective advantages and disadvantages. This section focuses less on the use of clearing as a maintenance tool, but rather, centers on its use as a restoration tool.

7.2 Clearing History

For thousands of years, humans have cut trees, cleared land, and created open landscapes to suit various needs. Open landscapes have been useful for grazing, farming, hunting, the establishment of settlements, and creating easier routes for travel. Trees have also been planted, raised, and harvested specifically for subsistence and marketing.

In New England, clearing practices have a long history, beginning with native cultures, which cleared not only for wood, but also for agricultural uses and creating foraging areas for deer. Native Americans also used girdling—the process of killing a tree by cutting its bark. The Native Americans in the northeast United States commonly used fire in combination with clearing or girdling to maintain open land for hunting, travel, farming, or settlement.[217]

Early European settlers on Martha's Vineyard used wood for fuel, fences, houses, and shipbuilding; the cleared land was used for agriculture and grazing.[218] As early as the 1700s, land-use practices were so intense in some towns that woodlands could not produce all the necessary wood products. As a result, Edgartown imported firewood.[219]

Landscape-scale, intensive land-use practices in New England continued until the nineteenth century, when the Industrial Revolution, westward expansion, and other factors led to farm abandonments. Agricultural practices of woodcutting, burning fields and forests, mowing, and grazing slowly decreased. Later, fire suppression and housing developments began to affect many areas. Early successional barrens habitats soon matured into woodlands and forests. Restoration of these open-canopied systems has become necessary to create functional early successional sand barrens landscapes.

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[217] This technique was effective in that it prohibited trees from producing leaves and consequently from photosynthesizing. The natives would also burn piles of logs around the trunks of trees to remove the bark, also causing the trees to die standing.

[218] Dunwiddie, P.W. 1994a. *Martha's Vineyard Landscapes: The Nature of Change*. The Vineyard Conservation Society. 60 pp.; Raleigh 2000a; Capece 2001.

[219] Freeman, James. 1807. A Description of Dukes County. Pages 1-51 *in* The Dukes County Intelligencer, Edgartown, MA: The Dukes County Historical Society. (12) 4; Dunwiddie, P.W. 1994a.

7.3 Clearing Options

For effective restoration, clearing is commonly combined with other management tools, such as prescribed fire, mowing, or herbicide use; and may be considered a first step in sandplain habitat restoration. In some cases, safe prescribed burning would not be possible without prior reduction of fuel build-up through brush cutting, tree felling, or grazing. In other cases, clearing can increase the available fuel for burning, through leaving shrub slash or girdled trees. Managers may use this option in areas with low fuel build-up.

A number of forms of clearing practices may be considered for habitat restoration. Several factors, however, must be accounted for in order to determine the method to be used. The method chosen, as well as the equipment used, depends on the objectives of the project, the expense that can be put into the operation, and the benefits that may be expected. The following sections (7.3.1, 7.3.2, 7.3.3) outline the most common land clearing options available for managers today.

7.3.1 Contractor with Heavy Machinery

The initial costs of equipment and machinery—along with the subsequent maintenance and repair costs—often exclude many agencies and organizations from purchasing heavy machinery. At an estimated minimum cost of $50,000 for a machine,[220] the purchase of such equipment is generally not practical for small to medium-scale land clearing, but may be rather worthwhile for large-scale restoration. Contracting out restoration projects that require heavy machinery may prove to be a cost-effective means to achieve habitat management objectives and goals.

Although a majority of the land clearing equipment available for contract is typically used for large-scale logging projects or for development, they can be quite useful for habitat reclamation. However, many machines used for land clearing will share certain costs and benefits to the project at hand. For example, of the machines listed below, all can be operated any time of year and under a range of weather conditions and are able to break up the duff layer and expose bare mineral soil. Conversely, these machines may also excessively scarify the soil—especially machines that mobilize on tracks.[221] Table 7.1 below outlines the most common forms of machinery used for land clearing along with the associated costs and benefits of using each. In addition, the experience and skill levels of operators vary, which will affect costs, efficiency, and the quality of the work. For this reason, the availability of skilled labor is an important factor in the choice of a clearing method and its subsequent success.[222]

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[220] See http://www.goces.com for one example.

[221] In order to minimize potential damage to a site, machinery may be used when the ground is frozen or has enough snow cover to prevent excessive damage.

[222] http://www.fao.org/docrep/x5378e/x5378e05.htm

Table 7.1: *The benefits and costs of using heavy equipment for sand barrens habitat restoration.*

Machine	Description	Rate	Benefits	Costs
Feller Buncher[223]   	A feller buncher is a machine designed to fell standing trees and arrange them in bunches on the ground. Although taking on many different forms, the typical feller buncher has an articulating arm with a felling head attached. The felling head can be in the form of a disk saw or chainsaw. The machine is also equipped with hydraulic fixtures that will hold the tree to allow the felling head to sever the tree from the stump. The machine can then lower the tree to the ground or onto a pile of logs.[224]	Able to fell and bunch 500-700 trees (approximately 3-5 acres, depending on density) in an 8-hour period.[225]	• Trees may be removed from a site to reduce biomass accumulation. • With models equipped with limbing knives, trees can be delimbed at a rate up to 14.8 feet per second.[226] • Can manage rocky ground moderately well if undercarriage is higher than rocks or other obstructions.[227] • Operator can practice selective cutting.	• May require additional resources for removing biomass. • In order to prevent resprouting, additional resources may be required to apply herbicides, remove, or grind stumps. • If biomass is not removed, wood products can stifle herbaceous and other plant growth. • May not saw or sever trees low enough to be flush with ground, possibly making mowing infeasible as a future management option for that site.

[223] Top photograph: http://www.cnr.vt.edu/dendro/forsite/ jedfellerbunchers.htm; middle photograph: http://www.tigercat.com/pr-822.htm; bottom photograph: the cutting disc of a feller buncher, http://www.tigercat.com/pr-822.htm.

[224] A feller buncher was used in the Manuel F. Correllus State Forest on Martha's Vineyard at a cost of $150 per hour. Work rates were dependent upon tree density (2 acres per day for thinning the canopy and 1 acre per day for clearing thick Pitch Pine stands); John Varkonda, personal communication.

[225] http://www.xyz.net/~rls/forest/clear1.htm

[226] http://www.timberjack.com/downloads/pdf/harvesters/608B-Brochure.pdf

[227] http://www.unb.ca/web/standint/3703/ccarson.htm

Machine	Description	Rate	Benefits	Costs
Hydro Ax[228]  	The Hydro Ax is one specific form—and brand name—of feller buncher machinery. The machine is sold in five models—including a three-wheel tractor—and may be used with a variety of shear and saw attachments. The Hydro-Ax is able to remove trees using hydraulic shears. These machines can reach up to 15 feet high and can grind the lower portion of the bole to a 6-inch stump.[229]	Able to fell up to 10 acres in one day.[230]	• Operator can practice selective cutting. • Tractors outfitted with rubber tires may reduce excessive ground scarification • Trees may be removed from site to reduce biomass accumulation. • When fitted with a 22-inch saw head, the Hydro-Ax is able to cut a 20-inch diameter hardwood in little time.[231]	• May require additional resources for removing biomass. • In order to prevent resprouting, additional resources may be required to apply herbicides, remove, or grind stumps. • If biomass is not removed, wood products can stifle herbaceous and other plant growth.

[228] Top photograph: http://www.suttleequipment.com/hydroax.html; bottom photograph of hydraulic sheers, http://www.b4ubuild.com/photos/deckhouse/images/clearing/feller_buncher2.jpg.
[229] http://www.fs.fed.us/fmsc/sdu/vegmgt/upsouthplatte/index.php.
[230] http://www.fs.fed.us/r2/nfp/Article.PDF.
[231] http://www.blueoxtimber.com/equipment.htm

Machine	Description	Rate	Benefits	Costs
Articulating arm mulcher[232]  	These mobile mulching machines move on tracks and are outfitted with an articulated arm and grinding drum. The Brontosaurus is one specific brand, and is available in five models. The cutting range of mower head spans between 24-inches and 48-inches.[233] The teeth on the drum spin at 1,500 revolutions per minute, and are able to mulch a softwood tree in seconds.[234]	Able to clear 3-8 acres per day.[235]	• Operator can practice selective cutting. • Timber not left behind. • Able to mulch trees up to 40 feet tall. • Has been used with success on various land reclamation projects in the northeast. [236]	• To prevent resprouting, additional resources may be required to apply herbicides, remove, or grind stumps. • Mulch left behind adds biomass to duff layer. • May be unable to mulch Scrub Oak (due to its gnarled shape) • Relatively low maneuverability in tight spaces.

[232] Top and bottom photographs from: http://www.ouellettelookconstruction.com/page2.htm
[233] http://www.brownbronto.com/products_bronto2.htm
[234] http://www.capecodonline.com/cctimes/archives/2000/feb/10/apasture10.htm.
[235] http://www.ouellettelookconstruction.com
[236] A grinding flail was used in the Manuel F. Correllus State Forest on Martha's Vineyard for shrub type areas at a cost of $200 per hour. The machine cleared 3-5 acres per day in thick brush. John Varkonda, personal communication.

Machine	Description	Rate	Benefits	Costs
Mulching mower[237]    	Several brand names of mulching mowers and mulching decks exist on the market today. Some of the more popular versions are the Rayco and Gyro-trac[238] machines. Both machines are capable of mulching standing timber. The forward rotation of the cutting tools distributes the processed material downward while the push bar directs the fallen trees in front of the mower to be mulched.[239]	The Rayco models are able to mulch standing timber up to 8-inches in diameter, with a mowing rate of 2.5 acres per hour on one pass.[240] Other models, such as the Seppi Forest Mower,[241] are able to chip and fell a standing tree up to 18 inches in diameter.	• Smaller tractors have greater maneuverability • Some tractors may be outfitted with other attachments, such as stump grinders. • Mulching decks may be quickly installed. • May be used to mulch timber and slash from other felling operations. • May also be used to create access to a site for other felling operations. • May be able to scarify duff layer and expose bare mineral soil.	• Mulch left behind will add biomass to duff layer. • Clearing performance may be relatively non-selective, depending upon technique.

[237] First photograph: http://www.raycomfg.com/Land_Clearing/land_clearing.html; second photograph: http://www.feedlotmagazine.com/issues/200007/shredder.html; third photograph, a silvicultural stand thinned with a seppi mower: http://www.forestryimages.org/browse/subimages.cfm?sub=3162; fourth photograph: a detailed view of the mulching teeth that grinds vegetation: http://www.gyrotrac.com/public/cont-ang/products-heads.html#

[238] The Gyro-trac is built with a fully hydrostatic transmission, allowing for lower maintenance and operational costs compared with mechanical transmission type vehicles. These machines also distribute the weight of the vehicle so that ground pressure is low (less than 1.6 p.s.i) creating little disturbance on soils result. .For more information, visit: http://www.gyrotrac.com/public/cont-ang/company.html.

[239] For more information, see: http://www.raycomfg.com/Land_Clearing/FM7260/fm7260.html

[240] Ken Skoczen, Sales Dept., Rayco Manufacturing Inc., personal communication. A second pass may be necessary to mulch further.

[241] Since 1939, Seppi Manufacturing has been a major manufacturer of industrial mulching mowers. For more information, see: http://www.seppi.com/new/EN/attivita.html.

Machine	Description	Rate	Benefits	Costs
Bulldozer[242]   	Properly outfitted, a bulldozer can be used for clearing practices such as blading or chaining (also referred to as cabling or grubbing.) Blading involves plowing trees over using a single large blade. Cabling involves dragging large chains or cables between two machines running parallel to each other to sever or unearth entire trees. Cabling is often done in two directions: on the first pass, trees are bent over in the direction of travel, while on the return trip the trees are uprooted.[243] These methods remove entire trees; and were used for clearing practices on Nantucket sandplain habitats in the 1920s.[244] Due to the relatively damaging effects of this method to an ecosystem, it is rarely used in habitat restoration today.	Able to clear 3-4 acres per day in dense stands.[245] However, since these methods involve uprooting whole trees, approximate rates can vary greatly depending upon several variables, including: site conditions, technique, timing of clearing operation, size of machine, age class and type of vegetation.	• Clears large stands of small diameter trees in little time. • With roots removed, resprouts will not result. • Exposes bare mineral soil.[246]	• Removing trees and other debris may be labor intensive and require the use of additional heavy machinery and skilled operators. • Large pits are created as a result of unearthed root systems. • Highest site-disturbance of the clearing options described above. • Tree felling is relatively non-selective. • Machines may be unable to unearth trees with large root systems. • High diameter trees and dense stands may prohibit efficiency and success. • May excessively expose bare mineral soil.

[242] Top photograph: http://www.continentalgroup.org/construction_equipment/ buldozer.htm; middle photograph: http://www.qccqld.org.au/ Landclearing.htm; bottom photograph of dozer pushing tree: http://www.fao.org/docrep/x5380e/ x5380e04.htm.

[243] According to www.ia.nrcs.usda.gov/fotg/section4/pstands/460std.pdf , chaining is most effective on large trees in loose, shallow, or moist soils where trees are easily uprooted, or in stands.

[244] VanLuven, D.E. 1994b. *Site Conservation Plan for the Concord Pine Barrens: Concord, New Hampshire*, submitted to the U.S. Fish and Wildlife Service, white paper. P. C-2.

[245] http://www.feedlotmagazine.com/issues/200007/shredder.html

[246] It is important to note that the effects of exposing bare mineral soil through this method are not well known, and may not actually benefit an ecosystem under certain circumstances.

7.3.2 Manual Clearing Using Chainsaws and Chipper

The use of chainsaws and other handheld clearing equipment may be the most worthwhile for smaller-scale land clearing projects. Although much more time consuming, the job is often done more effectively and more economically than heavy machinery—with minimal environmental harm. In addition, the use of chainsaws is effective in clearing or thinning in remote areas, ecologically sensitive areas, and areas where topography will not accommodate large machinery. Biomass may also be fully removed from a site through chipping any timber and slash, and transporting the chips elsewhere. The chips may be sold to the public, garden centers, or landscape companies to offset clearing costs. Depending upon the model and type of chipper, chip size may be tailored to fit consumer needs; see Figure 7.1 for example.[247] To further offset operational costs, oak logs may be spared from chipping and sold as firewood.

Figure 7.1: *For some machines, chip size can be regulated between ¼ and 1 inch landscape chips.*

Time is often the foremost limiting factor for choosing the use of heavy equipment over the use of chainsaws for completing smaller-scale projects. For The Trustees of Reservations on Martha's Vineyard, in-house costs have approximated $1,700 per acre, including: labor, maintenance, cost of fuel, and repairs, but not including the purchase, registration, and insurance of clearing equipment. Volunteer hours, however, have reduced this estimate from $2,600 with chipper costs not depreciated.[248] Hiring a Student Conservation Association crew reduced costs to $1,400 per acre.[249] We anticipate that these costs can be further reduced in the future.

7.3.3 Girdling

Girdling is perhaps the most primitive method of killing trees. This method involves cutting a groove in the bark of a tree, which inhibits the flow of water, nutrients, and carbohydrates between the roots and the crown of a tree. Depending upon tree species and soil type, twigs and branches may fall from girdled trees as early as three to four years, while the trunks may remain upright for up to nine years.[250] See Figure 7.2 for three methods that can be used effectively to girdle trees.[251] Using these methods, the groove must completely encircle

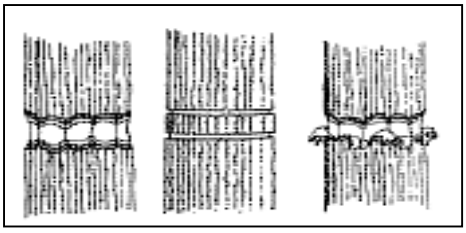

Figure 7.2: *Three techniques for girdling trees. From the left: (1) using a girdling tool; (2) using a chainsaw; (3) using an ax or hatchet.*

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[247] http://www.valbysales.com/newpage4.htm. The photograph from figure 7.1 was also excerpted from this site.

[248] Several methods exist for hand clearing which can drastically alter actual costs. These methods include hiring staff in-house, contracting a clearing specialist, or contracting a crew through the Student Conservation Association (SCA).

[249] The Trustees of Reservations are currently experimenting with the SCA program and are finding it a satisfactory balance between practicality, cost-effectiveness, and minimization of on-site damage resulting from clearing efforts. For more information, visit the SCA website at http://www.thesca.org. The cost per acre includes all costs: training, housing on Martha's Vineyard, equipment, etc. The crew was not experienced using chainsaws, therefore training costs could be reduced by hiring a SCA crew with chain saw experience. This would make the work more efficient as well.

[250] Whitney 1994, p. 133.

[251] Excerpted from: http://ohioline.osu.edu/for-fact/0045.html.

the trunk and penetrate at least ½ inch. The width of the notch will vary upon the size of the tree. A gap one inch in width will suffice for small diameter trees, but larger diameter trees might need a gap width of up to 8 inches.[252]

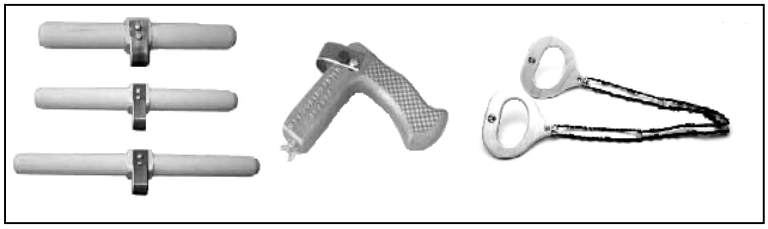

Figure 7.3: *The girdling tools to the left are inexpensive but must be purchased according to the diameter of the tree. The girdling tool in the middle is more expensive, but may be adjusted according to diameter. The girdling tool to the right uses chains and is designed for trees with thicker bark.*

Girdling is a fast, inexpensive method to induce tree mortality and drastically reduce canopy cover. Aside from the initial purchase of tool—which may range from $25 for the cost of a hatchet to $150 for the cost of an industrial grade girdling tool[253]—the costs associated with a girdling project will be based chiefly on labor. The amount of labor required to perform a girdling project, however, will depend upon several factors, including site location and accessibility, stem density, stem circumference, and the type of tool used. See Figure 7.3 to view a few different types of girdling tools.

Through girdling, sunlight will be able to reach the forest understory within a matter of days. Such open canopied systems are essential in sandplain habitats in order to support understory vegetation. In addition to providing suitable conditions for understory vegetation, girdling also allows for dead standing trees that provide important habitat for insect, mammal, and bird species.[254]

Although the use of girdling may present a strong case, it may not be practical in every circumstance. The main setback to the use of girdling as a management tool is the presence of the dead standing trees and downed slash. Although girdling may be a useful tool to modify habitat to support various wildlife species, above ground biomass is not removed from the process, and downed slash may pose risks of fire.

7.3.4 Discussion

Many methods exist that can be used to clear land. Each method, however, has its associated costs and benefits. Several fundamental questions should be answered in order to determine the best strategy to achieve management objectives:

1. What are the management objectives and what are the desired future conditions?
2. Is it even possible to alter the present conditions to suit management objectives and needs?
3. How will plant and animal species respond to clearing operations (see Section 9.8)?
4. What degree of clearing should be made to attain objectives?
5. Is clearing supplementary or complimentary to other tools that may be used?
6. What equipment, labor, time, and money are available for the clearing operation? How much is needed?

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[252] http://ohioline.osu.edu/for-fact/0045.html

[253] http://www.forestry-suppliers.com/product_pages/view_Catalog_Page.asp?id=1886

[254] Gary Haase, Kitty Todd Nature Preserve Manager, The Nature Conservancy, Ohio, personal communication. The Nature Conservancy has been using girdling in the Kitty Todd Nature Preserve in Ohio, and found that redheaded woodpeckers and bluebirds use the dead standing trees for nesting.

Of the clearing methods discussed in the previous sections, few may be practical for small- to medium-scale operations due to high initial costs and potential environmental damage to smaller scale ecosystems. Collaborating with other groups may offset some of these financial costs; however, the potential for irreparable environmental damage caused by some machines may pose a risk too great to be used for smaller scale projects. Girdling and manual clearing may be the most environmentally sound, and possibly the most selective methods to achieve habitat management objectives at a small scale. To achieve larger habitat management goals (clearing 50 acres in one year for example), other methods may be more realistic.

In general, clearing is a management tool to control overstory composition and structure and to restore habitats that are more open. For example, certain trees may be left to remain on-site to create a savanna or an oak opening habitat. Clearing the overstory in a woodland or forest will allow more light to penetrate to the understory, changing plant growth and composition. Other management tools may then be needed to achieve specific habitat management objectives—such as using fire to remove downed brush, or using mowing to mulch the brush. Selecting a clearing site based on land-use history and its configuration within other habitats may help to achieve these management objectives. See Sections 9.1 through 9.5 for the importance of land-use based restoration projects.

Using heavy machinery to restore habitat may achieve quick results, and may severely affect a site. Long-term costs to an ecosystem, however, are likely to be offset if a well-though out and reliable plan is properly followed and executed. In sand barrens, disturbances caused by some machines may actually accelerate restoration through breaking up duff and exposing patches of mineral soil, depending on the initial habitat structure and composition. Over the long-term, these disturbed soils and structurally open landscapes will allow for the colonization of plant and animal species. Although the actual outcome of species colonization may be difficult to predict, it will be heavily influenced by the plant, tree, and animal species inhabiting the surrounding environment and the seed bank at the site.

Tree sprouting from roots or stumps will strongly influence community structure and will lead to increased restoration costs if resprouting trees are not a desired outcome for a management unit. Sprout vigor can be modified by the timing and method of cutting. Sprouting is inhibited by spring or summer cutting and enhanced by winter cutting, presumably, because carbohydrate storage in root systems are greatest in winter and least in spring and summer. The ability of most trees to sprout, however, decreases with age. Useful methods to effectively control resprouting may involve the use of herbicides and is discussed in Section 8.

7.4 Conclusions

Although there are many ways to clear a landscape, the appropriate method or combination of methods must be considered cautiously. The selection of the appropriate clearing method must address the scale of the work as well as all financial and time constraints. Clearing is an intense disturbance and has a tremendous effect on habitat structure. Several factors—such as timing, season, target species, and adjacent habitats—may determine the success of a land-clearing project. Combining clearing with other management tools, however, may greatly facilitate the success in achieving specific habitat management objectives.

Section 8: The Use of Herbicides

8.1 Introduction

Herbicides are a sand barrens habitat management tool that can be used to control invasive species—either for succession management or for invasive exotic species control. The successful and safe use of herbicides as a sand barrens management tool depends on many factors including herbicide toxicity, herbicide selectivity, applicator training, the biology of the target plants and non-target plants, weather conditions, and its use in combination with other habitat management tools. The costs and benefits of herbicides and their application must also be considered carefully and weighed against other options. The following guiding principles should be taken into account when reading this section: 1) considering a full suite of options for controlling target species, 2) using the least toxic, most species specific herbicide, 3) using the most specific application technique possible, 4) applying herbicides at the time of maximum effectiveness, taking into account weather conditions and the target species' biology, 5) considering the long-term effect of herbicides on habitats and successional patterns, 6) using extreme care and judgement around wetland areas, 7) ensuring all local, state, and national laws and guidelines are followed, and 8) ensuring safety of the applicator, other humans, and the natural environment.

8.2 Herbicide Toxicity

Within the past ten years, the use of chemical vegetation control has progressed to formulate new compounds that are more effective and more environmentally sensitive.[255] Although many herbicides are effective at killing plants and plant parts, there is a general misperception that these chemicals are also highly toxic to humans, wildlife, and non-target plants; this is not always the case, however. Some herbicides are able to function on biochemical pathways that are specific to plants and not animals.[256] Table 8.1 lists the relative toxicity of some commonly used herbicides using the LD50 rating system for chemical toxicity.[257] As the table illustrates, caffeine produces a higher acute toxicity level in lab animals than any of the most commonly used herbicides.[258] Lab studies have shown that 95% of ingested glyphosate is eliminated from the body of test animals within 5 days, 93% of hexazinone is eliminated in 24 hours, and 93% of 2,4-D is eliminated within 2 hours.[259] Although these chemicals are considered non-toxic to lab animals, the potential to be toxic to wildlife still exists.

Greater research is ultimately required on herbicides to determine the harmful effects on wildlife under all methods of application. It has been argued that under widespread applications, certain

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[255] http://www.aces.edu/ department/extcomm/publications/anr/anr-846/anr-846.html

[256] Chemicals must be applied only according to the uses listed on the label. All manufacturers recommendations, precautions and directions must be followed. Most over-the-counter products require dilution with water. Toxicity of the chemical may be increased—or decreased—substantially if the product instructions are not followed carefully.

[257] According to the Canadian Centre for Occupational Health and Safety (http://www.ccohs.ca/oshanswers/chemicals/LD50.html), LD stands for "Lethal Dose." LD50 is the amount of a material, given all at once, which causes the death of 50% of a group of test animals. The LD50 is one way to measure the short-term poisoning potential (acute toxicity) of a material and is expressed as milligrams (mg) of chemical per kilogram (kg) of body weight.

[258] This table excerpted from http://www.aces.edu/department/extcomm/publications/anr/anr-846/anr-846.html.Of the products listed, none are considered toxic when label instructions are properly followed. Some of the products, however, may be toxic to lab animals under extraordinarily high doses. For example, an animal would be required to eat near its own body weight or more in treated foliage of Krenite® UT in a given amount of time for any adverse effects to result. For more information contact: DuPont Company, Vegetation Management, WM4-134, Wilmington, DE 19880-0038.

[259] http://www.aces.edu/department/extcomm/publications/anr/anr-846/anr-846.html.

chemicals, such as glyphosate, may have adverse consequences for non-target, beneficial species and biodiversity.[260] In order to avoid affecting non-target species, the most selective method of herbicide application possible should be used. See table 8.2 for common methods.

Table 8.1: *The Relative Acute Toxicity of Commonly Used Silvicultural Herbicides.*

Trade Name	**Active Ingredient**	**LD50[261] of the Active Ingredient mg/kg**
Arsenal	imazypyr	5,000
Garlon	triclopyr	630
Oust	sulfometuron methyl	5,000
Roundup	glyphosate	4,320
Tordon	picloram	8,200
Velpar	hexazinone	1,690
Weedone	2,4-D	375
For Comparison:	Table Salt	3,750
	Aspirin	1,700
	Malathion (insecticide)	370
	Caffeine	200

8.3 Herbicide Selectivity

In determining the risks associated with the use of herbicides as a habitat management tool, three major questions exist: First, how selective is the herbicide? Second, how selective is the method of herbicide application? Finally, what are the potential responses of target and non-target species to herbicide application?[262] Applicator training by state regulators and professional organizations has assisted in ensuring that herbicides are applied safely and in more environmentally-selective ways. Nevertheless, the potential for run-off, vapor drift, and other non-target damage should always be considered.[263] Various methods exist, however, to minimize or prevent non-target damage from occurring, especially to rare and other desired species.[264] Non-target damage can be avoided by using as specific an application technique as possible. Table 8.2 lists a variety of herbicide application methods that can be used to control woody plant species. They are ranked from the least selective method (1) to the most selective method (16).[265] See Figure 8.1 for three examples of selective herbicide application methods.[266]

Table 8.2: *An ordering of herbicide application techniques ranging from general to specific.*

1	Broadcast foliar application by aircraft	9	Basal bark spraying
2	Broadcast soil application by aircraft	10	Basal bark painting
3	Broadcast foliar application by truck or tractor	11	Rope or wick application

[260] http://panna.igc.org/resources/panups/panup_19991027.dv.html. One author reports that glyphosate may pose a significant risk to various predatory mites and parasitoids.
[261] Because LD50 is expressed as mg of chemical per kg of body weight, the lower the number displayed here, the higher the acute toxicity actually is.
[262] Luken 1990.
[263] Vapor drift occrs when the herbicide re-vaporizes from the target plant, irrespective of the application technique, and causes damage outside of the treated area. Cooke, Arnie. 1993. The use of herbicides. *Enact: managing land for wildlife*. (1) 2.
[264] In addition to the herbicide application technique, the potential for non-point toxicity can further be minimized through the addition of a surfactant to the herbicide. Surfactants are liquids that increase the surface tension of the herbicide, subsequently decreasing runoff from plant surfaces.
[265] Table excerpted from Luken 1990, p. 75.
[266] Images excerpted from http://pested.unl.edu/catmans/row.skp/rowch07.htm.

4	Broadcast soil application by truck or tractor
5	Foliar application by hand sprayer
6	Broadcast bark or stem spraying
7	Stump spraying
8	Stump painting

12	Bark frill and spray
13	Bark frill and paint
14	Bark notch and spray
15	Bark notch and paint
16	Notch and inject

In addition to the method of herbicide application, the effectiveness of any application will depend on the type of herbicide used. Many herbicides have been formulated to target weed species for agricultural purposes, but may also be used for habitat management. Table 8.3 provides the common names, trade names, and manufacturers for most herbicides used in succession management.[267]

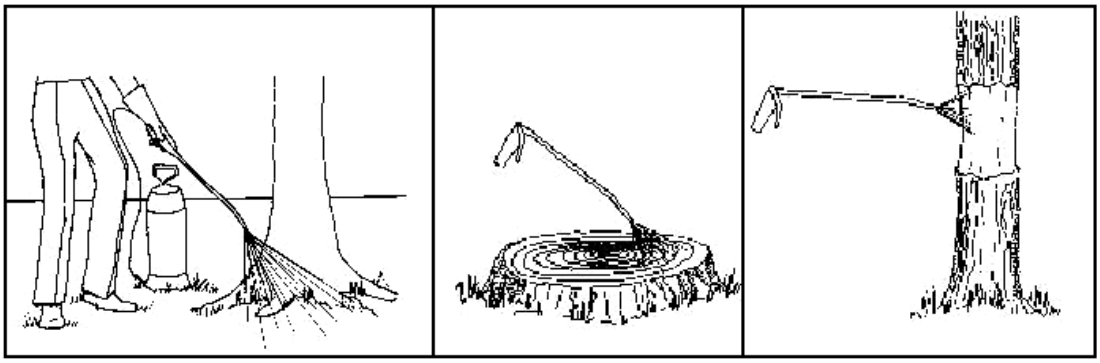

Figure 8.1*: From left: basal bark spraying, stump spraying, and bark frill and spray.*

Table 8.3: *Common herbicides used frequently in succession management.*

Common name	**Trade name**	**Manufacturer**
Ammonium sulphamate	Ammate X-NI	Dupont
Asulam	Asulox	May and Baker
Bromacil	Hyvar X	Dupont
Dicambra	Banvel CST	Velsicol
Dichlorprop	Weedone	Dupont
Glyphosate	Roundup	Monsanto
Hexazinone	Velpar L	Dupont
Krenite	Krenite-S	Dupont
Monuron	Telvar	Dupont
Picloram	Tordon	Dow
Tebuthiuron	Spike	Elanco
2,4-D	2,4-D	many
2,4,5-T	2,4,5-T	many
2,4-D + picloram	Tordon RTU	Dow
Triclopyr	Garlon 3A	Dow

[267] Table excerpted from Luken 1990, page 76.

A degree of variability exists in plant response to different herbicides and application methods. For example, when cut, some trees and shrubs will sprout from the stump, the roots, or both. For trees and shrubs that sprout only from the stump, a phenoxy-based herbicide may be the most effective.[268] Picloram or glyphosate has been recommended for killing entire root systems and can be used to kill invasive trees or exotic species.[269] The time of herbicide application can also have a marked effect on the success of a project. Although one particular herbicide may be effective during one season, it may be entirely ineffective in another.[270] As a general rule-of-thumb, higher mortality is often achieved if herbicides are applied at the time of maximum physiological activity.[271]

8.4 Limitations of Herbicide Use

The use of herbicides must be considered carefully, taking into account the life cycle, growth pattern, and physical characteristics of target plant species. Moreover, the density of target species is important and may severely limit the selectivity of the application method. The success of herbicide use is also limited by weather conditions; the application parameters of over-the-counter herbicides are typically provided on the product labels.[272] For example, under high humidity or strong winds, herbicides may not adhere to the plant and cause non-target toxicity.

8.5 The Use of Herbicides in Succession Management and Invasive Species Control

Herbicides can play a strong role in targeting individual plant species and developing a specific plant community pathway. For this reason, herbicides are useful in controlling invasive exotic species and in succession management. On Martha's Vineyard, for example, application of herbicides has been used to restore heathlands and grasslands that have been invaded by trees. Manual clearing followed by immediate stump application of glyphosate to prevent sprouting has achieved a success rate that approaches 100 percent.[273] By preventing the sprouting from occurring, the costs of future management were significantly reduced. As another example, in the Florida sandhills, herbicides have been used to reduce encroaching hardwoods in Longleaf Pine-Turkey Oak communities.[274] Herbicides have also been used to control invasive exotic species in barrens communities.[275] In the Albany Pine Bush, for example, herbicides are used to control Black Locust, which has invaded 400 acres of habitat. Although invasive plants may not be a significant problem at barrens sites, the potential threat may be high; control of these species before they become a problem may be a more cost-effective and prudent option.

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[268] http://spectre.ag.uiuc.edu/archives/phc/1998/2360.html.

[269] Caution must be taken in the use of these herbicides. For trees that have prolific root suckers, clonal connections will be exposed to the toxins and kill trees that were not directly applied with the herbicide. The use of phenoxy herbicides, which are unable to translocate as well as picloram or glyphosate, will minimize the risk on non-target standing trees.

[270] This is based on herbicides that function on inhibiting the biochemical pathways that occur during such processes as photosynthesis. Herbicides will be ineffective if applied in the season, that these processes do not take place.

[271] Luken 1990.

[272] Some forms of Roundup®, for example, are only effective when applied at least six hours before precipitation is expected. Most manufacturers also specify minimum and maximum temperature scales, providing optimal results when applied within a specified range. Low wind speed is also recommended.

[273] According to current monitoring data on Martha's Vineyard. Since many woody plant species are able to regenerate above ground structures, root killing is the goal in most forms of succession management.

[274] Hexazinone was used and is more effective on soils with relatively high sand content, low pH values and low organic matter levels. For more information, see: http://www.wec.ufl.edu/research/range/lleafherb/hexazinone.html.

[275] As a resource, the Nature Conservancy provides a Weed Control Handbook that can be downloaded at http://tncweeds.ucdavis.edu/handbook.html.

8.6 The Costs of Using Herbicides

When considering the use of herbicides as a management tool, the financial costs are low when compared to the potential environmental and ecological costs. The financial costs associated with applying herbicides typically involve two factors: the purchase of the product and labor. A staff member who is certified to apply herbicides—or an outside individual who is contracted to do the work—may perform the actual labor. In order to weigh financial costs with ecological costs, a lengthy investigation should be completed that involves the type of herbicide to be used, its associated risks to wildlife and humans, its potential for non-point contamination, and costs of remediation if such an occasion was to arise. The costs of herbicide application should also be weighed with the costs of additional forms of management if the use of herbicides is ineffective. For example, if resprouts are not controlled with herbicides, frequent mowing or grazing treatments may be necessary to maintain a habitat in a desirable condition. This is costly and may not be ecologically beneficial.

8.7 Regulations and Licensing in Massachusetts[276]

In Massachusetts, the use of pesticides is regulated by the Massachusetts Department of Food and Agriculture. Under the Groundwater Protection Regulation, also known as the Public Drinking Water Regulation (333 CMR 12.00), the active ingredients of many pesticides are enforced as restricted use products.[277] Wellhead protection zones,[278] wetlands and their buffer areas, and other sensitive areas may be protected by local or state laws; these areas require a permit for herbicide application. In Massachusetts, a pesticide applicators license is needed for most publically-accessible lands.

8.8 Conclusions

Although the use of herbicides may serve as an effective short-term management tool, their use should not serve as a long-term solution. Habitats being restored to shrublands or heathlands, for example can be cleared followed by stump applications of an herbicide. This selective treatment of herbicides allows managers to avoid the use of excessive mowing or grazing treatments in the future to remove resprouting vegetation. For this reason, the benefits of chemical vegetation control may outweigh the costs when management goals call for reducing tree cover in open habitats.

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[276] The application of herbicides must adhere to local, state, and federal regulations, particularly to the standards set forth by the U.S. Environmental Protection Agency (EPA) and the U.S. Occupational Safety and Health Administration (OSHA), which require an applicators license to apply certain herbicides.

[277] For an up-to-date listing of all active ingredients restricted for use in Massachusetts, contact: The Commonwealth of Massachusetts, Department of Food and Agriculture, 100 Cambridge St., Room 2103, Boston, MA 02202.

[278] Massachusetts can provide a listing of towns with Zone II areas (wellhead protection zones) that are covered under these regulations. Areas that do not fall under Zone II may not be subject to these groundwater regulations (333 CMR 12.00).

Section 9: Management Summary and Application of the Framework to Martha's Vineyard Sand Barrens Habitats

9.1 Introduction

This section will tie together all previous sections to create a framework for sand barrens management on Martha's Vineyard. We will discuss the island's history of disturbances, including fire, grazing, mowing, and clearing. In doing so, we will present a prescription for how to restore threatened habitats on this island, and take a closer look at the effects of various treatments on common sand barrens species and rare species, the risks involved, and the regional ecological context of Martha's Vineyard. Because these disturbances were historically practiced frequently and intensively, they were driving forces in determining habitat structure and composition across the landscape.[279] Today, we use these disturbances as tools to restore and manage rare sand barrens habitats.

9.2 Fire History

Fire history on Martha's Vineyard involves a combination of many factors, including soils and human settlement patterns. When European settlers arrived, Martha's Vineyard had one of the highest densities of Native Americans—known as the Wampanoag—in New England.[280] These Wampanoag settlements were concentrated around the great ponds and periphery of the island, where access to marine resources and water sources was easier.[281] By contrast, the center of the island was largely unpopulated.[282] The Wampanoag burned for many reasons and likely started accidental fires as well.[283] Although conclusive evidence does not exist for when these burns took place, woods were likely burned most commonly in the fall "when the grasse is withered, and the leaves are dryed".[284] Most resources describe an annual fire frequency,[285] but this does not imply that the same sites were burned each year. Fire, combined with the clearing and cutting of forests, as well as agriculture, led many of the heavily settled areas to be composed of various combinations of early- to mid-successional habitats.[286] Farther away from settlements, the community composition undoubtedly changed, with forested areas in mesic or hydric sites and Scrub Oak-dominated habitats in the xeric Great Plains.[287] Forested areas also occurred throughout Native American settlements and were sources for forest products. Native Americans

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[279] Underlying these disturbances are factors such as soils, weather, and climate. These factors change over much longer time periods and form the foundation for the barrens habitats.

[280] Cook 1976. Cook's numbers show a density of 35 people per square mile compared with four in southeast Massachusetts and 50 on Nantucket. By comparison, other mainland areas in New England show low densities, ranging from 0.5 individuals in Maine to 10 in the Connecticut River Valley. The arrival of the colonists marked the end of the Woodland Period, when native tribes were more sedentary and agriculture-based. A more sedentary population would lead to a higher frequency of fires in proximity to native settlements. In: Patterson, and Sassaman, 1988.

[281] Ritchie 1969. See also: Banks, C. E. 1966. *The History of Martha's Vineyard, Vol. II*. Edgartown, MA: Dukes County Historical Society, p. 24.

[282] Foster and Motzkin 1999.

[283] Reasons for burning may include: facilitating travel, hunting, improving berry crops, and enriching agricultural soils.

[284] This implies that woodlands were grassy or savanna-like. A 1634 quote by William Wood, quoted by Byers (1946:19) in W. A. Patterson and K. E. Sassaman. 1988.

[285] Russell, E. W. B. 1983. Indian-set Fires in the Forests of the Northeastern United States. *Ecology*, 64(1), pp. 78-88.

[286] Raleigh 2000a. Capece 2001.

[287] Foster and Motzkin 1999. The Great Plains is the fireshed in the center of the outwash plain. Fire frequency was historically higher in the Great Plains firesheds due to the layout of the landscape.

also used burned woodlands for planting corn.[288] Because of this high level of land-use, fire frequencies on Martha's Vineyard were higher in pre-European settlement times than post-settlement.[289] After Europeans settled on Martha's Vineyard, fires continued at a high frequency, as the new settlers used many of the practices of the Native Americans, including burning. Consequently, many fires escaped from control and burned large areas. Some of these large, intense fires were documented and described in the *Vineyard Gazette:* fifteen recorded fires burned 40,000 acres between 1903 and 1968.[290] Most of these frequent fires occurred in the spring. More recently, however, fire regulations, fire suppression, and a lack of prescribed burning reduced the fire frequency and size considerably (See Section 4).

All evidence, therefore, points towards a fire regime with frequent fires throughout the historical and pre-historical periods, with more frequent fires likely around settlements around the ponds of the south shore and more intense, large-scale fires occurring within the fireshed of the Great Plains. This fire regime was a driving force in the persistence of rare sand barrens habitats and species.

9.3 Grazing History

Prior to European settlement, Martha's Vineyard was free from domesticated livestock. Livestock were first imported to the Island in 1653 in order to provide Vineyard colonists with wool for clothing, and the essential milk, meats, and cheeses for their diet.[291] Colonists soon realized that Martha's Vineyard held a number of advantages for raising livestock over the rest of New England. Not only did the landscape have areas of open habitats readily converted to pasture, but also sheep were safe from natural predators, Martha's Vineyard was free from wolves, coyote, and other large predators found elsewhere in the New World. This, in large part, made sheep grazing economical on Martha's Vineyard, as mainland sheep farms had to use considerable resources to stave off predators.[292]

Although many portions of Martha's Vineyard were open-canopied habitats by the time Europeans arrived, cattle and oxen were often used in combination with clearing efforts to further create open landscapes.[293] Once trees were cut down, agricultural fields were created using oxen to pull stumps out of the ground. In order to prevent these newly created landscapes from reverting to shrublands and woodlands, cattle were often released to graze on any resprouts that emerged from the fields. Throughout New England, a density of one cow per two acres of land

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[288] Bragdon, K. J. 1996. *Native People of Southern New England, 1500-1650*. Norman, Oklahoma: University of Oklahoma Press, 301 pp., Capece 2001. Evidence for woodlots exists at the Long Point Wildlife Refuge site. Raleigh 2000a.

[289] Stevens, A. 1996. *The Paleoecology of Coastal Sandplain Grasslands on Martha's Vineyard, Massachusetts*. Ph. D. Dissertation. Univ. of Massachusetts, Amherst. This contrasts with most other areas in the Northeast (see Section 4).

[290] *Vineyard Gazette*, folder on fires.

[291] Banks 1966, vol. I

[292] The cost of hiring shepherds and constructing fences became so prohibitive on the mainland that Boston and its surrounding towns were supplied with wool primarily from Martha's Vineyard, Nantucket, and the Elizabeth Islands. Interestingly, wolf attacks were so common in Massachusetts that residents considered building a wolf-proof fence across Cape Cod to create a livestock sanctuary on the outer Cape; see Whitney 1994.

[293] Open landscapes facilitated the establishment of agricultural fields, farmlands, and pastures for livestock. European agriculture on Martha's Vineyard began in these areas (e. g. Katama, around Tisbury Great Pond).

would suffice to eliminate most of the trees less than 6 inches in diameter.[294] Because of this technique, large tracts of open areas were pasture and farmland were rapidly created. Concurrently, while the early Vineyard settlers were creating fields and pastures throughout the south shore, Edgartown, Chilmark, and the rich soils surrounding the Mill Brook and Tiasquam River, an industry fueled by a demand for wool began emerging within the surrounding American colonies. As the Island's European population grew, the need for wool to clothe its inhabitants also grew. Although sheep were initially raised as a part of the self-sufficient farm economy on Martha's Vineyard,[295] a number of factors in the 1800s caused farmers to shift even more from crops to pasture, furthering the establishment of the island's sheep-raising efforts.[296] In 1846, a wool importation tariff was removed, which, combined with the Civil War, further westward settlement and railroad construction, and the beginnings of a tourism-based economy, led to farm abandonment and the end of the sheep industry by the turn of the 20th century.[297] After grazing ceased, Martha's Vineyard was home to thousands of acres of grasslands that undoubtedly supported many rare species of plants and animals. These plants and animals likely persisted in fallow lands, unimproved lands, and in less intensively managed pastures.

9.4 Mowing History

From the middle of the 17th century up to the early 1900s, hand scythes were used to mow grasses, or hay, on Martha's Vineyard. Hay provided forage and bedding for livestock, a material that was necessary for an animal's survival to endure the cold winter months. Providing livestock with sufficient fodder was an on-going and relentless task. The typical cow of the Vineyard colonial era would consume, on average, approximately two tons of hay or the product of one or two acres of meadow or mowing land.[298] Hayfields, or "thatch lots," were not only important to provide food and bedding for livestock, but were also necessary to provide roofing material for early colonial style log huts.

As populations of humans and animals grew, hayfields and meadows became all the more critical, and were often created by clearing land, burning, and grazing—all of which removed woody growth. Once a landscape was opened, the settlers seeded non-native European grasses to allow these areas to better suit their needs.[299] Over time, hay was grown and cultivated in such large quantities island-wide that it came to be the principal farm product of Martha's Vineyard. Mowing these meadows and fields was arduous and generally began in early July and lasted a month or more. The cut grasses were stacked and left to dry in areas called "stackyards" in order to prevent them from molding.[300] For a number of years, the dried hay would be lifted into a

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[294] Whitney 1994.

[295] Bidwell, P.W. and J.I. Falconer. 1888. *History of Agriculture in the Northern United States, 1620-1860*. Washington: The Carnegie Institution of Washington.

[296] Factors leading to the shift in farming from crops to grazing include the opening of the Erie Canal in 1825, the beginning of wool importation tariffs in 1828, increasing land taxation, and competition with western farmers.

[297] MacKenzie, C.L. 1997. The History of Dairy Farming on Martha's Vineyard. Pages 3-44 in *The Dukes County Intelligencer*. Ed. Arthur Railton. Edgartown, MA: The Dukes County Historical Society. By 1939, an insubstantial number of sheep—tallied at 523—remained on Martha's Vineyard. See: Capece 2001. In 1874 Professor Nathaniel Shaler noted that taxation of farmers in Tisbury was leading to farm abandonments and that everywhere fields were reverting to forest. In 1903, hunting clubs began buying large areas of farmland on the south shore and grazing essentially ceased. See: Raleigh 2000a.

[298] Whitney 1994, with several references to others.

[299] Dunwiddie 1994a. These areas were termed "English meadows" and were the most valuable of any meadow on a per-acre basis. For more information, see: Raleigh 2000a.

[300] These "stackyards" were often mentioned in land deeds. For examples at Long Point see: Raleigh 2000a.

large crib on a wagon and brought back to the farm. By the early 1900s, however, advances in technology allowed mowing practices on Martha's Vineyard to be greatly eased. The arrival of mowing machines and dump rakes harvested hay and collected them in rows, saving the settlers from the back-breaking work of doing it manually.

9.5 Clearing History

Land clearing has been a driving force in altering habitats on Martha's Vineyard for thousands of years. Prior to European settlement, Wampanoag used wood products for their homes, for fuel, for boats, for tools, and to cook food. They also cleared areas to create agricultural lands. To keep the 3,000 Wampanoag on Martha's Vineyard fed and warm a large amount of wood was needed. Woodlots were found near settlements and cornfields were often planted in woodlands in which the trees were girdled. When early colonists arrived, they accelerated the process of clearing land to create conditions that were suitable for agriculture and pasture. To clear this land, trees were cut using hand-axes, and stumps were removed using oxen. By the 1800s, many parts of Martha's Vineyard were predominantly free of forest and underbrush, and were used to pasture an estimated 20,000 sheep.[301]

As much of Martha's Vineyard was tied up in farming, agriculture, and grazing, wood scarcity on the island ultimately became a problem.[302] As early as 30 years following the first Vineyard settlement, for example, the town of Edgartown resorted to passing legislation that would actually fine a person for cutting down any live standing trees in the town. Again, in 1683, the town declared that anyone who cut any living trees, "oak, pine, or brush" on the town commons would be charged a fine. In the same year, it was also declared that no one would be allowed to cut any trees less than six inches in diameter. By the early nineteenth century, the town of Edgartown was forced to import wood from Cape Cod.[303]

Despite the overall shortage of wood, woodlots were part of the agricultural landscape, allowing landowners a constant supply of wood, if properly managed.[304] Wood from these lots was used for a variety of purposes, such as to construct houses and fuel fires to warm the home.[305] Because oaks on Martha's Vineyard were able to sprout from their stumps and root systems, coppice woodlots could be harvested on a fairly rapid rotation.

Large areas of the island were considered unimproved land or shrubland. Much of this land was concentrated in the center part of the outwash plain, where excessively dry soils, frequent fires, and a lack of water made agriculture and forest related land uses infeasible.[306] These were likely the areas where many of the rare early-successional sand barrens habitats—shrublands and barrens—persisted.

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[301] MacKenzie 1997. See also: Dunwiddie 1994a.

[302] Capece 2001. The scarcity of high quality trees at this time is not likely a result of clearing practices, however, but may be attributed to the effects of Native American burning, which ultimately created an extensive plain in Edgartown, in combination with the sand barrens soil.

[303] Freeman 1807. Freeman noted that very little woodland remained in Edgartown and Chilmark. Tisbury held approximately 2/3 of the woodland found throughout the island. Woodlands in Edgartown had declined so drastically that firewood had to be imported from Buzzard's Bay, Waquoit, and Coxit.

[304] Raleigh 2000a; Capece 2001.

[305] Other uses of wood included cedar shingling, tanning hides, creating barrels, building ships, and making furniture and tools, for example.

[306] Foster and Motzkin 1999.

9.6 Martha's Vineyard in the Regional Framework

Within the regional framework of the northeastern United States,[307] Martha's Vineyard is important ecologically for the following reasons:

- Grasslands and heathlands that only occur in small patches region-wide, with their associated rare species, specifically Sandplain Gerardia (*Agalinis acuta*, G1[308]), Nantucket Shadbush (*Amelanchier nantucketensis*, G3), Bushy Rockrose (*Helianthemum dumosum*, G3), and Northern Blazing Star (*Liatris scariosa var. novae-angliae*, T3).[309]
- A very low incidence of DDT and Bt spraying, commonly used elsewhere in Massachusetts, except for Nantucket and the Elizabeth Islands, which were also spared extensive spraying.
- A low incidence of an exotic, parasitoid tachinid fly, *Compsilura concinnata*, which is typical of the coastal plain fringes and has led, in part, to the extirpation of rare moth species.
- The Scrub Oak-heath shrublands, therefore, hold a rich diversity of invertebrate species, specifically Lepidoptera such as Barrens Metarranthis (*Metarranthis apiciaria*, G1), *Ptichodis bistrigata* (G2), and six G3 species. Many of these species have been extirpated from other or all regional sites. In addition, the sheer number of rare Lepidoptera on Martha's Vineyard is unrivaled when compared to similar sites.

The *threat* of land development is high on Martha's Vineyard, as compared to other sites which are either well protected already (New Jersey Pine Barrens) or developed significantly (Concord). Approximately 25% of Martha's Vineyard is protected as open space. Many of the conservation areas, however, are under threat of being fragmented as land development continues at a rapid pace.

The impact of succession on Martha's Vineyard has been high, as large areas have changed from shrublands, heathlands, and grasslands to woodlands and forested areas. Oak woodlands continue to close their canopies throughout the island, which is now predominately forested. Once this occurs, Scrub Oak disappears as a significant structural component. Black Huckleberry is more shade-tolerant, yet decreases in ground cover when Pitch Pines close their canopy. Many of the Scrub Oak-heath shrublands that once covered broad areas of the central fireshed are now confined to frost pockets. As more development occurs, habitat management at a landscape scale becomes more difficult due to habitat fragmentation, noise pollution, an increased need for public safety and education, smoke management concerns, and escaping livestock—all restoration issues that must be addressed.

9.7 Rare Species Risk Analysis

On Martha's Vineyard, rare plants, invertebrates, and birds[310] are threatened by succession and development, yet our own management can adversely affect these species if not carried out properly.[311] For example, the extinction of the Heath Hen, which took place on Martha's

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[307] See Section 3.

[308] G-ranks refer to the status of a species worldwide. G1 is critically imperiled, G2 is imperiled, G3 is vulnerable, G4 is uncommon, and G5 is common.

[309] Other rare species are at the fringe of their range (mainly northernmost fringe) and are important to protect to avoid range contraction and due to their potential genetic uniqueness at the periphery of its range.

[310] For more details on rare species, see Raleigh 2000b; Frey and Raleigh. 1998; and the various species summary sheets published by the Massachusetts Natural Heritage and Endangered Species Program.

[311] Studies on invertebrates shows how sensitive this group of organisms can be: Kalisz, P. J. and J. E. Powell. 2000. Effects of Prescribed Fire on Soil Invertebrates in Upland Forests on the Cumberland Plateau of Kentucky, USA. *Natural Areas Journal* 20:336-341. Swengel, A.B. 1996. Effects of Fire and Hay Management on Abundance of Prairie Butterflies. *Biological Conservation* Vol. 76. pp. 73-85

Vineyard in 1932, was precipitated in part by a wildfire that occurred during the birds breeding season. With rare species confined to small pockets of habitats and a lack of adequate monitoring data, the risk to these species must be considered when planning a management action. In some cases, long-term habitat choices mean balancing the risk of multiple species. A risk description of key rare species can be found in table 9.1. The at-risk period describes the time when management actions may cause the most harm to that species. During that time, a species may be flowering, in larval form, breeding, or be in an especially susceptible stage, such as having low nutrient reserves in the rootstock.

The spatial and habitat distribution of these rare species can be helpful when ascertaining risk. Most rare species, for example, are found in habitats ranging from grasslands to Pitch Pine barrens (table 9.1). Forested habitats, therefore, can be restored to habitats that are more open with a lower risk to rare species. In contrast with forested habitats, coastal heathlands may have nesting Northern Harriers and Nantucket Shadbush present, increasing the risk of managing this habitat. The spatial distribution of these species and habitats, however, can assist with management. Unmanaged areas of the same habitat or with the same rare species can serve as refugia. Following management, areas can be monitored to see the response of rare species. Therefore, managing with at-risk periods, spatial distribution of rare species, and refugia in mind will reduce the risk to rare species. Over the long term, proper management should ensure their survival and even increase their numbers as species colonize newly restored habitats.

Table 9.1: Rare Species At-risk Periods.

Species of Interest	Preferred Habitats	At-risk Periods
Sandplain Gerardia	Grasslands, or grassy patches within other habitats	July to early October. As an annual, this species is highly susceptible to treatments during its growth, when flowering, and when seeds are developing.
Northern Blazing Star	Grasslands, or grassy patches within other habitats	August to early October. If grazing or burning, treatments in the summer may also adversely affect this species.
Bushy Rockrose, Sandplain Blue-eyed Grass	Grasslands, or grassy patches within other habitats	May to July.
Sandplain Flax	Grasslands, or grassy patches within other habitats	July and August, when flowering and seeds are developing.
Nantucket Shadbush	Grasslands and heathlands, shrublands	May, when flowering and leaves are flushing, indicating root carbohydrate reserves may be low.
Barrens Buckmoth	Scrub Oak shrublands	Late May to early August, when in larval form. Also in October when an emerged adult.
Barrens Metarranthis	Scrub Oak shrublands, barrens[312]	Summer. Little is known about this species.
Pine Barrens Zale	Scrub Oak shrublands, barrens	June and July, during the larval stages.

Goldstein 1997; Simmons et al. 1995. With birds, the effects of managing during the breeding season are fairly obvious: Ells, S. F. 1995. Bobolink Protection and Mortality on Suburban Conservation Lands. *Bird Observer*. 23(2):98-112.

[312] Remember, the term "barrens" here refers to sparse tree cover, not the poor soils that define "sand barrens." See section 2.5.

Species of Interest	Preferred Habitats	At-risk Periods
Barrens Daggermoth	Scrub Oak shrublands, barrens	July to early September, when in adult or larval stages.
Northern Harrier	Heathlands, Scrub Oak shrublands	Breeding season: May to mid-August.
Melsheimer's Sack-bearer	Scrub Oak shrublands	Year-round except Spring. Uncertainty about susceptibility to treatments during pupal and larval stages.
Imperial Moth	Pitch Pine barrens, Pitch Pine woodlands	Mid-July to September. The remainder of the year they pupate underground.
Gerhard's Underwing Moth	Scrub Oak shrublands, woodlands	Year-round, potentially. As this species pupates in the leaf litter, any treatments may affect it.
Chain-dot Geometer	Heathlands, shrublands	June to September, when in the larval and adult stages.
Coastal Heathland Cutworm	Grasslands, barrens	Year-round. This species overwinters underground in the larval stage.
Savanna Sparrow, Grasshopper Sparrow	Grasslands	Breeding season: mid-May to late July.

9.8 Species Responses to Management Tools

On Martha's Vineyard, the most common barrens plant species are tree oaks, Scrub Oak, Black Huckleberry, Pitch Pine, Little Bluestem, Pennsylvania Sedge, and Poison Ivy. Understanding how these species respond to various treatments is integral to determining the overall community response. In addition, the desired habitat may require more, or less for that matter, of a given species or groups of species. Table 9.2 summarizes species characteristics that ultimately affect their responses to both short- and long-term disturbances . Table 9.2 also describes potential treatments that may most effectively increase or decrease that particular species. This information is based on monitoring data, personal observations, and literature.

***Table 9.2**: Species Characteristics and Responses.*

Woody Species	Resprouting	Above-ground traits	Reproduction	Treatments to Increase	Treatments to Reduce	Other Considerations
Tree Oaks: Black, Scarlet, Post, and White	Sprouting ability ends at 80+ years of age for white oaks and at 150+ years for black oaks.[313]	Medium to thick bark, increases with age and depends on species.	Acorns; produces first acorns at 20-50 years old, depending on species.[314]	• Periodic fires enhance advance regeneration. • Lower intensity and severity of fires will reduce adult mortality, yet create openings for regeneration.	• Severe prescribed fires in older stands. • Frequent burning or mowing (for coppice growth). • Mechanical removal.	Some confusion exists in the literature about fire tolerance of the various tree oak species, although Post Oak and Scarlet Oak appear least adapted to more competitive environments so are more abundant in open areas, where fire is more prevalent.
Scrub Oak	Vigorous resprouter	Thin bark. The structure of Scrub Oak may increase fire intensity.	Acorns; produces first acorns at 3-5 years; maximum productivity at 5-7 years.[315]	Treatments every 7-10 years to maximize acorn production and rootstock growth.	Long-term annual treatments, focusing on late spring, when leaf-out occurs. Annual treatments may limit tools to grazing and mowing, for fuel loads may not be sufficient for burning.	To maintain status quo, treatments are needed every 4-5 years.[316] Mouse herbivory and leaf litter may be important factors in Scrub Oak regeneration.[317]
Black Huckleberry	Vigorous resprouter from rhizomes.	Above-ground vegetation may increase fire intensity through flammable organic compounds.	Berries; can produce fruit the year following a burn. Clonal patches can spread through rhizomes.	• Depends on other plants competing with Black Huckleberry. • To reduce competition from tree and scrub species, dormant season treatments every 2-5 years will likely favor this species.	• Burning followed by prescribed grazing using sheep or goat. • Long-term annual summer treatments.[318]	Older plants may not resprout as vigorously. Shallow roots in the duff layer may be sensitive to summer prescribed burns. When duff is lowered through more frequent burning, rootstocks move into mineral soil, increasing rootstock survival.[319]

[313] Jordan 1999.
[314] Windisch, A. 1999.
[315] Jordan 1999.
[316] Windisch, A. 1999.
[317] Jordan 1999.
[318] Bill Patterson's Truro plots are evidence of the effectiveness of annual treatments in decreasing huckleberry cover.
[319] http://www.fs.fed.us/database/feis/plants/shrub/gaybac/index.html.

Woody Species	Resprouting	Above-ground traits	Reproduction	Treatments to Increase	Treatments to Reduce	Other Considerations
Pitch Pine	Vigorous resprouter from rootstock, stem, and branches, up to 40 years old[320] even if tree appears dead following a fire.	Thick bark; increases with age. Dead branches will remain on a tree, increasing flammability and ladder fuels. Pitch is highly flammable, as are needles.	Reproduction through seed dispersal at 8-12 years of age.[321] Germination is enhanced by mineral soil and high sunlight. Cones are non-serotinous on Martha's Vineyard.[322]	High severity duff-reducing fires or other ground scarification treatments at intervals of 12-15 years will increase small Pitch Pines through new seedlings and resprouts.[323]	• Fall treatments when Pitch Pine is likely most susceptible due to low carbohydrate reserves in roots.[324] • Repeated prescriptive grazing.	In some other sites, this species biology is considerably different in that it possesses serotinous cones or may exist in a dwarf form.
Little Bluestem	Resprouts from rootstock; not an aggressive clonal propagator—rhizomes are short.	Susceptible to summer burning or grazing treatments due to meristems placed above the soil.	Seed production is enhanced significantly through burning. Seeds may be viable for 70 years or more.[325] Highly fertile. Seed does not disperse well (6 feet max.)[326]	• Overstory removal in areas where Little Bluestem exists as an understory species. • Late spring treatments of mowing or burning.	Summer grazing or burning, when growth meristems are approximately one inch above the soil.[327]	The longevity of the seed bank for Little Bluestem makes its restoration possible in many areas on Martha's Vineyard that were more open in the early to mid-twentieth century.
Poison Ivy	Resprouts readily from rootstock and rhizomes buried deep in the soil.[328]	Above-ground biomass is susceptible to fire.	Fruit; spread by wildlife.	Infrequent to no treatments; Poison Ivy is common throughout Martha's Vineyard in untreated areas.	• Frequent treatments may reduce the cover and frequency of Poison Ivy. • Grazing using sheep will target Poison Ivy.	"The poison-ivy dermatitis-causing compound, urushiol, is not a volatile oil; however, it can be carried by particles of soot when the plant is burned."[329]

[320] Windisch 1999.
[321] Jordan 1999.
[322] Jordan 1999.
[323] For more information, see Windisch 1999.
[324] Sablon 1904.
[325] Livingston, R. B.; Allessio, Mary L. 1968. Buried viable seed in successional field and forest stands, Harvard Forest, Massachusetts. *Bulletin of the Torrey Botanical Club*. 95(1): 58-69; Holtz, S. L. and Howell, E. A. 1983. Restoration of Grassland in a Degraded Wood Using the Management Techniques of Cutting and Burning. In: Brewer, Richard, ed. *Proceedings, 8th North American Prairie Conference*. 1982 August 1-4. Kalamazoo, MI. Western Michigan University, Department of Biology: 124-129.
[326] http://www.fs.fed.us/database/feis/plants/graminoid/schsco/index.html
[327] http://www.fs.fed.us/database/feis/plants/graminoid/schsco/index.html
[328] http://www.fs.fed.us/database/feis/plants/vine/toxrad/index.html
[329] http://www.fs.fed.us/database/feis/plants/vine/toxrad/index.html

Woody Species	Resprouting	Above-ground traits	Reproduction	Treatments to Increase	Treatments to Reduce	Other Considerations
Pensylvania Sedge	Will propagate aggressively through rhizomes present close to the surface.	Treatments during the early growing season, when sedges are most active, and are most harmful.	Clonal, through rhizomes. Also through seed germination.[330]	Summer treatments significantly increase sedges.	Spring treatments, especially grazing, may reduce sedge cover.	"Because its roots and rhizomes do not penetrate deep into the soil Pensylvania Sedge exploits fire-generated gaps in the litter layer through aggressive clonal propagation."[331]

9.5 Summary of Management Tools and Uses

Each management tool is summarized in table 9.3 in terms of practical issues, ecological advantages and disadvantages, and applied uses. For more information, refer to sections four through eight.

Table 9. 3*: Management Tools, Issues, Ecological Costs and Benefits, and Uses.*

Management Tool	Practical Issues	Ecological Advantages	Ecological Disadvantages	Applied Uses
Prescribed Fire (Section 4)	• Ability to burn into wetlands and areas not feasible for other tools. • Safety. • Training. • High equipment and personnel costs. • Highly regulated in the northeast. • Insurance issues. • Partnerships. • Notification and Education. • May leave large amounts of dead standing trees.	• Flexibility of ecological effects. • Increase in species diversity. • Drought conditions or summer burning may reduce duff immediately. • Altering overstory structure through mortality. • Ability to manage large areas.	• Difficult to choose optimal burning conditions and full range of seasonality. • Growing season burning may eliminate breeding birds, invertebrates, and other species. • Spring burns do not appreciably reduce invasive woody growth in heathlands and grasslands.	• Reducing fuel loads. • Maintaining grasslands and heathlands. • Converting forests to more open habitats through overstory cover reduction. • Removal of fire-intolerant species. • Changing shrub structure.

[330] Seed germination is uncommon, however.
http://www.fs.fed.us/database/feis/plants/graminoid/carpen/index.html
[331] http://www.fs.fed.us/database/feis/plants/graminoid/carpen/index.html

Management Tool	Practical Issues	Ecological Advantages	Ecological Disadvantages	Applied Uses
Prescribed Rotational Grazing (Section 5)	• Can target vegetation that other tools may not target. • Can control growth in areas other tools cannot. • May be relatively inexpensive. • Palatability of target species depends on its development stage. • Obtaining livestock may be difficult. • Requires specialized labor and resources. • Insurance and liability issues.	• Can increase species diversity. • Can reduce woody growth. • Ability to break up the duff layer. • Can use grazing over a wide variety of seasons for a diversity of desired ecological effects. • May spread desirable species through restoration units. • Livestock can be selected to control specific species, giving this tool a high degree of control over ecological effects.	• Exotic species may be spread (although this can be mitigated through quarantining species). • Rare species and other desired species may be consumed. • Additional research is necessary to ascertain possible negative effects.	• Effects are for understory vegetation only, in most cases, although girdling may occur. • Increasing species diversity. • Converting shrub-dominated understories to a variety of habitat types. • Maintaining heathlands and grasslands.
Hand Clearing With Stump Application of Herbicides (Section 7 and 8)	• Reduce fuel loads to allow for safer prescribed burning. • May be contracted out. • Expensive, although results are dramatic both ecologically and aesthetically. • Herbicide application training is typically needed.	• Ability to control all aspects of overstory: composition, density, and diameter distribution. • Removal of biomass from the restoration site. • Some ground scarification, depending on treatment.	• Requires the use of machinery that may be environmentally insensitive (fuel spills, herbicide use).	• Converting overstories to more open habitat types.
Mowing (Section 6)	• Minimal staff and experience are needed. • Equipment may be expensive. • Mowing can only be carried out without natural obstacles.	• Ability to use at any time of the year to control effects. • Ability to avoid sensitive areas. • Can significantly reduce invasive species in heathlands and grasslands. • Can target problem areas that would not be feasible for burning or grazing. • May scarify selected areas, increasing exposed mineral soil.	• Does not remove biomass from the site, increasing duff build-up. • Can introduce exotics if used in different areas. • Can crush sensitive species such as lichen.	• Maintenance of grasslands, heathlands, and shrublands. • Reducing woody species through multiple treatments.

9.6 Habitat Restoration

Priority rare barrens habitats on Martha's Vineyard and elsewhere include woodlands; savannas; oak, pine, or mixed barrens; Scrub Oak shrublands; grassy shrublands; coastal heathlands; and sandplain grasslands, in order of decreasing tree cover.[332] Based on the research presented in the previous eight sections and in this section, table 9.4 outlines the steps, issues, and costs and benefits of restoring various habitat types from a current condition to a desired future condition. These habitats, however, are all part of a continuum and are highly variable and dynamic in space and time. Within a given site, for example, a range of habitats likely occurred historically, depending on the disturbance regime. Choosing what to manage for at a site, therefore, means that management objectives must take into account land-use history, costs, benefits, rare species, risk analysis, as well as the disturbance regime. Once a future desired condition is reached, management can focus on maintenance activities, providing for variability in the system. On the other hand, management could also allow the habitat to "relax," with an absence of treatments for up to many years. These approaches should allow for the natural variability that occurs in sand barrens.

***Table 9.4**: Restoring Habitats to Various Desired Future Conditions.*

Current Conditions	Desired Future Condition	Management Steps	Issues	Costs and Benefits Synopsis
Forest	Woodland	• Overstory density can be decreased through girdling, burning, or clearing. • Understory diversity can be increased through a combination of spring burning and grazing or grazing alone. • Burning followed by grazing would also be an effective combination, with a mixture of burning and grazing treatments long-term.	• What seed sources or seed bank are available? • Typically, dry oak forests support few rare species, facilitating high intensity restoration.	The least expensive method would be girdling and grazing, yet initially a grazing system would have to be developed. A combination of low-intensity burning and grazing could be used long-term, adding flexibility and multiple effects to the woodland maintenance efforts. Girdling can be used to create oak openings, with more intensive prescribed grazing focused on these openings.
Forest	Oak or pine barrens	• Overstory density reduction can be accomplished through burning, girdling, and clearing. • Understory shrubs can be increased through increased light penetration (overstory density reduction) and through infrequent burns. • Grassy shrubland openings can be created through clearing and mowing. • Long-term, infrequent burns of various intensities would maintain this habitat.	• What seed sources or seed bank are available? • How can Scrub Oak be restored as a major component of the barrens? • What are the nearest locations of rare Lepidoptera? • To determine appropriate burn intervals, monitoring, rare species, and vegetation life histories should be analyzed.	Initial low-cost and effective steps focusing on overstory density reduction and an increase in Scrub Oak and other shrubs may be accomplished on a large scale through burning and girdling. Infrequent burns would be inexpensive and would benefit rare Lepidoptera, which would be given time to recolonize burned units.

[332] See Section 2 for community descriptions.

Current Conditions	Desired Future Condition	Management Steps	Issues	Costs and Benefits Synopsis
Forest	Shrubland	• Clearing followed by infrequent burns of various intensities or mowing where feasible would create and maintain this habitat.	• What seed sources, current understory vegetation, or seed bank are available? • What are the nearest locations of rare Lepidoptera? • What is the spatial arrangement of all shrubland restoration units (viability of rare Lepidoptera at a local and regional scale).	Costs for this type of restoration are initially high, but the restoration provides rapid benefits in that the community is structurally restored in short order, depending on the pre-existing understory. The time necessary to restore rare species would depend on their proximity to the site, the quality of the site, and other potential factors.
Forest	Grassland and heathland	• Clearing followed by burning, mowing, and grazing at frequent intervals would create and maintain this habitat.	• What seed sources or seed bank are available?	A variety of management tools would create more diverse effects.
Woodland	Oak or pine barrens	• Overstory density reduction can be accomplished through burning, girdling, and clearing. • Understory shrubs can be increased through increased light penetration (overstory density reduction) and through infrequent burns. • Grassy shrubland openings can be created through clearing and mowing. • Long-term, infrequent, burns of various intensities would maintain this habitat.	• Are there rare Lepidoptera in the unit that may be impacted by management? • To determine appropriate burn intervals, monitoring, rare species, and vegetation life histories should be analyzed.	Initial low-cost and effective steps focusing on overstory density reduction and an increase in Scrub Oak and other shrubs may be accomplished on a large-scale through burning and girdling. Infrequent burns would be inexpensive and would benefit rare Lepidoptera, which would be given time to recolonize burned units.
Woodland	Shrubland	• Clearing followed by infrequent burns of various intensities or mowing where feasible would create and maintain this habitat.	• Are there rare Lepidoptera in the unit that may be impacted by management? • What is the spatial arrangement of all shrubland restoration units (viability of rare Lepidoptera at a local and regional scale).	Costs for this type of restoration are initially high, but the restoration provides rapid benefits in that the community is structurally restored in short order, depending on the pre-existing understory. The time necessary to restore rare species would depend on their proximity to the site, the quality of the site, and other potential factors.

Current Conditions	Desired Future Condition	Management Steps	Issues	Costs and Benefits Synopsis
Woodland	Savanna	• Burning, girdling, and clearing used in combination will reduce the overstory density. • To increase herbaceous diversity grazing, mowing, and burning may be used. • Once species have recolonized, treatments are necessary as based on monitoring to maintain the habitat while avoiding further tree mortality and providing for long-term tree and shrub regeneration (by occasionally increasing the frequency between treatments). • High-intensity burns should be avoided.	• Are there rare Lepidoptera in the unit that may be impacted by management? • Balancing management tool use to maintain a savanna will require a high degree of focus on monitoring.	Costs of restoration are fairly high, for they involve multiple treatments. Restoring this habitat from a woodland is more cost effective than restoration from a forest, involving less overstory density reduction and understory management. Many of the herbaceous species or their seeds may already be present in the woodland as may many rare Lepidoptera, opening the habitat further will create additional species habitats.
Oak or pine barrens	Shrubland	• Initially a high-intensity burn can top-kill overstory species. Clearing in high-density shrubs typical of barrens is not likely to be cost-effective for larger areas, as preparation for clearing would require extensive brush cutting. • Following the initial burn, trees can be removed, if necessary, for aesthetic purposes. • Infrequent burns of various intensities or mowing where feasible would create and maintain this habitat.	• Are there rare Lepidoptera in the unit that may be impacted by management? • What is the spatial arrangement of all shrubland restoration units (viability of rare Lepidoptera at a local and regional scale)?	As these habitats share similar characteristics, restoration is not very extensive. The maintenance phase would occur fairly rapidly. By opening the canopy further, more optimal habitat for several species would be created.
Shrubland	Heathland	• Depending on the shrub species, mowing and burning treatments should be used in tandem, with a fairly high frequency, as based on monitoring. • Grazing may be used to target invasive woody species, as necessary.	• Some heathlands, once in the maintenance phase, become fairly stable. Creating stability by removing or reducing invasive woody species will be key to creating a high-quality heathland. • More information on how various livestock differentially feed on heath species versus oaks and pines is needed.	Heathland restoration and maintenance will be moderately expensive, especially if pine and oak saplings form a significant component of the shrub layer. Balancing invasive woody species removal with maintenance of the heathland component becomes the most significant maintenance issue for which to weigh the costs and benefits.

Current Conditions	Desired Future Condition	Management Steps	Issues	Costs and Benefits Synopsis
Shrubland	Grassland	• Following an initial burn, regular mowing and grazing should be conducted.	• Due to the high frequency of management, treatment effects on various species should be consulted regularly as based on monitoring and research. • Treatments should avoid seasons when rare species are in vulnerable stages (flowering, breeding, larvae).	Costs of grassland restoration will be high due to the intensive management necessary. Grasslands will create habitats for additional species.

9.7 Conclusions and Guiding Principles

When managing sand barrens, many issues must be addressed to ensure the success of a project. The following issues must not be overlooked:

The importance of land-use history. Pre-historical and historical records of vegetation composition and land-use activities can give a land manager a good idea of potential restoration goals as well as a solid knowledge of what management tools have shaped a site's present species composition.

The importance of knowing how a site fits into the bigger picture. How does a site relate to adjacent management areas? What rare species are present at the site and nearby? What are the threats to sand barrens and its rare species? The regional context can bind together sites that, at first glance, may appear scattered and unconnected.

The constraint of cost and frequency. The costs of any management program are high, and with thousands of acres needing some form of management, applying management tools to the landscape should be done with costs in mind. Ensuring that each treatment is chosen carefully to create the desired effect means that costs are reduced and future treatments will not be needed as often.

The need for monitoring rare species and habitat change. Not knowing what species are present at a site and how they are responding to management is dangerous in that species may be lost. In addition, important information about how management affects habitats allows managers to assess their success; without monitoring, results cannot be demonstrated and management cannot be considered ecologically-driven.

The need to look at risk to rare species when managing. Even at a basic level, risk analysis can increase the viability of rare species. For example, grasslands management should proceed with care when rare breeding birds are present in a unit. The larger landscape context of a breeding bird population and risk to the population at a site should be considered in this case. Also, Scrub Oak shrublands and other shrub-dominated habitats should be monitored for rare moth and other rare species and managed so that refugia (unmanaged areas) are always present and so that species have time to recolonize managed areas.

The flexibility of having many tools for habitat management. Using a wide variety of tools can potentially lead to greater habitat diversity at a variety of scales. A greater variety of tools can also allow for flexibility when managing.

The importance of using the toolbox in a dynamic manner. Sand barrens are highly dynamic habitats. When looking at site goals, habitat diversity, time between treatments, and variability between and within habitats should all be considered. Flexible unit boundaries, allowing for variability over time within units, and realizing that change is a constant part of sand barrens systems are all important concepts when applying the toolbox.

The need for information sharing and continued research. Managers learn from their successes, failures, and through others. Only through information sharing and building on research and past experiences can we improve our ability to manage sand barrens in a sound ecological manner.