Grassland Management Plan

World's End

Hingham, Massachusetts

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The Trustees of Reservations

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1.0 Introduction

World's End is a 251-acre peninsula located in the Town of Hingham between Hingham Harbor and the Weir River (Fig. 1). Rolling fields interspersed with woodlands and winding, tree-lined avenues are perhaps the most enduring image of World's End. The property's grasslands, forest patches, and four miles of undeveloped shoreline provide important habitat for a variety of plant and animal species. Over five miles of walking paths allow visitors access to all parts of the Reservation, including the drumlin hills of World's End proper, scenic ledge overlooks along Rocky Neck, and the coastal pond and marshes of Damde Meadows.

Grasslands, which are broadly defined in this plan as grass-dominated communities and early successional habitats with an abundance of woody plants, cover just under half of the total acreage of World's End. The fields at World's End provide sanctuary for a variety of common and uncommon species including grassland birds, butterflies, moths, and rare plants. In addition to providing vitally important habitat for numerous species, these open, airy environments allow visitors the unique opportunity to enjoy broad, sweeping views of the surrounding landscape. The expansive grasslands at World's End contribute significantly to its pastoral quality, a visitor experience that is increasingly threatened in this part of the Commonwealth.

The grasslands at World's End, however, are not ecologically stable environments, but are subject to rapid change due to community succession and competition from invasive exotic plants. Moreover, some grassland species (e.g., nesting birds) are easily disturbed by inappropriate recreational use. The rapid decline of grasslands and their associated species in the Northeast over the last 150 years underscores the need to conserve the ecological and scenic value of grasslands at World's End. However, without active management, these important grassland values at World's End will diminish, resulting in the loss of regional biological and scenic diversity.

1.1 Purpose of the Grassland Management Plan

The World's End Management Plan[38] identified the need for a detailed grassland management plan to address the conservation goals and primary threats to the grasslands at World's End. The primary management goal for grassland management at World's End is maintaining a grassland/early successional mosaic that supports a diversity of species that depend on these habitats. Specific conservation targets include: native grassland patches, grassland wildlife including butterflies and nesting birds, rare species, and plant diversity. Preserving the pastoral, open character associated with grasslands was also identified as a primary recommendation in the management plan.

The primary threats to the ecological and scenic values of grasslands at World's End include the encroachment of woody vegetation, invasive plant species, and inappropriate recreational use (e.g., unleashed dogs). Therefore, the purpose of the grassland management plan for World's End rises largely from the need to maintain the grasslands in a state that optimizes their habitat and scenic

values while controlling uses and processes that threaten these important values. The intent of the grassland management plan is to apply appropriate management actions to meet the grassland stewardship goals and to mitigate existing or potential threats to these resources.

1.2 Plant Community Types at World's End

Grasslands are the most common plant community type at World's End, covering approximately 40 percent (or roughly 100 acres) of the Reservation (Fig. 2). Both coastal and freshwater wetlands occur at World's End, including small pockets of salt marsh along the shoreline and a small pond/shrub swamp (known as Ice Pond) on Rocky Neck. Damde Meadows, a 14-acre tidal pond and marsh whose connection to the sea was restored in early 2003, is the largest wetland system on the property. Forest habitat is mostly confined to Rocky Neck and the area east of Damde Meadows. Rocky Neck is vegetated by relatively young forest communities that have developed on lands that were historically grazed up until the first half of the twentieth century. A mature oak-hickory forest, known as the Loud Lot, is located east of Damde Meadows. Small patches and strips of mixed forest occur elsewhere on World's End, many of which divide or fragment grassland patches. As elsewhere at World's End, invasive exotic species are common in many of these forest patches.

2.0 Grassland Communities and Current Management

2.1 Grassland Type, Size and Composition

Grassland is the most common plant community type on World's End, covering approximately 100 acres of the Reservation. Although fragmented by tree-lined avenues and hedgerows, World's End supports some of the best remaining grasslands in the greater Hingham area. Moreover, grasslands at World's End provide some of the only habitat for grassland dependent fauna (birds, butterflies, etc.) in the greater Boston and South Shore areas.

Most of the grasslands at World's End can be classified as mowed fields; that is, "non-agricultural grasslands that are maintained by mowing".[42] While grasses and forbs define this community, woody vegetation is also present in the fields and is increasing. This is particularly true in many of the smaller fields and along the margins of larger fields. Woody shrubs and vines represent at least 25 percent of the total vegetative cover in the fields at World's End[A], and significantly more in some areas. Therefore, the term grassland, as used to define a community type at World's End, should be interpreted broadly to include not only true grasslands but successional habitats with abundant woody plants.

The grasslands at World's End generally occur in discrete units separated by tree-lined avenues or small forest patches. Nineteen grassland units have been identified at World's End, and are referenced with a unique code (Fig. 3; Table 1). All of the fields are less than 20 acres in size, with the majority of the fields 8 acres or less in area. The largest, unfragmented field at World's End is located on Planter's Hill (PH-2), and is 18-19 acres in size. Four additional fields range in size from 8-9 acres, while there are seven fields that are 3-7 acres in size. There are seven small fields that range in size from less than an acre to just under 3 acres. The fields are generally irregular in shape with most fields having a relatively high ratio of forest edge to field.

With a few notable exceptions, the fields at World's End are vegetated by cool-season grasses. These mainly non-native species were introduced for crop and pastureland because they grow well in the cool, moist spring and fall weather conditions of the Northeast.[13] They are dormant during the summer, and can be grazed closer to the ground during the summer and winter than warm-season grasses without reducing vigor. Cool-season grasses form a dense cover due to reproduction by rhizomes and less suitable for some nesting grassland birds. Orchard grass (*Dactylis glomerata*), Kentucky bluegrass (*Poa pratensis*), red-top (*Agrostis alba*), and sweet vernal grass (*Anthoxanthum odoratum*) are common cool-season grasses in the fields at World's End. Several forbs, including Canada thistle (*Cirsium arvense*), butter and eggs (*Linaria vulgaris*), as well as numerous species of goldenrod (*Solidago* spp.) and aster (*Aster* spp.) are common in the fields. Common woody species include poison ivy (*Toxicodendron radicans*), multiflora rose (*Rosa multiflora*), common blackberry (*Rubus allegheniensis*), and dewberry (*Rubus* sp.).

Table 1
Grassland Units, World's End

[A] Based on vegetation plot data collected in 2000.

Location	ID No.	Approx. Size (acres)	Conservation Targets
Pine Hill	PiH-1	3.6	
	PiH-2	3.7	
	PiH-3	3.3	Showy goldenrod
	PiH-4	8.6	Grassland breeding birds, native grassland
Planter's Hill	PH-1	6.4	Grassland breeding birds
	PH-2	18.6	Grassland nesting birds, native grassland
	PH-3	2.9	Old field habitat
	PH-4n	6.4	*Spartina pectinata*
	PH-4s	6.6	*Spartina pectinata*
	PH-5	2.2	
World's End drumlin (inner)	WEi-1	8.5	Breeding birds, showy goldenrod
	WEi-2	9.3	Breeding birds, showy goldenrod
	WEi-3	1.4	
	WEi-4	0.4	
	WEi-5	0.9	Showy goldenrod
	WEi-6	1.3	Showy goldenrod
World's End drumlin (outer)	WEo-1	8.5	Native grassland
	WEo-2	5.5	
NE of Damde Meadows	DM-1	1.3	Native grassland

Native grasslands, those dominated by indigenous warm-season and cool-season grasses and forbs, occur in a few, relatively small patches at World's End (Fig. 4). Ecologically, these grasslands more closely resemble the original grasslands of Massachusetts before the introduction of exotic, cool-season grasses and European style agriculture. Warm-season grasses grow in the summer when cool-season grasses are dormant, and are drought-resistant, winter hardy, and adapted to sandy, infertile soils. Little bluestem (*Schizachyrium scoparius*) is the dominant warm-season grass in most native grassland patches at World's End. Switch grass (*Panicum virgatum*), another warm-season native grass, was introduced locally by planting but probably also occurs naturally along the upper edge of salt marshes bordering World's End. Canada bluejoint (*Calamagrostis canadensis*), a native cool-season grass, comprises roughly half of the native grassland patch located east of Planter's Hill. Small patches of prairie cordgrass (*Spartina pectinata*), a native grass of freshwater and brackish marshes, are found in a few low-lying areas at World's End. Warm-season grasses typically grow in clumps that allow ground nesting birds to move about. Although native grasslands provide more suitable breeding habitat for some grassland birds, bobolinks (the most common grassland nesting bird at World's End) prefer more uniformly dense stands of cool-season grasses with high litter cover.[5]

The largest area of native grasses at World's End, approximately 2.5 acres in size, is located on the outermost drumlin of World's End (WEo-2). Much smaller patches persist on the east and west flanks of Planter's Hill, as well as northeast of Damde Meadows (1.3 ac.). Some native grassland patches, such as the field used for Solstice Event parking, may exist today due to past management (e.g., late spring mowing). The total area of native grasslands at World's End is approximately 6 acres, or about 6 percent of the total area of grasslands on the reservation.

2.2 Current Grassland Management

With few exceptions, all of the grasslands at World's End are mowed on an annual basis after July 15th to allow nesting grassland birds to fledge young. The small native grassland located on the west slope of Planter's Hill is mowed during the first week of June to allow parking for the summer solstice event. Field management staff typically mows the fields at World's End using a rotary disc mower and a brush hog. The rotary disc mower, which is side mounted onto a New Holland 545D backhoe, is the most efficient tool for mowing grass and forb-dominated fields with little woody plant cover. Fields overgrown with woody plants are mowed using the brush hog, which is pulled behind a John Deere tractor (Model 5200). The sickle bar mower is essential for mowing along the tree-lined avenues and roadside trenches.

The largest fields (e.g., PH-2) are generally mowed first (after July 15). The typical open field mowing pattern involves 2-3 passes along the perimeter of the field, then mowing from the field interior to its edges. Fields are cut to height of approximately six inches, and cuttings are left in the fields. Field staff spend a considerable amount of time every year trimming around trees and field edges with weed whackers and hand cutting woody vegetation along field edges where necessary. The only field not cut on an annual basis is PH-3, which was mowed in 2000 and 2002. Herbicides, burning, and grazing have not been employed as management tools by Trustees' staff to maintain the property's grasslands.

The South Shore Management Unit annually dedicates an estimated 930 man-hours (or nearly 8 weeks of labor for three men) to mow all the fields and clear field edges at World's End (Appendix 1).[10] An estimated 34 additional man-hours is spent on routine and non-routine maintenance tasks. The estimated annual labor costs to currently maintain the fields at World's End is approximately $15,400. Fuel and parts for the mower equipment and power tools cost an additional $1,500 annually. The estimated depreciation of mowers and tractors over 10 years is approximately $3,300. Refer to Appendix 1 for a detailed breakdown of current grassland management costs at World's End.

2.3 Resource Monitoring

The dynamic nature of grasslands and other early successional habitats at World's End require regular field monitoring as management proceeds to ensure that stewardship goals are being met. Breeding bird and vegetation surveys follow standard Trustees protocol for resource inventory and monitoring. Eight, 50-meter radius plots were randomly established in the grasslands at World's End in 2000 to survey grassland breeding birds (Fig. 5).[3] Three, 4-meter radius plots are nested within each 50-meter radius breeding bird plot to inventory plant species. The vegetation plots are located 25 meters from the center of the plot at 0^{o}, 120^{o}, and 240^{o} compass bearings. Plots 9 and 10

are single, 4- meter radius plots and are surveyed for plant species only. Plots 1 and 2 are located on Pine Hill, and plots 3, 4, 5, and 9 are located on Planter's Hill. Plots 6 and 7 are located on the World's End drumlin north of The Bar, while Plot 8 is located on the outermost drumlin. Plot 10 is located east of Damde Meadows in a small patch of native grasses. Field data was collected from all plots in 2003.

An Experimental Mowing Plan for World's End was initiated in 2002 to assist ecology and property management staff in determining the effects of different mowing frequencies on plant species composition (Appendix 2). Seven experimental mowing plots (Fig. 5), each approximately ¼-acre in size, are undergoing mowing treatments at four week (2 plots), six week (2 plots), and three month (3 plots) intervals through the growing season from June to October. Plant species and frequency data was collected in 17 subplots nested within each experimental mowing plot prior to the initial cutting in mid to late June 2002. Vegetation within the experimental mowing plots will be inventoried following three growing seasons to identify any changes in species composition and abundance. Continuing the experimental mowing plan after the 3-yr. study period will depend on the results of the study and the existing workload of field management staff.

3.0 Grassland Habitat Values

3.1 Ecology of Grasslands at World's End

General Wildlife Use: The grasslands at World's End support a variety of wildlife species, including birds, small and medium-sized mammals, and insects, during all or some part of their life cycle. The size of World's End and its peninsula setting may diminish its capacity to support larger, wide-ranging species that utilize non-forested habitats, such as coyote and white-tailed deer. The size and shape of the fields at World's End as well as their plant species composition influence the type of grassland birds and insects that can be found. The low availability of freshwater sources may also limit the range of wildlife that occurs at World's End, including those species that depend on grasslands.

Little specific information is currently available regarding mammals at World's End. Although large mammals are generally uncommon, red fox are resident and are regularly observed during daylight hours. Coyotes, on the other hand, are seldom observed at World's End, although residents occasionally observe them along Martins Lane.[32] White-tailed deer are also scarce at World's End, and those that are observed on the property typically do not stay. Other mammals, such as the eastern cottontail, woodchuck, opossum and striped skunk, have been recorded at World's End and are likely to be common.[36] Small mammals, including meadow vole, northern short-tailed shrew, and probably the meadow jumping mouse, are common in the grasslands at World's End. The little brown myotis (bat) has also been recorded on the Reservation.[36] Although upland fields are not their preferred habitat, the little brown myotis utilizes grasslands for feeding during the breeding season.

A number of birds utilize early successional habitats at World's End during all or some part of the year. Of the several species that breed at World's End, most require open, shrubby, or edge habitats while few are true grassland specialists. Bobolink, a grassland dependent species, is common in several of the larger fields at World's End during the breeding season. Savannah sparrow and eastern meadowlark, also grassland specialists, have occasionally been observed in the fields at World's End although neither species has been documented in breeding bird surveys in recent time. Several common bird species that utilize early successional and forest edge habitats occur at World's End including song sparrow, tree swallow, eastern kingbird, northern mockingbird, Carolina wren, and red-winged blackbird. Red-winged blackbirds were recorded in at least four of the eight breeding bird plots in 2003. Uncommon breeding birds at World's End that utilize early successional habitats include brown thrasher, orchard oriole, and eastern bluebird. The fields also provide feeding habitat for over-wintering raptors such as the red-tailed hawk and the less common northern harrier (state threatened species).

Little is currently known regarding invertebrates at World's End. However, recent inventories by Brian Cassie have determined that World's End supports an astonishing variety of butterflies.[1] Forty-eight species have been documented at World's End, with an additional 28 species identified as probable or possible residents. Of those butterfly species observed to date, five species have been recorded as "Massachusetts record single-day, single locality counts", including pearl crescent (1600), little wood satyr (7300), common ringlet (3000), long dash (195), and Hobomok skipper (30). Several rare butterfly species have been observed including the variegated fritillary, sachem,

pipevine swallowtail, and hickory hairstreak. The large upland meadows of World's End support grasses and wildflowers that provide larval food plants and adult nectaring plants for many of the observed butterfly species (e.g., pearl crescent, variegated fritillary, common ringlet, sachem, and long dash). While fields provide critical habitat for many species, early successional environments (e.g., brushy fields and old field habitat) are essential for others such as the juniper hairstreak (a probable resident) whose host plant is eastern red cedar.

Most early successional habitat at World's End occurs in relatively dry, upland settings, therefore, limiting its value to many species of amphibians and reptiles. In addition, the overall lack of freshwater resources at World's End, which many herp species rely on for breeding habitat, is scarce.

Grassland-dependent Birds. The fields of World's End host at least two bird species, bobolink and eastern meadowlark, that require grasslands for breeding. Bobolinks are long-distance migrants that over-winter mainly in central South America, and are known during the breeding season for their striking black and while plumage and noisy, bubbling songs. They begin arriving in Massachusetts during the first week of May[1], with breeding activity typically occurring between May 25 and July 5. While most grassland breeding birds require large grassland tracts for breeding, bobolinks will nest in fields as small as five acres. In New England, optimal nesting habitat consists of dense, older stands of taller grasses with little or no alfalfa and legume cover, high litter cover, and scattered broad-leaved forbs to provide nest site cover.[4] Caterpillars, grasshoppers, and beetles are the primary food source for adult birds and nestlings during the summer. Although bobolinks are common in many hayfields throughout the northeast, their numbers have declined since the mid-1900's as agricultural fields have reverted to forest.[41] Early and more frequent mowing (before July 15th) threatens the breeding efforts of bobolinks in the remaining fields where they do occur.

Bobolinks have reliably been observed during breeding bird surveys in 2002 and 2003 in fields located on both of the outer drumlins (Plots 7 and 8) as well as in the large field on the southwest side of Planter's Hill (including Plot 4). Two or more breeding pairs have been observed in each of these locations. Male bobolinks have also been observed in fields on the north side of Planter's Hill and the west side of Pine Hill, although disturbance or field conditions may be preventing nesting from actually taking place. Based on previous surveys, the distribution of bobolinks identified during the breeding season at World's End has varied. The 2000 breeding bird survey detected bobolinks in Plots 6 and 7 (on the drumlin located north of the Bar), as well as Plot 5 (northeast side of Planter's Hill) and Plot 2 (west side of Pine Hill). These findings suggest that nesting activity on the west side of Pine Hill and northeast side of Planter's Hill might be achieved if management and seasonal use activities are adjusted. The absence of bobolinks in field unit WEi-1 (Plot 6) during the 2002 and 2003 surveys suggest that field conditions may no longer be appropriate for nesting bobolinks and should be investigated. Human activity (along with unleashed dogs), plant community composition, and/or the size and configuration of fields are likely the primary factors influencing the selection of breeding sites by bobolinks at World's End.

Eastern meadowlarks, also declining regionally due to the loss of grassland habitat, are much less common than bobolinks at World's End. Meadowlarks nest in a variety of grassland habitats including grassy meadows, hayfields, agricultural grasslands of alfalfa and clover, and open weedy orchards. Typically, they require at least 15-20 acres of open fields for breeding. Meadowlarks

prefer a variety of grass heights (10-20 in.) and densities for nesting, with scattered shrubs or forbs for perching.[13] Up to two broods may be produced in a year, making the meadowlark nests and their young particularly susceptible to mowing of hayfields prior to mid-August. Insects, particularly grasshoppers and beetles, and weed and grass seeds are the most important food items for meadowlarks. While two meadowlarks were observed during both the 2000 and 2002 breeding bird surveys (outside plots), none were observed or heard during the 2003 survey. Meadowlarks typically nest only in fields greater than 15-20 acres in size, which may partly explain their absence as breeders at World's End.

The savannah sparrow is a grassland generalist that has been observed at World's End in May. However, they have not been documented during breeding bird surveys over the last five years. This species uses grasslands of all ages, tolerating successional growth, and breeding in areas of scattered saplings, shrubs and forbs. The size of most or all grassland patches at World's End is probably inadequate for breeding savannah sparrows, which requires relatively large areas of open habitat, typically on the order of 20-40 acres.

Rare Species. The grasslands at World's End support four rare species: showy goldenrod (*Solidago speciosa*), spartina borer (*Spartiniphaga inops*), hickory hairstreak (*Satyrium caryaevorum*), and the eastern bluebird (*Sialis sialis*). Showy goldenrod, currently "watch-listed" by the Massachusetts Division of Fisheries & Wildlife (MDFW)[17], typically occurs in dry fields underlain by limey soils It occurs in greatest abundance on the drumlin north of The Bar, with smaller patches elsewhere on the reservation including northeast of Damde Meadows and on the southeast-facing slope of Pine Hill (Fig. 4). The large flowers and late summer/early fall flowering of showy goldenrod attract large concentrations of insects at World's End including migrating monarch butterflies in September. Currently, there are 10-11 documented sites for this species in Massachusetts. The World's End population represents the only known extant population in the greater Boston area, with the closest populations occurring in Worcester County to the west and southern Bristol County to the south.

The hickory hairstreak is also a watch-listed species. Although the preferred food plants of the hickory hairstreak are common, it is rarely reported anywhere in the state. The caterpillar of this butterfly feeds primarily on hickories, especially bitternut hickory (*Carya cordiformis*), but oak, chestnut and ash are also reported.[12] The hickory hairstreak prefers open fields adjacent to deciduous woods and is apparently uncommon throughout its range. Bitternut hickory is a common understory tree in several forested areas adjacent to the fields. Current resource management and the continued presence of bitternut hickory should maintain this species' presence at World's End.

The eastern bluebird is currently on the MDFW's watch list[18] due to significant population declines as a result of competition from exotic species (i.e., house sparrows and starlings), pesticides, and loss of agricultural lands. They inhabit open areas such as fields and orchards, and require low cavities for nesting and perches for foraging.[4] Bluebirds have increased in numbers since the mid-1980's as a result of nesting box programs in rural and suburban areas, including World's End. At least five pairs of bluebirds nested at World's End in 2000, with others probably nesting in natural cavities. (Although eastern bluebirds were observed during the 2002 and 2003 breeding bird surveys, none were recorded within the survey plots.)

Small patches of freshwater cordgrass (*Spartina pectinata*) (Fig. 4) at World's End support the spartina borer, a moth whose occurrence in Massachusetts has been documented in only a few locations in southeast Massachusetts. Its geographic range includes the northeast coast and the upper plains states where freshwater cordgrass grows. Although currently listed as a species of "special concern" in Massachusetts, the spartina borer may be more widespread than suggested by current field data. However, the patchy distribution of freshwater cordgrass and the moth's parochial habit may explain its apparent rarity. Adult moths fly for a brief period during very late August and early September, probably laying their eggs near the rootstalk of the freshwater cordgrass.

Freshwater cordgrass grows in several locations and habitats at World's End, but mainly near the wetland/upland transition zone near Damde Meadows and in small patches in nearby fields. Annual, late season mowing probably maintains cordgrass in drier areas by reducing competition from woody shrubs, and allows the adults to emerge unmolested. Freshwater cordgrass can also be found growing along the upper edges of salt marsh along the margins of World's End. Continued tidal inundation will likely sustain these populations by limiting competition with other plant species.

3.2 Historic Values of Grasslands at World's End

The first cultivated fields in the town of Hingham were located on the drumlins of World's End. Even before the town was settled in 1634, Native Americans cleared land at World's End to grow corn.[39] Over the next 100 years, the "Old Planters" of Hingham cleared almost all of the remaining woodland left at World's End to grow rye, barley and corn. Most of the fields remained in cultivation throughout the post-settlement period, while cattle, horses and sheep owned by John Brewer were occasionally pastured on the outer drumlins. The agrarian landscape that characterized World's End for over three centuries persists to this day in the form of extensive fields, stonewalls, and fence remains that probably mark original property boundaries dating back to the late 17th century. Today, the relatively large expanse of grassland acreage at World's End echoes an agricultural past that typified almost all of southern New England 150 years ago.

3.3 Cultural Values of Grasslands at World's End

The rolling fields at World's End and the sweeping vistas they provide figure prominently in the visitor experience at the Reservation. The scenic elements that define World's End, and are most highly valued by the visiting public, include its pastoral/open character, designed landscape, unusual and expansive views, and diversity of landscape texture.[38] All of these landscape values are directly or indirectly linked to the large area of grasslands at World's End. Annual visitation at World's End has averaged 38,000 visitors per year since 1991, with about 75% of those being repeat visitors. A visitor survey conducted in 2000 indicated that nearly all visitors come to World's End to take a walk, with the majority coming to enjoy the scenery.[38] Whether the scenery is defined by long views of the surrounding bays, inlets and urbanized landscape, or vignettes contained within the immediate landscape, it is the grasslands of World's End that typically provide the context. Given that the pastoral, open landscape of World's End is an integral part of its scenic value, regular visitors have come to expect that management will preserve this aspect of the reservation.

The fields at World's End do not currently serve any agricultural purpose. However, they do have a rich agricultural history principally involving the cultivation of vegetables and pasturage for livestock.

3.4. Economic Values of Grasslands at World's End

No income has been directly generated or is currently directly generated from the grasslands at World's End[B]. However, as previously mentioned, the scenery that is a major attraction for most visitors to World's End is related in large part to the abundance of fields and other successional habitats. The summer solstice event at the top of Planter's Hill is a traditional community event that has drawn large numbers of people in recent years (up to 600). Increasingly, it has become an important source of income for The Trustees, with all monies generated directed back into the operating budget for World's End. Hayrides, music, and refreshments are featured during the event. However, without the spectacular view from the fields on Planter's Hill, it is unlikely that the event would attract many participants. Hence, the income generated from member dues, non-member entrance fees, and special events is associated, at some level, with grasslands at World's End.

[B] Most or all of the fields at World's End are unsuitable for the production of hay for forage due to the abundance of woody plants and the low quality of its grasses.

4.0 Existing and Potential Threats to Grasslands at World's End

Non-native invasive plants, plant community succession, and recreational use are among the most significant threats to the ecological values of grasslands at World's End. In addition, fragmentation of grasslands by existing tree-lined avenues and hedgerows diminishes the value of some fields to certain area-sensitive grassland breeding birds such as eastern meadowlark and bobolink. Without appropriate management, grassland habitat at World's End will likely support fewer grassland birds and invertebrates as species composition and structure shifts toward a more shrub-dominated community.

4.1 Non-native Invasive Plants

Invasive exotic plant species are common in almost every plant community type at World's End, including grasslands. The primary impact of invasive exotic plants on native plant communities is the reduction of plant diversity, which, in turn, influences the variety of wildlife species supported by the plant community. Invasive plants generally share several biological traits including 1) production of large quantities of seeds; 2) highly effective dispersal mechanisms; 3) rapid establishment and growth, and 4) high competitive potential with native plant species.[19] The combination of these characteristics gives invasive species an advantage over many less aggressive, native plants.

Although much of the grassland acreage at World's End is vegetated by introduced, cool-season grasses, these species are generally not aggressive competitors with associated herbaceous plants. Non-indigenous, invasive plants, on the other hand, may quickly spread and dominate any given plant community. Based on plant surveys in 24 randomly selected plots in 2000, invasive plants comprise almost 2% of the vegetative cover in grasslands at World's End (Table 2).[38] The abundance of invasive plants is considerably greater in some grassland areas, particularly field borders, and will increase over time without management.

Table 2
Percent Cover of Invasive Plants in Fields (n = 24)
Vegetation Survey - 2000

Species	Common Name	% Cover
Rhamnus frangula	Glossy buckthorn	0.85
Rosa multiflora	Multiflora rose	0.52
Lonicera sp.	Honeysuckle	0.23
Cynanchum nigrum	Black swallow-wort	0.13
Linaria vulgaris	Butter and eggs	0.10
Celastrus orbiculatus	Asiatic bittersweet	0.06
Rumex acetosella	Sheep sorrel	0.04
Euphorbia sp.	Spurge	0.02
Ulmus sp.	Elm (exotic)	0.02
Total		1.98

Glossy buckthorn (*Rhamnus frangula*), multiflora rose (*Rosa multiflora*), honeysuckle (*Lonicera* sp.) and black swallow-wort (*Cynanchum nigrum*) currently pose the greatest threat to the fields and wildlife at World's End. Invasive shrubs form dense thickets that shade out wildflowers and grasses that provide important microhabitat for grassland wildlife (e.g., butterflies, small mammals). The dominance of invasive shrubs and vines encroaching along field edges also diminishes or eliminates other native berry-producing shrubs of value to wildlife (e.g., blackberry, viburnum, winterberry, etc.). On the other hand, the prevalence of some invasive plants may benefit certain wildlife species. For example, the abundance of multiflora rose on the landscape may be partially responsible for the northern expansion and overwintering of mockingbirds, robins and cedar waxwings. Native biodiversity is affected by invasive plants in other, more insidious, ways as well. Black swallow-wort, a member of the milkweed family, is a host plant for monarch butterflies, which lay their eggs on this exotic plant. Unfortunately, the larvae cannot survive on swallow-wort and they die, effectively reducing the number of monarchs that reach maturity.

Tree saplings of exotic invasive species, such as Norway maple, European turkey oak, and English oak, are common along field edges. Turkey oak is most common in fields on the outer drumlins, and is replaced by English oak elsewhere on the reservation. Native tree saplings, including basswood (*Tilia americana*) and quaking aspen (*Populus tremuloides*), also invade fields at World's End at the expense of grasses and herbaceous plants. The lack of aggressive invasive plant management in the grasslands at World's End will gradually reduce species biodiversity, including rare and uncommon species.

4.2 Plant Community Succession

The grasslands at World's End represent an early successional stage that requires regular disturbance at relatively frequent intervals to persist. Without regular disturbance, whether natural or human-induced, the quality of grassland habitat will decline due to woody succession. The increase in woody vegetation in the fields reduces grass and forb diversity by over-shading and out-competing native plants, including rare species (e.g., showy goldenrod). The loss of high quality grassland habitat and the reduction in field size will ultimately jeopardized the existence of grassland wildlife at World's End. Loss of plant species diversity will also reduce the number and variety of butterflies and other invertebrates that contribute to the overall biodiversity at World's End.

The 2000 vegetation survey found that woody plants cover 25% of the fields at World's End (Table 3).[38] Four native woody plants (bristly dewberry, poison ivy, and two species of raspberry) account for over 20% of the woody cover in the fields. Although woody growth is common throughout many fields, it is most common around field margins and in some linear field units along the perimeter of World's End (e.g., PH-4). The increasing abundance of woody plants in the fields also has management implications. Heavy woody growth dulls mower blades, punctures tires, and prolongs the mowing of fields particularly if woody stems become tangled around the mower blades.

Table 3
Percent Cover of Woody Plants in Fields (n = 24)
Vegetation Survey - 2000

Species	Common Name	% Cover
Rubus hispidus	Dewberry	8.42
Toxicodendrown radicans	Poison ivy	5.42
Rubus idaeus	Red raspberry	4.63
Rubus sp.	Raspberry	2.10
*Rhanmus frangula**	Glossy buckthorn	0.85
Myrica pensylvanica	Bayberry	0.81
Rhus typhina	Staghorn sumac	0.71
Ulmus americana	American elm	0.65
*Rosa multiflora**	Multiflora rose	0.52
Parthenocissus quinquefolia	Virginia creeper	0.29
*Lonicera sp.**	Bush honeysuckle	0.23
Rosa virginiana	Virginia rose	0.23
Viburnum dentatum	Arrow-wood	0.08
*Celastrus orbiculatus**	Asiatic bittersweet	0.06
Prunus serotina	Black cherry	0.06
*Pyrus sp.**	Apple	0.06
Juniperus virginiana	Eastern red cedar	0.02
Populus tremuloides	Quaking aspen	0.02
Tilia americana	Basswood	0.02
Vacinium corymbosum	Highbush blueberry	0.02
*Unknown sp.**	Exotic elm	0.02
Total		25.23

* = non-indigenous plant species

4.3 Early Mowing

While mowing is an important tool in maintaining grasslands and preventing field succession, proper scheduling is critical for the conservation of grassland breeding birds. Most of the grasslands at World's End are mowed on an annual basis after July 15th to allow nesting grassland birds to fledge young and to promote a diversity of wildflowers for the benefit of invertebrates. Mowing prior to this date in fields used by nesting birds would probably destroy nests and juvenile birds and may eliminate wildflowers that are essential caterpillar food plants and adult nectaring plants.

4.4 Recreation

World's End is one of The Trustees of Reservations' most popular destinations, attracting over 38,000 visitors every year.[38] In general, the impacts to grassland wildlife by the visiting public are minor since most visitors stay on the trails and cart paths. Trails that traverse fields (e.g., unmapped trail on the north side of Planter's Hill) may fragment fields and further limit the available breeding habitat for grassland birds. Unleashed dogs also pose a significant threat to grassland wildlife, especially nesting birds, which are sensitive to frequent disturbance. Despite a policy instituted by The Trustees' in 1995 prohibiting dogs except on a leash, many visitors continue to ignore this rule. In addition, house cats are frequently observed near the entrance to World's End. Cats are effective predators on small mammals and may pose a significant threat to ground nesting birds at World's End.

5.0 Grassland Management Tools and Feasibility Assessment

5.1 Introduction

The World's End Management Plan[38] identified the need to preserve both scenic and biodiversity values associated with grasslands at World's End. In order to meet these objectives, a management strategy is needed that maintains the existing grassland/early successional mosaic and preserves the resources necessary to meet the specific grassland conservation targets identified in the management plan. The conservation targets identified in the Management Plan for World's End include native grassland patches, grassland wildlife (nesting birds and butterflies), rare species, and plant diversity.

Several management tools and techniques have been employed to maintain and restore the open habitat required by early successional species. Cultural grasslands in the northeast were created over historic time by a predominantly agrarian society that cleared the land by hand and often maintained its open character with grazing livestock. The management tools used today basically seek to imitate the collective efforts of countless farmers and their livestock albeit on a much smaller scale.

Managing the grasslands at World's End to achieve scenic and conservation objectives is complicated by the fact that no single management strategy will achieve each of the goals uniformly. Control of woody vegetation that is invading the fields at World's End is perhaps the most pressing management need. Reducing or eliminating woody plants, however, requires aggressive management techniques that would likely conflict with management that promotes grassland bird productivity or sustains rare species (e.g., showy goldenrod) and invertebrates.

Land management, particularly as it applies to early successional communities, is an inexact science and the impact of various management practices in maintaining open landscapes is not clearly understood. Thus, a conservative and adaptive approach to managing the grasslands at World's End is necessary to allow flexibility in management practices over the long-term. Resource monitoring (e.g., birds, vegetation) at World's End will be critical over the coming years, allowing The Trustees to evaluate the effects of management and shift management as needed to achieve the desired conservation objectives.

5.2 Management Tools and their Feasibility

Several management tools are available to restore early successional landscapes including mowing, prescribed fire, grazing, herbicides, hand clearing, or a combination of the above tools. A number of questions must be asked when evaluating the feasibility of any management option at World's End:

- How practical is this tool in achieving the desired scenic and conservation goals?
- How well does the management option fit with the unique physical setting at World's End (i.e., hilly, open terrain insulated by bay waters)?
- Will the tool pose a safety hazard to visitors or nearby residences?
- Will the tool have negative impacts on rare species and sensitive resources?
- Can results be achieved with a reasonable amount of effort? What are the short and long-term dollar costs?
- Does the tool provide a sustainable management option over the long-term?

Each of the management tools are described and evaluated for use at World's End based on the above considerations.

5.2.1 Prescribed Fire

Fire is an important process in maintaining grasslands, as well as many other ecological communities. The ecology of fire-dependent habitats depend on periodic burns to maintain the specific conditions required by plants and animals adapted to them. Historically, lightning ignited fires on the landscape. Native Americans also used fire to clear land for agriculture, improve forage for game species, enhance berry and acorn production, and to ease travel. Although Native Americans had established plantings on World's End before the arrival of the first colonists[39], the use of fire by Native Americans for clearing land at World's End is undocumented.

Most research on prescribed fire pertains to warm-season grasslands, while little is known regarding the use of fire on cool-season grasses[25,20] that comprise the majority of fields at World's End. In southeastern Massachusetts, prescribed fire has been limited largely to pine barrens habitat in Plymouth County.

The Benefits of Prescribed Fire

Prescribed burning is the controlled application of fire to accomplish a specific conservation or land management goal. Land managers use prescribed fire as an effective means of plant community restoration, rare species management, and invasive species control. Prescribed burning also mitigates fire hazard risks by reducing fuel loads (i.e., deadwood, plant litter), thereby reducing the threat of catastrophic wildfire. Burning early successional habitat may stimulate grass and forb production, although it can sharply reduce the number of some species. Controlling the intensity of a prescribed burn and its attendant ecological effects is more difficult, and can generally be done only by scheduling the burn for a specific season.

Timing of the Burn

The effects of fire on the ecology of early successional communities vary depending on the time of year when the fire is set. Summer (or growing season) fires typically burn deeper into the soil (due to lower soil moisture) than spring (or dormant season) fires, killing the roots of woody plants and consuming more soil organics. Thus, summer burns typically are more effective in reducing woody growth and restoring early successional conditions.[26] Spring fires, on the other hand, may control but not eliminate shrubby growth since below-ground carbohydrate reserves remain available to support the growth of new sprouts.[30] Invasive plant control using prescribed fire can be maximized by conducting burns during periods of low below-ground carbohydrate storage (i.e., immediately after spring flushing and growth), followed by a second growing season burn before carbohydrate levels are replenished.

The timing of prescribed fire influences plant species composition and structure.[7,33,30] Dormant season burns generally favor warm-season grasses, while summer (or growing season) burns favor

cool-season grasses.[34,5] Spring burning may also increase the abundance of late season forbs, such as goldenrod spp.[20]

The direct impacts of prescribed fire on wildlife also largely depend on timing, with late spring or early summer fires interfering with nesting birds, while late season burns may impact invertebrate populations or, in the case of World's End, rare species such as showy goldenrod. Although periodic growing season burns (June to September) would be optimal for controlling or eliminating woody plants in the fields at World's End, prescribed fire before July 15 in the larger fields would impact grassland nesting birds. However, breeding activity by grassland birds has been documented from only 5 of 19 grassland units at World's End. The total acreage of the five grassland units that support nesting grassland birds is approximately 50 acres, leaving the remaining 50 acres available for potential burning with little or no impact on grassland birds. The effects of prescribed fire on sensitive species can be mitigated by limiting the size of the burn and allowing species to re-colonize burned areas from nearby refugia.

Size and Frequency of Burn

The size of any given burn at World's End would be controlled by the size of the grassland unit. Burns may not be practical in small field patches (2 acres or less) or irregularly shaped fields with significant forest edge. Prescribed fire at World's End may also damage trees along avenues that border many of the fields. The frequency of prescribed fire treatments often dictates its effects on the landscape. While frequent burning may eliminate fire sensitive species from the landscape, it may not eliminate some persistent species without more aggressive measures such as herbicide applications or combining mowing and fire.[7] Any proposed fire regimen should achieve management goals, yet allow for the recolonization of desirable species.

Although permits are still required, spot burning invasive woody plants with a propane torch is cheaper and simpler that implementing a more large scale prescribed burn. Spot burning can be used to target individual or groups of plants, and has been used to kill seedlings and saplings of buckthorn.[40] As with a larger prescribed burn, repeat burn treatments are necessary to kill re-sprouts and seeds in the soil that will germinate later. Obviously, spot burning is most appropriate for small infestations.

Ecological Effects of Prescribed Fire

The effect of prescribed fire on plants depends on the species, timing of the burn (season), and fire behavior.[29] Whether a woody plant survives a fire is related to its ability to re-sprout, the thickness of its bark, location of its root zone, and the amount of carbohydrate reserves stored in the plant's root system. Pitch pine, black huckleberry, and lowbush blueberry, for example, are fire-adapted species that are better suited to survive frequent burns than fire sensitive species such as hemlock, beech, and sugar maple.[14] Fire generally enhances the growth of native, warm-season grasses and forbs.[23] Periodic burning benefits most grassland birds (e.g., bobolink, savannah sparrow) by removing accumulating thatch, which promotes grassy clumps interspersed with bare, open areas that allow nesting birds to forage or escape predators.[13,33]

Although prescribed fire offers many potential ecological benefits to grasslands at World's End, there are several potential drawbacks. While bobolinks will nest the year following a burn, they avoid recently burned areas where all ground litter has been consumed.[13] Moreover, burning may discourage nesting by eastern meadowlarks for 2-4 years until plant composition and structure recovers sufficiently to meet its needs. Invertebrate populations, including butterflies and moths, are sensitive to fire and can be significantly reduced in number by late season burns. Summer burning would impact invertebrate populations by destroying eggs and larvae. The impact of fire on other wildlife (e.g., small mammals) may not be significant since animals can avoid fire by going below ground or moving to unburned patches of vegetation. Overall, the primary effect of fire on wildlife is habitat alteration, not mortality.[25]

Prescribed Burn Planning and Permitting

The use of prescribed fire as a management tool requires a trained burn crew (including a "burn boss"), equipment, permits, and appropriate weather conditions.[29] Most dormant season burns are performed between mid-March and the end of April, following snowmelt and before the leaf-out and the arrival of nesting birds. Although summer burns are known to be more effective than dormant season burns in controlling woody invasives, Massachusetts air quality regulations restrict most burning to the spring.[26]

A rigorous planning process is undertaken before fire is applied to determine acceptable conditions under which the burn will be conducted. Relative humidity, wind speed and direction, air temperature, soil moisture, and fuel conditions are among the factors influencing the timing of the burn. The burn plan (or "prescription") must also identify the location of firebreaks, both existing and constructed. Smoke management is a key component of the burn plan, particularly in densely developed areas similar to World's End. Prescribed burning techniques and burning during favorable atmospheric conditions can minimize public health and safety risks while still achieving management goals. Prior to applying prescribed fire, an air quality permit (5 yr. permit) must be obtained from the Massachusetts Department of Environmental Protection, as well as a burn permit from the Hingham Fire Department.[6] The local fire chief issues the burn permit on the day of the burn, and may order a burn to cease at any time if public safety is at risk. The U.S. Environmental Protection Agency must also approve the burn plan.[31] Finally, landowners abutting the burn site must be notified and a public meeting must be held to solicit public comment. The planned burn is postponed if conditions fail to meet the conditions identified in the prescription.

Costs of Fire

The costs associated with prescribed burning include labor, equipment, planning, administration, and monitoring. The development of a burn plan raises the initial costs, as does equipment, staffing and training, if none is available. In addition, an experienced burn boss is required to direct any controlled burn. Prescribed burns for ecological restoration are currently performed by a seasonal fire crew employed by The Nature Conservancy, as well as volunteer crews consisting of individuals from many organizations including The Trustees. Unfortunately, fire crews have been unable to keep pace with the demand for prescribed fire. The current average cost for prescribed burning, once the burn plan, staffing, equipment, and training are in place, is roughly $300 per acre.[28] In

general, the overall costs of using prescribed fire can be lowered by burning larger patches and partnering with local fire departments or state agencies (e.g., DEM) that have trained staff and equipment. However, additional expenses would be incurred if prescribed fire were used at World's End; these costs would include: community outreach to inform the public of the goals of prescribed burning, coordination with burn partners, and lost income due to closure of the Reservation while burning was taking place. Resource monitoring costs will exist regardless of the management tool used.

Practical Considerations of Prescribed Fire at World's End

Due to smoke and public safety concerns, only spring, or dormant season burning is likely to be permitted at World's End. As previously mentioned, dormant season burns generally have little impact on woody vegetation, the reduction of which is the primary management goal at World's End. However, limiting burning to the dormant season avoids several limitations for prescribed fire at World's End including grassland nesting birds, insect populations (particularly butterflies), and rare plants. Assuming prescribed fire is limited to the dormant season, its function would mainly be to reduce plant litter buildup, eliminate fire sensitive plant species (if this is desirable), and to stimulate herbaceous growth by cycling nutrients back into the soil.

Since prescribed burning is labor and equipment intensive, it is most cost effective as a management tool for successional landscapes typically larger in size than those existing at World's End. The use of prescribed fire at World's End is complicated by the relatively small size of field patches and their fragmentation by tree-lined avenues. Many field units are rectilinear in shape, small in size (most 8 acres or less), and characterized by relatively high amounts of edge with little interior field habitat. The close proximity of forest edge in most, if not all, fields increases the risk that fire may damage tree crowns or escape into adjacent forest where fuel loads may be higher. However, the cost effectiveness of burning small field patches is minimized if the patches are adjacent to one another and can be treated as one unit.[28] In addition, collateral damage to adjacent woodland and tree-lined avenues can be minimized or avoided by modern prescribed burning techniques (e.g., wetting grass around trees). In all likelihood, only the larger fields suitable for nesting grassland birds (approximately 50 acres) would be burned, although other small fields could be burned if time allowed.

The Regional Ecologist (or other TTOR staff) would likely lead the effort to organize a burn crew, prepare the burn plan, obtain necessary permits, and act as the primary contact between burn partners and The Trustees. Training would be required upfront before the Regional Ecologist can perform any of these functions. The Nature Conservancy, which performs most of the prescribed burning in Massachusetts, focuses most of their efforts on rare species habitats such as barrens and fens, and would not likely view burning at World's End as a priority.[28] Therefore, any prescribed burning at World's End would probably entail the participation of local fire department and state agency staff (e.g., DEM), as well as TTOR staff. The local community would also need to be informed (and educated) regarding the use of controlled burning well ahead of any planned burn activities.

The aesthetics of controlled burning is an important consideration given that World's End is one of The Trustees most popular reservations. World's End draws over 38,000 visitors every year, most of

which come to walk and enjoy the scenery.[38] Many visitors may find the blackened fields and residual smoke from prescribed burning objectionable. While smoke from a controlled burn can be managed by proper planning to minimize or avoid public health and safety concerns, smoke management is a major concern due to the proximity of dense residential development.

Table 4
Prescribed Fire – Summary

Management Tool	Advantages	Disadvantages	Practical Considerations and Estimated Costs
Prescribed Fire	• Reduces build-up of plant litter that retards new growth. Heavy thatch also creates unfavorable nesting habitat for some grassland birds. • Stimulates grass and forb production by releasing nutrients into the soil. • Can control species composition and structure depending on burn timing. • Produces a patchwork of burned and unburned habitats due to variability in fire temperature, intensity, and rate of spread.	• Will damage or kill fire sensitive plant species. • Can only be applied once every few years in order to allow plant regeneration. • Discourages nesting of some grassland birds for a year or more following the burn (e.g., bobolink, meadowlarks). • Impacts sensitive butterfly and moth populations and kills eggs and larvae (growing season burns).	• Estimated cost = $300/acre minimum • Highly regulated in the Northeast. • Smoke and public safety concerns may limit burns to dormant (spring) which will not likely achieved management goals of woody plant removal. • Requires trained crew and large amount of equipment. Trained crews are very limited. Initial training and equipment costs are high. • Requires rigorous planning process (i.e., prescription), and application requires precise conditions. • Smoke management important to prevent impacts to densely developed area surrounding World's End. • Visitor impacts (e.g., aesthetic, temporary closures of parts of reservation) may affect Reservation use. • Spot burning may be useful for treating small areas of well-established invasive shrubs.

5.2.2 Mowing

Mowing has been used to maintain hayfields in the northeastern United States since the arrival of the earliest European settlers. Today, mechanical mowing is commonly used for maintaining grasslands and other early successional communities. The Trustees of Reservations has maintained the formerly cultivated lands on World's End by mowing since 1967. The 1971 Master Plan for World's End recommended mowing fields on Planter's and Pine Hills on an annual basis and fields on World's End (outer drumlins) once every three years.[36]

To date, the fields at World's End have been managed primarily for their ecological and scenic value, allowing for a flexible mowing schedule. However, annual mid to late season mowing has not reduced the abundance of woody vegetation and may, in fact, be increasing the density of certain shrub species.

The Benefits of Mowing

Mowing has several advantages over other management tools, particularly in terms of flexibility in mowing frequency and timing. For example, a field can be mowed more than once in a given year or season, and can be cut regardless of its shape or size. In addition, mowing can also be done virtually any time during the growing season to avoid impacting key plant or animal species. Mowing also allows the land manager to select a desired vegetation structure by adjusting the height of the mower blades. Control of target woody species can be optimized by adjusting the mowing schedule to a time of year when carbohydrate stores are the lowest in below-ground storage organs.[29] As with other management tools, the timing of the treatment may be more important than the type of treatment itself in controlling invasive plants.[30]

Ecological Effects of Mowing

Mowing affects the ecology of grasslands by altering plant species composition and structure, woody plant growth, and the quantity of plant litter. How a plant community is affected by mowing depends largely on the timing and frequency of the cut, as well as the intensity of cutting (i.e., number of passes) and blade height.[29] Annual mowing is generally thought to control invasive woody growth while maintaining grass and forb species diversity.[44] Frequently mowed grasslands support fewer plant species and support less structural diversity by eliminating plants intolerant of regular disturbance (i.e., forbs) and favoring grasses that withstand regular cutting. Mowing also results in the accumulation of plant litter (unless cuttings are removed), which impedes the movement of grassland birds (e.g., affecting foraging and predator avoidance). In addition, thick duff accumulations may inhibit the germination of some plants. .

Mowing impacts wildlife species via direct mortality, loss of food sources, and changes in plant structure that reduces cover for birds and small mammals. Mowing can also eliminate food sources for certain wildlife. For example, fields cut during mid-late season may destroy host plants for butterfly larvae or plants that supply nectar for adult butterflies (e.g., goldenrod, aster, milkweed, etc.). Larval development and adult survival of many butterfly species is dependent on specific plants (e.g., monarch butterfly and milkweed association). Grass cut before it reaches 14 inches tall

lowers seed production, which may impact small mammal populations and the raptors that hunt for them.[37]

However, the impacts of mowing can be easily minimized by reducing the frequency of mowing, leaving some field patches unmowed, and adjusting mower height to leave 8-10 inches of standing grass to provide habitat for small mammals. Mortality can also be reduced by mowing from the interior of the field toward its periphery, which prevents the "herding" of small mammals toward the center of the field where they may be killed by the mower.[42] In fields where nesting birds exist, mowing impacts can be minimized by leaving approximately 25-50% of the field uncut around the nest until the birds have fledged their young.

The timing of mowing is critical to the reproductive success of grassland breeding birds. Although young birds may be observed by late June, some species (e.g., eastern meadowlark and savannah sparrow) raise a second brood, which fledge in late July. Therefore, early cutting (before July 15) can destroy the nests of grassland birds, while cutting before August 1 may kill fledgling birds from the second brood. Some species, including bobolink, eastern meadowlark, and red-winged blackbird, will abandon fields mowed during the breeding season.[34] Delaying the first cut until at least July 15 improves the chances of survival for nesting grassland birds and their young.

Mowing performed any time during the growing season results in direct and indirect mortality to small mammal and invertebrate populations, including larval forms of moths, butterflies and other insects. The reduction in herbaceous plant cover by late season mowing may expose voles and other small mammals to higher predation risk during winter, as well as reduce the quantity of weed seeds for wintering birds and small mammals.

Mowing is most effective in controlling woody growth and other undesirable plant species when timed to the plant's maximum growth. In general, woody plants are most vulnerable to the effects of mowing during the growing season when they are expending resources toward production of leaves and reproductive structures. Late season perennials (e.g., composites) may be more susceptible to late summer mowing when much of their biomass is above-ground. Mowing may also have the unintended affect of dispersing certain invasive exotic plants within and between fields.

The Costs of Mowing

Mowing is currently the primary grassland management tool at World's End (refer to Section 2.2). Costs associated with mowing include labor (man-hours), fuel, parts, and routine and non-routine maintenance costs associated with the tractors and mowers. The overall costs associated with grassland management at World's End are minimized by the current practice of mowing once per year. However, current management practices have allowed woody vegetation to encroach on many of the fields, placing additional stress on the equipment and dulling mower blades more quickly.

Routine maintenance costs associated with mowing include the cost for fuel, grease, hydraulic oil, and other fluids. Non-routine costs often depend on the frequency and duration of equipment use, and include repairing flat tires, sharpening mower blades, and other equipment repairs. The condition of the fields is equally important is projecting the future costs of non-routine maintenance tasks. Heavy woody plant growth will quickly dull mower blades, perhaps requiring daily

sharpening. Moreover, mowing with dull blades may result in stems becoming tangled around the mower blades, potentially damaging the equipment. The presence of stones in the fields may also damage mowers. Finally, the overall costs of maintaining the fields at World's End must consider the depreciation of existing equipment (e.g., tractors, mowers).

The estimated annual costs for one-time mowing all of the fields at World's End is approximately $20,000, or approximately $200 per acre (Appendix 1). This estimate includes the cost for mowing all fields and brush cutting along field edges and around tree-lined avenues. Due the time-intensive nature of cutting around the many ornamental trees, the actual cost of mowing the fields at World's End may be lower than $200 per acre.

Practical Considerations of Mowing at World's End

Since The Trustees currently manage the fields at World's End by mowing, the management infrastructure (i.e., mowers, repair facilities, trained staff, etc.) is already in place. Therefore, no outside contractor is needed to perform this management. In addition, visitors to World's End are generally accustomed to mowing as the primary land management tool at the Reservation. However, more intensive mowing may be required to achieve the stewardship goals identified in the World's End management plan. Additional mowing effort at World's End will also exact greater costs to field operations in terms of additional staff time, and increased fuel, maintenance, and repair expenses.

Table 5
Mechanical Mowing - Summary

Management Tool	Advantages	Disadvantages	Practical Considerations and Estimated Costs

Mowing	• Flexibility in frequency and timing of mowing treatments. • Can be applied in field of any shape or size. • Ability to target field units too small to be burned. • Can select desired vegetation structure by adjusting mower blade height. • Can avoid sensitive resources (e.g., rare plants).	• Results in thatch build-up that is unfavorable to some grassland nesting birds and suppresses the germination of some plants. • Creates a uniform vegetation structure. • Mowing schedule may be restricted by nesting birds and other sensitive resources (e.g., rare plants). • Late season mowing may kill host plants for butterfly larvae and/or nectar sources for adults. • Grass cut before seed set reduces a food source for small mammals and raptors that hunt them.	• Estimated cost = $200/acre (maximum) • Trained staff and mowing equipment currently exists for managing fields at World's End. • More intensive mowing may be needed to achieve management goals (i.e., increased staff time). • Wear and tear on equipment will result from increased mowing effort.

5.2.3 Prescribed Grazing

Livestock farming, particularly with sheep and cattle, played an integral role in New England agricultural economies during the 18th century and the first half of the 19th century. During the mid-1800's, sheep and goats were pastured on land that was to become Whitney and Thayer Woods, a Trustees reservation located within two miles of World's End. Although livestock may have pastured on Rocky Neck and occasionally on the outer drumlins of World's End, grazing was not an important component of the agricultural history of World's End.[39]

Livestock grazing has been successively used as an effective management tool for restoring and maintaining early successional landscapes by reducing woody vegetation, promoting the growth of perennial grasses, and increasing habitat and species diversity. However, prescribed grazing is an inexact science, and if applied improperly can degrade natural systems by eroding and compacting soils, polluting water bodies, damaging sensitive vegetation, and contributing to the spread of invasive plants.

Using Livestock Grazing as a Management Tool

Grazing effects the landscape in both positive and negative ways depending on the type of livestock used, the number of livestock deployed within a given area, and the duration of grazing. Breed selection is important in achieving management objectives since food preferences vary among species. Cattle forage primarily on grasses and shrubs, while sheep favor grasses, sedges and forbs.[42,29] However, Bellwether Solutions employ sheep to control woody vegetation along utility easements.[27] Although sheep will graze forbs and grasses before woody plants in dense, luxuriant

fields (e.g., hayfields), they generally prefer woody species over wiry grasses. Goats prefer woody plants (i.e., twigs and bark) and are able to consume vegetation that may be unpalatable to other grazing animals. Goats, unlike sheep or cattle, destroy shrubs and saplings by defoliation and debarking, and are not deterred by thorny vegetation (e.g., multiflora rose). West Virginia researchers found that goats reduced shrub cover in a pasture from 45% to less than 15% in one season,[24] while sheep required three seasons to achieve the same reduction. Sheep are more likely to overgraze grasses before foraging on woody plants, whereas goats have the opposite preference.

The foraging behavior, physiological condition, available forage, and the timing of grazing are other factors critical to a successful prescribed grazing plan. Prescribed grazing for reducing woody vegetation is most effective when target species have the maximum amount of carbohydrates stored in their above-ground plant parts. Since this typically occurs when leaf size is at its maximum, grazing allowed at this time will achieve its greatest effect.[C] Similarly, to maintain healthy grasslands, fields should be grazed in a way to allow excess energy to be stored in the root systems of the grasses. Stored carbohydrates allow grass plants to recover from grazing pressure and winter dormancy. Insufficient energy storage due to excessive grazing will result in reduced plant vigor and degraded pastures.[9] Other considerations when selecting a breed include maintenance requirements and the ability of a species to fend off predators (neither wild or domestic predator control is likely to be a concern at World's End).

Since different livestock types forage on different plants, continual grazing over time by a specific breed will result in a gradual decrease in the preferred food plant with a proportional increase in the less palatable plant species. Selective grazing by livestock without appropriate management oversight may significantly influence the composition and structure of plant communities. Exceeding forage supplies within a grazing area for a short duration will force livestock to graze on non-preferred species. However, allowing the preferred forage plants (typically grass and forbs) to recover is critical in maintaining habitat and species diversity.

Manipulation of stocking density and stocking rates is critical if the management goal is to reduce or eliminate woody vegetation or a particular nuisance plant species. The response of vegetation to grazing is influenced not only by the number of animals (i.e., stocking density), but the frequency, intensity, and season in which the grazing occurs (i.e., stocking rate). Two grazing systems, continuous stocking or rotational stocking, can be employed on a given site, as well as the stocking rate, to achieve the desired management goals.

Continuous stocking, or free range, allows livestock to forage within a grazing unit for as long as the forage supply lasts.[9] Although this stocking technique is the simplest and cheapest to manage, it allows livestock the opportunity to selectively graze preferred plant species, while avoiding undesirable ones. Plant species diversity and structure is reduced, with the possible elimination of the preferred plants through spot grazing. If the preferred forage includes the nuisance plant species (e.g., woody and/or invasive plants), however, then this grazing system may be successful.

Rotational stocking utilizes at least two grazing units that are alternately grazed and rested. Under this system, units are monitoring for grazing impact and livestock transferred to another unit before

[C] Spring and early summer are the critical times for brush control with goats and sheep; grazing after August 1 was of negligible value.

re-growth is grazed. Selective grazing by livestock is minimized, therefore, maintaining plant species diversity over time.

Ecological Effects of Grazing

Livestock grazing, if properly managed, controls woody vegetation, promotes habitat heterogeneity, and reduces litter build-up since livestock consume the plants. The distribution of palatable and unpalatable plants results in an uneven grazing pattern, increasing plant species diversity and structure. Dung piles, which contain seeds, ultimately contribute to the mosaic of plant species and structure in the grazing unit. Although livestock grazing can be an effective land management tool, however, grazing animals can do significant ecological damage if managed in an inappropriate manner. Overall vegetative diversity may diminish as the intensity of grazing increases since livestock selectively browse preferred plants. Selective grazing may alter native plant species composition and structure, and potentially eliminate certain plant species. Grazing animals also have the potential to introduce exotic and invasive plants and/or exacerbate their spread within the grazing unit. Overgrazing can degrade grasslands and emergent wetlands, compact and erode soils (which inhibits plant seed germination), and lower water quality by increasing sedimentation and turbidity. Animal wastes in surface runoff may also elevate nutrient levels in nearby wetlands and water bodies.

The Costs associated with Prescribed Grazing

Livestock may be purchased outright or leased from local farmers or livestock owners. Leasing animals for habitat management purposes would likely be the best option at World's End due to current management need, although the purchase of a small herd of livestock would make sense if prescribed grazing were implemented by The Trustees on a regional basis (e.g., Weir River Farm and Turkey Hill). In this case, the costs associated with raising, housing, and caring for the animals would be an important consideration.

The costs to lease grazing livestock for prescribed grazing ranges from roughly $400/day to $1000/day[D]. The cost includes 300-400 sheep, 1-2 caretakers, guard dogs, fencing, water, and insurance. The client's management goals (in this case, removal of woody plants) are identified in the contract. The sheep are pastured within a two-acre temporary paddock surrounded by portable electric fencing. The area grazed by the sheep depends on several factors, including the type and density of vegetation. In areas of dense, woody vegetation, sheep will graze roughly two acres per day, while up to 10 acres a day may be grazed in more sparsely vegetated fields. To effectively reduce woody plants, fields must be grazed at least twice during the growing season (first at leaf out, then again following re-sprouting and leaf out), and generally for three consecutive years. Assuming a grazing rate of five acres per day (300-400 animals), the estimated costs for one-time grazing by sheep at World's End is roughly $100-$160/acre. However, the estimated annual cost for grazing ranges from $200-$320/acre since grazing treatments must be applied at least twice during the growing season to have any significant effect to woody plants. Although goats may be preferable to sheep for the removal of woody plants, few (or no) vegetation management companies lease them.[2]

[D] Cost estimate from Wayne Castonguay (General Manager, Appleton Farms) for leasing sheep and services from Bellwether Solutions (Concord, NH) and Sheepscapes (Surry, NH).

Practical Considerations of Prescribed Grazing at World's End

The well-defined grassland units at World's End are well suited to a rotational grazing system. However, rotational grazing requires active management of livestock to ensure that management goals (e.g., reduction of woody plants) are being met. Since continuous, "free range" grazing allows little control over the frequency and intensity of grazing events and the potential for reducing species diversity, use of this grazing method would be impractical. Both systems require an available freshwater source that is not readily available at World's End. Although livestock grazing may be a practical means of controlling woody vegetation within powerline corridors where shrub cover is the dominant vegetation type, selective livestock grazers (e.g., sheep and cattle) may graze grasses and forbs at World's End before turning their attention to woody shrubs[E]. Goats, on the other hand, prefer woody vegetation and may be well suited for controlling shrubs in field units that are dominated, or nearly so, by woody growth (e.g., PH-4C). Prescribed grazing in the spring and early summer (the season when it is most effective in combating woody vegetation) would be restricted in fields supporting nesting grassland birds.

Although few freshwater wetlands are located at World's End, the property is surrounded by coastal waters (including the Weir River ACEC) that may be impacted by waste from a large number of livestock on the site. In addition, the moderate and steeply sloping terrain characterizing much of the property creates a potential erosion hazard if field units are overgrazed. However, potential contamination and erosion issues should be minimized or avoided if grazing is closely monitored.

Visitors would likely accept and probably enjoy the sight of grazing livestock in some fields at World's End, although the presence of dogs (even when leashed) may disturb the animals[F]. The presence of grazing livestock offers a strong interpretive opportunity for The Trustees. However, livestock and farm animal interpretation at Weir River Farm (a 10 minute drive from World's End) may render this opportunity less important.

Table 6
Prescribed Grazing - Summary

Management Tool	Advantages	Disadvantages	Practical Considerations and Estimated Costs
Grazing	• Breed selection allows specific management objectives to be achieved (e.g., reduction of woody plants) since food preferences vary different types of livestock. • Flexibility in timing, duration, and intensity of grazing to allow a variety	• May cause erosion and sedimentation in water bodies and wetlands, and may compact soils. • Animal wastes in surface runoff may elevate nutrient levels in nearby wetlands and water bodies. • Overgrazing can reduce	• Estimated cost = $200-$320/acre (assumes two grazing treatments with animals grazing 5 acres/day) • Leased livestock would require the round-the-clock presence of a caretaker. • Temporary fencing

[E] Although sheep prefer luxuriant grasses over woody browse, they typically graze woody plants before wiry grasses that typically grow in unfertilized fields (W. Castonguay, pers. comm.).
[F] Visitors and dogs have had no effect on grazing animals at Appleton Farms (Wayne Castonguay, pers. comm.)

	of ecological results. • Promotes plant species diversity and reduces plant litter build-up. • Uneven grazing pattern creates diverse plant structure. • Grazing livestock can reach areas inaccessible to mowing or prescribed fire.	plant species diversity. • May damages sensitive resources (e.g., rare plants) by trampling. • Livestock may introduce in invasive plants.	would be needed to define rotational grazing units and holding pens for quarantining species between grazing units. • Liability insurance must be considered. • Dogs may disturb grazing livestock. • Erosion and sedimentation is a potential risk if fields are overgrazed due to steep slopes underlain by relatively impervious glacial till.

5.2.4 Hand Clearing

Hand clearing of invasive plants, whether woody or herbaceous plants, includes pulling plants by hand or with hand tools, cutting plants with a brush saw, etc., or otherwise disabling the plant (e.g., girdling). Although these techniques can be very specific and minimize damage to desirable plants, they are very labor and time intensive. As such, manual removal of weedy species is best suited for small infestations or where invasive plants are just gaining a foothold. Projects that involve hand clearing are facilitated most easily when volunteer help is readily available.

When hand pulling small woody plants, care must be taken to remove as much of the root system as possible to prevent re-sprouting. Plant removal should minimize soil disturbance to prevent creating germination sites for additional weeds. Weed pulling tools, such as the Root Talon or Weed Wrench can be used to remove larger shrubs (up to 2.5 inches in diameter). Cutting and girdling shrubs and saplings may be effective against pines and some oaks, but may exacerbate the problem if the plant is capable of re-sprouting from stumps (e.g., red maple, buckthorn) or root systems (e.g., black locust, tree-of-heaven). These methods may work best if combined with herbicide applications.[21]

Brush clearing with hand tools (e.g., weed whacker, brush saw, chain saw, chipper, etc.) is currently performed by property management staff to limit the encroachment of woody plants along the edges of the fields. Although hand clearing would be an ineffective means of achieving overall stewardship goals (due to the abundance and distribution of woody plants), it will remain an important tool for maintaining field margins. Other means of brush clearing, including Hydro-axe, cabling or grubbing, are unlikely to be used on the property except in rare instances by a contractor if woodland is cleared to create additional field habitat.

Table 7
Hand Clearing - Summary

Management Tool	Advantages	Disadvantages	Practical Considerations

Hand Clearing	• Plant specific removal technique that avoids impacts to desirable plants.	• May increase the density of certain woody plants that re-sprout from cut stumps. • Can result in soil disturbance and/or compaction that may encourage colonization by invasive exotic plants.	• Labor intensive and time-consuming activity. Unsuitable for large scale field restoration. • Best suited for small infestations or where invasive plants just gaining a foothold. • May be implemented most easily as a management tool where a volunteer pool is available.

5.2.5 Herbicides

Herbicides are an effective and economical option in managing specific unwanted woody and herbaceous plants in early successional landscapes. Previous studies have found that herbicides are effective in controlling some of the most common invasive plants at World's End (e.g., European buckthorn, multiflora rose).[15,16] Although the use of herbicides presents potentially lethal effects to non-target plants and animals, selecting the appropriate type of herbicide to be used and the method of application can minimize or avoid harmful effects. Most herbicides kill plants by altering or disrupting one or more of their metabolic processes. Since most herbicides sold today affect biochemical pathways specific to particular plants, they exact little or no impact on animals.[40] The chemical composition of an herbicide dictates its "mode of action" and its effectiveness in affecting any given plant. Therefore, if one herbicide is ineffective, another type with a different mode of action may provide better results.

The formulation of an herbicide includes its active ingredient(s), any additives that improve its effectiveness, stability, or ease of application (e.g., surfactants, or other adjuvants[G]), and whether it's available in spray, liquid, or dry solid form. The species to be treated and application method will determine which formulation is most appropriate for use.

Behavior in the Environment

[G] Adjuvants are added to pesticides to facilitate mixing, application, or pesticide efficacy, and allows manufacturers to customize a formulation that is most effective for a particular situation. Surfactants, one the most important adjuvants, facilitate the movement of the active herbicide ingredient into the plant.

Herbicides dissipate in the environment due to the movement, degradation, or immobilization of their constituent compounds. Degradation occurs as an herbicide decomposes into smaller chemical compounds through photochemical, chemical, and/or biological (microbial metabolism) reactions.[11] Most herbicide degradation occurs through biological means, which yields several compounds ("metabolites"), each having its own chemical properties including toxicity, adsorption capacity, and resistance to further degradation. Some metabolites are more toxic and/or persistent than the parent compound.[40] Degradation processes vary based on numerous factors, and, in some cases, their effectiveness in the field is not clear. Herbicides may be immobilized by adsorption to soil particles or uptake by non-susceptible plants, effectively arresting the herbicide's movement in the environment. However, both of these processes are reversible (i.e., once the plant dies and decomposes) and, in general, adsorption can retard the rate of herbicide degradation. Finally, herbicides dissipate through volatilization or movement through the environment in surface water or groundwater.

The solubility of an herbicide in water is probably the most important factor in determining its fate in the environment. Water-soluble herbicides are generally more mobile in the environment (and, thus, subject to more microbial activity and other degradation processes) than ester-formulated herbicides, which are relatively insoluble in water, adsorb quickly to soils, and penetrate plant tissues more readily.[40] The persistence of an herbicide is described by its half-life, which is defined as the time it takes for half of the herbicide applied to the soil to dissipate. However, the actual rate of dissipation is strongly influenced by soil characteristics, weather (especially temperature and moisture), and the vegetation present at a site. Herbicides can contaminate water bodies by direct overspray, vapor drift (of spray herbicides), leaching into groundwater, or if they are transported by surface runoff. An herbicide's behavior once it reaches water is dictated by its solubility in water, as well as the acidity of the receiving water body. The formulation of the herbicide (i.e., whether it contains salts, acids, or esters) also determines its behavior in water.

Toxicity in the Environment

The toxicity of an herbicide may, in some cases, be less than the toxicity of adjuvants (e.g., petroleum solvents) that are added to it or impurities resulting from the manufacturing process.[40] An herbicide's toxicity is described by its LD50, which is the dose (orally or dermally) of an herbicide's active ingredient that kills half of the study animals.[29] The LD50 is typically reported in milligrams of herbicide per kilogram of animal body weight (mg/kg); therefore, the lower the LD50 value, the higher the acute toxicity of the active ingredient.

Similarly, the toxicity of an herbicide to aquatic organisms can be gauged by its LC50 value, which is the concentration of herbicide in water that would kill half of the study animals.[40] Generally speaking, ester formulations are more lethal to aquatic organisms than salt or acid formulations since they pass more readily through the skin and gills of aquatic species and are less likely to be diluted in water. The long-term impact of herbicide use on soil microbes is not well known.[40]

Some commonly used silvicultural herbicides are reportedly non-toxic to wildlife and do not bio-accumulate.[29] However, the potential for many herbicides to adversely affect wildlife by ingestion still exists. The broadcasting of non-selective herbicides can reduce insect diversity in northeastern grasslands over the short and long-term period.[7,42] In general, however, the direct toxicity of

herbicides on non-target plants and animals often result in less important effects than habitat alterations caused by killing the target species.[22,40] For example, the loss of weed species may result in reduced winter food supplies or less cover habitat, exposing birds or small mammals to predation. In addition, herbicides may render some food items unpalatable to wildlife and inhibit foraging.

Herbicide Selection and Use

The selectivity of an herbicide and its method of application should be determined prior to its use. Some herbicides are not effective against certain plants, or whole groups of plants, because they are manufactured to target specific biochemical pathways.[40] In most cases, herbicide applications should avoid or minimize impacts to non-target plants (e.g., rare species). An herbicide's potential for vapor drift should also be considered. Herbicide application methods range from broadcast spraying (least selective) to injection (most selective). Stump, or basal bark painting is an example of an intermediate application technique. Although labor intensive, the "cut and paint" method of herbicide application can be expedited if applied with a brush saw outfitted with an herbicide applicator[H]. An herbicide's effectiveness is maximized if applied in the fall when most of the plant reserves are transported to the roots. Since many woody plants are capable of regenerating above-ground plant structures, herbicides that kill root systems offer the most effective form of succession management.

Practical Considerations and Costs of Herbicide Use at World's End

Careful analysis of the overall impacts of herbicide use on conservation targets, other native species, and the ecological system will precede any use of chemical controls at World's End. To minimize secondary impacts to visitors, water resources, and wildlife at World's End, herbicide use would generally be applied on a selective basis. Spray herbicide applications over very limited areas may be warranted in certain instances (e.g., control of black swallow-wort), but should generally be avoided due to impacts to non-target organisms such as insects[35,43]. Therefore, while herbicide use is a viable invasive plant control option, it would be limited to small infestations or where plants are relatively few and widely dispersed[I]. Herbicide applications on or near wetlands are subject to state and local wetland protection regulations.

The toxic effects of herbicides to humans are potentially significant, and the health and safety of applicators and others in the vicinity must be considered before herbicides are applied. In addition to the effects of direct exposure to herbicides by accidental spills or inhalation, lesser doses can lead to skin or eye irritation, headache, and nausea, etc. Therefore, applicators should exercise all necessary safety precautions when using herbicides and be properly equipped and outfitted. Glyphosate (the active ingredient in Rodeo and Roundup) and triclopyr (the active ingredient in Garlon and Brush-B-Gone) are two non-restricted chemicals that are effective in controlling most invasive woody and herbaceous plants.[21] Given the potential risks associated with herbicides and their use, applicators must be licensed (for applicators of general use or non-restricted use

[H] Sprout-less Herbicide Applicator, available from M.K. Rittenhouse & Sons, R.R. # 3, 1402 Fourth Avenue, St. Catherines, Ontario, Canada L2R 6P9 (Phone: 905-684-8122; Fax: 905-684-1382)

[I] Any widespread, more intensive use of herbicides at World's End (e.g., broadcasting herbicide over an entire field unit) would be limited to situations where invasive plants are threatening a conservation target and all other management options have repeatedly failed.

herbicides) or certified (for applicators of restricted use herbicides) with the Mass. Dept. of Food & Agriculture. While the cost of the herbicide itself is relatively low (e.g., Roundup-$137/gal[J]), the labor associated with proper herbicide treatment is likely to be high depending on the technique (e.g., cut and paint, brush saw with herbicide applicator) and the size of the treatment area. Additional costs associated with herbicide use include staff training, protective equipment, and periodic toxic screenings (if staff use herbicides on a regular basis).

Table 8
Herbicide Use – Summary

Management Tool	Advantages	Disadvantages	Practical Considerations
Herbicides	• Effective and economical means of eliminating invasive plants if used properly and at the appropriate time. • Herbicides are formulated to target specific plants.	• May have potentially lethal effects on non-target species. • Can reduce wildlife diversity and contaminate surface water if broadcasting non-selective herbicides. • Handling herbicides require extreme caution due to potentially significant toxic effects.	• High visitation may require the selective application of herbicides targeted to a specific plant. • Herbicide applicators need to be trained and licensed by State DFA.

[J] Ben Meadows Company, 2003 (www.benmeadows.com)

5.2.6 Re-seeding

Cool-season grasses dominate most of the fields at World's End with the exception of three small native grassland patches and one, larger patch located on the outermost drumlin (WEo-1). Although native, warm-season grasslands provide optimal breeding habitat for some grassland nesting birds; bobolinks, the most common grassland nesting bird at World's End, prefer nesting in dense, cool-season grassland habitat.

Grassland birds have nested within, or in close proximity to two native grassland patches, including the larger one on the outermost drumlin (WEo-1). Any future expansion of native grassland patches (by replacing existing cool-season grasses) would need to avoid nesting activity by grassland birds. If, in the future, additional breeding colonies of grassland birds can be established in other fields (or nesting birds abandon native grassland patches for other fields on the Reservation), efforts to expand existing native grassland patches (e.g., WEo-1) may be considered. In the interim, management efforts will focus on maintaining existing native grasses and enhancing their quality through management actions.

Table 9
Re-seeding - Summary

Management Tool	Advantages	Disadvantages	Practical Considerations
Re-seeding	• Would add plant community diversity to the fields at World's End.	• Restoration work may disrupt existing grassland breeding bird colonies. • Although native warm-season grasses are generally more favorable for nesting grassland birds, bobolinks (most common grassland nester at World's End)	• Prescribed fire or herbicides needed to initially kill existing vegetative cover, followed by periodic burns to rejuvenate field once warm-season grasses are established.

		successfully breeds in the Reservation's cool-season grasslands.	

5.2.7 Combination of Above Management Tools

Combining the use of management tools may be necessary if long-term monitoring indicates that current management practices are not achieving management objectives. As described above, advantages and disadvantages accompany each of the primary grassland management tools. Any of the options described above could be combined to create a more flexible strategy that maximizes the benefits and reduces the unwanted effects associated with any single approach. For example, mechanical mowing alone leaves cuttings that increase thatch build-up, which is unfavorable for some nesting birds (e.g., bobolink)[13] and suppresses the germination of some plants. Combining mowing with prescribed fire during the spring would provide the benefits of mowing with the ability of fire to consume plant litter and re-invigorate soils. Mowing could also be combined with a carefully monitored grazing plan to target woody plants. However, attention would be needed to ensure that livestock graze woody vegetation and not further stress mowed grasses and forbs through grazing. Combining fire and grazing would likely benefit livestock by providing fresh growth, but may promote erosion on recently burned slopes with little vegetative cover. Mowing may also be supplemented with spot herbiciding to eliminate stubborn woody plants over specific areas.

5.3 Evaluation and Selection of a Management Tool

Each of the six grassland management tools described above offers advantages and disadvantages in their application at World's End. The available management tools were evaluated based on:

1. Effectiveness in achieving the desired management goals;
2. Practical application at World's End in light of its site conditions and surroundings;
3. Potential effect on rare species;
4. Short-term and long-term dollar costs of implementing the tool, and
5. Sustainability as a management option over the long-term.

While grassland management at World's End may benefit from each of the tools under consideration, only prescribed fire, grazing, and mowing can effect the needed changes on a scale large enough to meet grassland management goals. Hand clearing and herbicides, although useful on a limited basis for removing invasive woody plants, are not practical for achieving stewardship objectives on a large scale[K]. Re-seeding of fields with native, warm-season grasses would require major alterations to the existing large fields, disrupting existing sensitive resources. In most cases, the conservation targets identified at World's End can be sustained in a grassland setting dominated by cool-season grasses.

[K] An exception may be the use of spray herbicides over an entire field unit to eliminate an invasive plant. However, any intensive use of herbicides would be limited to a specific, urgent threat to a conservation target and all other mitigation alternatives to control the invasive species have repeatedly failed.

Previous grassland management involving annual, late season mowing of the fields has not adequately controlled invasive woody plants which pose the primary threat to conservation goals at World's End. However, modifying the timing of mowing in specific field units may help achieve management objectives. The lack of a detailed plan[L] to manage early successional habitats at World's End may be largely responsible for the failure of existing management practices in optimizing the ecological value of the fields[M]. Of all the available management options, mowing is the simplest to implement since the infrastructure is already in place (e.g., trained staff, mowers, repair equipment, etc.) and is the least expensive of all options on a per acre basis. In addition, the Trustees can exert full control over its use. However, the lack of equipment (e.g., hay rake, hay balers) to periodically remove cuttings to prevent thatch build-up may limit the value of mowing for ecological management.

The absence of fire-dependent species and communities (with the exception, perhaps, of native grassland patches) limits the ecological need for prescribed fire at World's End. While prescribed burning may stimulate grass and forb production and consume organic litter, only growing season burns are effective in killing woody plants. The difficulty in obtaining permits for a growing season burn likely precludes the use of prescribed fire during the summer months[26], which would more effectively control invasive shrubs. In addition, prescribed burning may impact sensitive populations of plants and wildlife at World's End (e.g., nesting birds, rare plants, invertebrates) as well as damage landscape features (e.g., tree-lined avenues). Unlike mowing or grazing, prescribed fire can only be applied once every few years in order to allow plant regeneration. In addition, the logistics of using prescribed fire are complicated by the small size of the fields at World's End and/or their high ratio of forest edge to field. Dormant season fires, although ineffective in controlling woody plants, do provide a valuable ecological function by consuming plant litter and stimulating plant growth. Combining spring burning with late season mowing may be a viable option in the future if proposed management actions fail. (Purchasing a hay rake or baler to remove thatch following mowing would nearly serve the same function as a dormant season burn, as would grazing.) The limited number of personnel in New England trained to conduct prescribed burns may ultimately determine the feasibility of this management option.

Prescribed grazing also offers several potential ecological advantages, although management goals may not be met if livestock are not carefully monitored. As with prescribed fire, little plant litter remains in the wake of grazing animals and livestock are potentially able to reach woody plants in areas inaccessible to fire or mowing. However, in addition to being the most expensive management option and carrying a significant logistical burden, the ecological outcome of managing the fields at World's End with prescribed grazing is not sufficiently known to warrant its use at this time.

Based on review of the available management options, property management staff believes that existing mowing practices can be modified to attain management goals and conserve important ecological features (e.g., rare species, nesting grassland birds). If future resource monitoring indicates that modified mowing schedules proposed under this plan are failing to improve or, at a minimum, sustaining conservation targets, then management practices will be reviewed and adapted as necessary.

LL

[M] Although the 1971 Master Plan for World's End outlines management recommendations for the fields at World's End, the plan was apparently not implemented over the long term.

6.0 Grassland Management Plan for World's End

6.1 Introduction and Stewardship Goals

The grassland management plan is designed to preserve the ecological, historic, and cultural values of the grasslands at World's End, as well as protect (or enhance) priority grassland resources identified in the World's End Management Plan. The plan also addresses the existing threats to the grasslands at World's End. As described in Section 1.1 (Purpose of the Grassland Management Plan), maintaining a grassland/early successional mosaic that supports a diversity of species is critical to preserving the ecological integrity and significance of World's End. Within this mosaic, specific conservation targets are identified including grassland wildlife diversity (nesting birds and butterflies), native grassland patches, rare species, and plant diversity (Fig. 4). The intent of the grassland management plan is to apply appropriate management actions to meet the following grassland stewardship goals:

1. Maintain early successional habitat diversity, which, in turn, will perpetuate plant species and invertebrate diversity.

2. Sustain native grassland patches, rare species, and rare species habitat to preserve overall community and species diversity.

3. Manage fields to perpetuate existing breeding grassland bird populations, and re-establish grassland birds in large fields (PH-1, WEi-1, PiH-4) that previously supported breeding populations.

4. Maintain the pastoral, open character of World's End to preserve its cultural history and overall visitor experience.

Critical review of the available management options has identified mowing as the most feasible tool for achieving stewardship goals. Adjusting the timing and frequency of mowing treatments followed by careful field monitoring will be critical in determining the success of the plan. The plan is designed to be adaptive such that management practices can be modified in the future if they are not meeting expectations.

6.2 Management Actions to Achieve Stewardship Goals

Grassland stewardship goals identified in the World's End Management Plan[38] will be achieved through the following management actions:

1. Modified mowing schedule;
2. Tree and brush clearing along field margins;
3. Minor trail closures, and
4. Limited field expansion to enhance habitat for grassland breeding birds.

Mowing will be the primary management tool used to achieve stewardship objectives at World's End. Other management tools (e.g., brush clearing, spot herbiciding) will be used as needed to

accomplished specific objectives. For example, exotic shrubs may be removed in specific field units (e.g., field with nesting birds) by cutting and herbiciding. Minor seasonal or permanent trail closures will be implemented to mitigate potential erosion problems and to reduce field fragmentation if nesting birds are documented.

6.2.1 Mowing Schedule

The timing and frequency of mowing treatments will respond to specific management needs and conservation targets. Field units will be mowed during one or more of five periods during the growing season (late spring, early summer, mid-late summer [after August 1], early fall, and mid fall). The following summarizes the protocol and rationale for the mowing section of the grassland management plan. (Refer to Fig. 3 for field unit codes.)

- With one exception (PH-3), all fields will be mowed at least once per year. Field unit PH-3 will be mowed once every 2-3 years and managed as old field habitat to promote community diversity.

- Large field patches that support grassland nesting birds will be mowed after August 1st to avoid disturbing nesting birds and to control woody vegetation. However, mowing will be delayed until the fall in WEi-2 to avoid cutting the large colony of showy goldenrod and in WEo-1 to avoid cutting native grasses.

- Large fields overgrown by woody plants that currently do not support nesting grassland birds (but have in the past) will gradually be restored to grass and forb-dominated systems by increasing the frequency of mowing and closely monitoring the results. Restoring all large fields at World's End (PH-1, PH-2, WEi-1, WEi-2, and WEo-1) to conditions more appropriate for grassland nesting birds is a long-term goal that will be phased over the coming years. The scheduling of field restoration projects will depend on the success of previous efforts. The results of the ongoing experimental mowing study will help inform the level of effort required to rehabilitate any given field. Grassland breeding bird surveys in 2000, 2002 and 2003 suggest that breeding colonies may shift location in response to field conditions that best suit their needs. To ensure sufficient habitat for nesting birds, restoration mowing will be limited to a small area of the overall large field system, and under no circumstances will early season mowing occur if nesting birds are present[N]. Field unit "WEi-1" will undergo repeated mowing in summer 2003 and 2004 to initiate restoration of this field (Table 6).

  Other field units identified for future restoration mowing include (in order of priority): PH-1, WEo-1 and PH-2. Which fields are identified for repeated mowing in the future will depend on the presence or absence of nesting birds. The overall restoration mowing schedule will also depend on the workload of property management staff.

- Native grassland patches in PH-2, PH-6, and DM-1 will be mowed during the late spring (last week of May, first week of June) to promote native grasses. If nesting activity is

[N] The Regional Ecologist will survey fields for nesting activity prior to early season mowing.

observed in or near these native grassland patches, mowing will be re-scheduled for the fall to prevent disturbing nesting birds and to benefit native grasses. Since grassland nesting birds have colonized WEo-1 in recent years, the native grassland patch in this field unit will be mowed in early fall (if nesting birds are absent, mowing will be scheduled for late spring).

- Most perimeter fields will be mowed once in the early fall to promote diversity of plant species composition and structure. Exceptions include those perimeter fields containing showy goldenrod and rare species habitat (patches of freshwater cordgrass); mowing in these fields will be delayed until mid fall. Field unit "PH-4" (north half) will be mowed twice, once in the late spring and once in the late summer, to control woody vegetation. Mowing in two perimeter field units (PH-4 [south half] and PH-6) will be delayed until mid fall to benefit late season forbs and invertebrates.

- The margins of some large fields supporting nesting grassland birds may be mowed in the late spring or early summer to control the growth of woody plants. Woody plants are encroaching on field units WEi-2 and WEo-1 and will eventually diminish their value for nesting birds. Mowing conducted prior to July 15 in large fields supporting nesting birds will be completed under the supervision of the Regional Ecologist and will comply with TTOR grassland management guidelines.[42]

- Populations of rare species (e.g., showy goldenrod), rare species habitat, and native grassland patches will be identified in the field prior to mowing to avoid accidental cutting. Property management staff will familiarize themselves with rare species locations.

- Except where described herein, mowing practices will follow TTOR's Grasslands Management Guidelines.[42] All fields (except those less than 3 acres in size) will be cut from the inside out to avoid small mammal mortality. Mower blades will be adjusted to cut grass to a height of 8-10 inches to provide habitat for small mammals.

The mowing schedule, frequency of mowing, and conservation targets for each field unit are summarized in Table 10. Table 11 chronicles the order of mowing for all field units during the calendar year. The mowing schedule described herein is subject to change depending on monitoring results and whether management objectives are met (Refer to Section 6.6). The availability of property management staff and resources will also influence the scheduling of tasks to implement the plan.

Table 10
Mowing Schedule
World's End

Grassland Unit		Mowing Schedule (mowing frequency/season)	Conservation Target and/or Management Objective
PiH-1		1/yr - Early fall	Plant diversity
PiH-2			
PiH-3			Plant diversity, rare species (showy goldenrod)
PiH-4		1/yr – Late summer	Grassland birds
PH-1		1/yr - Late summer	Grassland birds
PH-2		1/yr - Late summer (Mow native grassland patch in late spring to promote native grasses. If grassland nesting birds are present, delay mowing until fall)	Grassland birds
PH-3		Every 2-3 yr - Early fall	Plant and community diversity
PH-4	North half	2/yr – Early summer and late summer	Reduce woody plant cover, rare species (Spartina borer)
	South half	1/yr – Mid fall	Rare species (Spartina borer)
PH-5		1/yr – Early fall	Plant diversity
PH-6		1/yr – Mid fall (Native grassland patch mowed in late spring)	Plant diversity, native grassland
DM-1		1/yr – Late spring	Native grassland patch, rare species (showy goldenrod, *Spartina pectinata*)
WEi-1		3/yr – Late spring, early summer, late summer	Reduce woody plant cover and restore field for grassland birds
WEi-2		1/yr – Mid fall (May need to cut perimeter 2/yr to reduce woody plants)	Grassland birds, plant diversity, rare species (showy goldenrod)
WEi-3		1/yr – Early fall	Plant diversity
WEi-4			
WEi-5		1/yr – Mid fall	Plant diversity, rare species (showy goldenrod)
WEi-6			
WEo-1		1/yr – Early fall (May need to cut field edges earlier in the year to control woody encroachment.)	Native grasslands, nesting birds, plant diversity
WEo-2		1/yr – Early fall	Plant diversity

Table 11
Mowing Schedule by Season
World's End

Approximate Mowing Date	Grassland Unit	Management Objective or Conservation Target
Late spring (last week in May or first week in June)	NG-1, native grassland patches in PH-6 and PH-2 (Delay mowing until fall if grassland nesting birds are present)	Native grasses
	WEi-1	Restore grass/forb condition
Early summer (last week of June or first week of July)	WEi-1, PH-4n	Restore grass/forb condition
Late summer (after August 1)	PH-1, PH-2 (except native grassland), PH-4n, PiH-4	Avoid disturbing nesting birds and controlling woody plants
	WEi-1	Restore grass/forb condition (WEi-1)
Early fall (last week of September or first week of October)	PiH-1, PiH-2, PiH-3, WEi-3, WEi-4, WEo-1, WEo-2, PH-3, PH-5	Control woody plants Nesting grassland birds (WEo-1)
Mid fall (mid to late October)	PH-4 (south half), PH-6 (except native grassland patch), WEi-2, WEi-5, WEi-6,	Provide habitat for late season forbs and invertebrates, showy goldenrod (WEi-2) Nesting grassland birds (WEi-2)

6.2.2 Tree and Brush Clearing

Tree and brush clearing will be completed as needed to maintain the size and quality of the fields at World's End. Larger scale clearing will improve grassland bird habitat. The following summarizes the protocol and rationale for tree and brush clearing and describes specific vegetation clearing projects.

- Woody plants will be cut by hand where necessary with weed whackers and power tools in areas inaccessible to mowing equipment (e.g., around trees along tree-lined avenues and along field margins).

- Herbicide applications to kill invasive woody plants will be considered in select situations, such as in fields where woody plants are sparsely distributed[O] or in cases where an invasive plant(s) is stubbornly persistent. Herbicides will generally be selectively applied on cut

[O] Woody plants will not be removed in fields if they are not interfering with the conservation objectives identified for the field.

stumps or by basal bark painting to avoid impacting non-target species. Herbicide sprays will be used judiciously and only when absolutely necessary (e.g., to eliminate black swallow-wort). Herbicide use will be limited to TTOR staff licensed by the Mass. Dept. of Food & Agriculture to handle and apply herbicides.

- Tree saplings and shrubs that are encroaching on field unit "WEi-1" from the summit grove will be removed to restore the field's original size and to benefit grassland nesting birds (Fig. 3).

- Approximately 2.5 acres of woodland and hedgerow adjacent to field units PH-3, PH-5, and PH-2 will be removed (Fig.3) to enhance the value of PH-2 for grassland breeding birds. (The schedule for this project will be contingent upon the availability of funding.) The southeast half of field unit PH-2 supported nesting bobolinks in 2002 and 2003. The woodland and hedgerow are currently heavily overgrown by invasive shrubs and vines. Although the removal of the dense thicket will result in the loss of cover and feeding habitat for some migrant and resident birds and mammals, the potential for increasing breeding habitat for grassland birds (bobolink, and possibly meadowlark) greatly outweighs the loss. Field unit PH-3 will continued to be managed for old field habitat following the removal of the woodland strip and hedgerow.

6.2.3 Seasonal and Permanent Trail Closures

In an effort to improve ecological values and minimize erosion, a few small sections of trail will be closed on a seasonal or permanent basis. None of the trails proposed for seasonal or permanent closure appear on the current TTOR map of World's End.

- The footpath extending from the summit of Planter's Hill to south end of The Bar will be closed if grassland birds attempt to nest in the northwest half of PH-2. The trail closure will be announced by signage (stating the reason for the closure) and by allowing vegetation to grow in the path to discourage its use. If no breeding bird activity is observed, the trail will be mowed and foot access will be restored.

- Due to erosion and aesthetic concerns, the short trail extending from the north end of The Bar to the cart part along the south side of World's End will be closed permanently. The small field bordering this unmapped trail will be mowed according to the schedule in Table 6, leaving a dense shrub thicket near The Bar to discourage future use.

- The footpath leading southeast from the top of Planter's Hill may be temporarily closed if this section of field unit PH-2 is expanded in the future. This seasonal trail closure would be warranted only if nesting grassland birds are observed in this section of PH-2.

6.2.4 Signage

Unleashed dogs and visitors straying from established trails and cart paths pose a significant threat to nesting grassland birds, not to mention the risk of other potential hazards such as poison ivy, ticks,

thorny brambles, etc. In effort to minimize disturbance to nesting birds, temporary signs will be erected in discrete, though visible locations near fields harboring grassland birds from May to July. The temporary signs will inform visitors of our conservation objective and the importance of leashing pets and avoiding travel off established trails.

6.3 Approximate Costs of the Management Plan

Completed by JF

6.4 Feasibility of the Management Plan

The grassland management plan primarily entails changes in the timing and intensity of mowing treatments to various field units at World's End. Minor seasonal and permanent trail closures and approximately 2.5 acres of field expansion (contingent on funding) are also planned. Mowers, tractors, and other equipment are currently available for implementing the plan. In addition, the South Shore Management Unit currently employs staff experienced in this type of land management. Herbicides may be used in the future on a limited basis to manage invasive plant species. However, all Trustees staff must be licensed by the Massachusetts Department of Food & Agriculture before handling or applying herbicides[P].

Can the mowing schedule be integrated into the overall work plan? Approx. cost of tree clearing for field expansion

Completed by JF

6.5 Monitoring Plan

The success of management actions in achieving the intended ecological (and scenic and cultural) goals at World's End will be measured by long-term vegetation and breeding bird data collected according to a carefully designed monitoring plan. The results of the data collection will provide the basis for adjusting management actions in the future, if necessary, to better accomplish stewardship goals. Eight grassland breeding bird plots and 24 vegetation plots (located within the 50 meter breeding bird plots) were established on a random basis in 1999 to assess the effects of management practices at World's End (Fig. 5). In addition, seven experimental mowing areas (Appendix 2) were identified in 2002 to help Trustees' staff determine what mowing frequency is needed to attain a given species composition and structure. Several of the experimental mowing areas utilize the previously established vegetation plots.

The results of the monitoring plan outlined below will be summarized in a brief year-end report by the Regional Ecologist and submitted to the Superintendent of the South Shore Management Unit with any recommendations for future management actions. Any changes in future grassland management at World's End will be presented in writing and appended to the grassland management plan, or inserted to form an updated management document for distribution. The monitoring plan is as follows:

[P] Pesticide licensing requires successful completion of a written exam and annual renewal.

- A grassland breeding bird survey will be performed annually to track the location and abundance of nesting birds at World's End. Once the desired management objective is reached (nesting grassland birds in most or all large fields [PH-1, PH-2, WEi-1, WEi-2, WEo-1]), breeding bird surveys will be performed every other year. The breeding bird survey will be conducted according to The Trustees' breeding bird survey protocol.

- Baseline vegetation data will be collected in 2003 prior to mowing to provide comparative field data for future monitoring. Vegetation plot data will be collected after two growing seasons (i.e., end of growing season) in fields subject to repeated mowing (WEi-1), and every three years (prior to first mowing) in plots located elsewhere. Fields restored to the condition desired in the plan will be inventoried (i.e., plot data) or visually evaluated at a minimum of every three years. Vegetation plot data will be collected according to The Trustees' plant monitoring and inventory protocol.

- Experimental mowing plots will be inventoried at three-year intervals[Q] until conclusive results are obtained. Vegetation plot data will be collected according to The Trustees' plant monitoring and inventory protocol. (Note: the scope of the experimental mowing program will be at the discretion of the Superintendent).

- Rare plant populations (showy goldenrod) and rare species habitat (freshwater cordgrass patches) will be visually monitored annually by the Regional Ecologist to assess the effects of mowing.

- The overall condition of the field units will be visually assessed on an annual basis to determine the effects of mowing and whether management goals are being achieved.

- Future natural resource surveys may be performed to assess the biodiversity of World's End. For example, Brian Cassie completed a survey of butterflies at World's End in 2000[1] and Ted Elliman conducted a plant species inventory in 2001[8] as part of the Boston Harbor Island National Park resource inventory.

6.6 Adaptive Management Strategy

Achieving stewardship goals for the grasslands at World's End will require time and patience, and noticeable results may not be apparent for several years. However, the monitoring plan should allow ecology staff to detect changes in the coming year or two that indicates whether or not management actions are succeeding in accomplishing these objectives. For example, field data from the annual grassland breeding bird survey or vegetation plots may suggest minor changes in management strategy. The mowing schedule for field units undergoing restoration to grass and forb-dominated systems may be altered based on data collected from the experimental mowing plots. New scientific

[Q] The Experimental Mowing plan requires two seasons of repeated mowing; field data will be collected during the third season prior to mowing in early or mid fall.

findings regarding the management of grasslands and other early successional habitats or grassland birds may also influence future management at World's End.

In all likelihood, management (and possibly monitoring) strategies will need to be adapted in order to attain these objectives in the most efficient manner possible. Examples may include the use of prescribed fire (dormant season burning) or removing cuttings by raking to stimulate herbaceous growth. Future changes in grassland management, if warranted, will be proposed in writing and reviewed by ecology and property management staff to determine their feasibility. If approved, a written summary of the revised management action will either be appended to the grassland management plan, or inserted to form an updated management document for distribution.

7.0 Summary of Grassland Management Plan

7.1 Summary of Management Objectives

The grasslands at World's End are valued for the ecological and scenic values they support. The fields also provide evidence of the property's long agricultural history, with many field edges probably representing original property bounds. The primary ecological goal of grassland management at World's End is maintaining a mosaic of grasslands and other early successional communities to promote diversity among species dependent on these declining habitats. Specific conservation targets include grassland wildlife, including grassland nesting birds and butterflies, native grassland patches, rare species, and plant and community diversity. Maintaining the fields at World's End also preserves their pastoral and scenic character, perhaps the most important management goal in the eyes of most visitors.

7.2 Summary of Management Actions

Mechanical mowing will be the primary tool to achieve the grassland management objectives at World's End. The timing and frequency of mowing treatments vary in different field units depending on the management goal. Late spring mowing will perpetuate native grasses, while mowing during early to mid fall will allow many late season forbs to complete their life cycle and provide a food source for butterflies. Fields supporting nesting birds will be mowed in late summer to control woody plants and avoid disturbing grassland birds. Where woody plants are encroaching upon large fields that no longer support nesting birds, the frequency of mowing will be increased to 3-4 times per year in order to restore grass and forb-dominated conditions. Based on current field conditions and its high potential for supporting breeding grassland birds, field unit WEi-1 is scheduled for restoration mowing until the desired field conditions are achieved. Other large fields, including PH-1, PH-2, WEo-1, will undergo restoration mowing in the coming years. Delaying management actions in field units PH-1, PH-2, and WEo-1 until more conclusive results from the experimental mowing study are gained will allow TTOR staff to complete these projects more efficiently.

Brush will be cleared in areas inaccessible to mowers using power tools, with herbicides used by licensed TTOR staff only as necessary. Shrubs and saplings growing along the perimeter of fields undergoing restoration may be removed to maintain the field's original size (e.g., WEi-1). Approximately 2.5 acres of woodland and hedgerow will be removed on the southeast side of Planter's Hill (subject to funding availability) to improve nesting habitat for grassland birds. Minor trail closures, either on a seasonal or permanent basis, will be implemented to optimize the ecological function of a field (e.g., minimize disturbance to nesting birds), reduce erosion, and/or improve aesthetics of the property. All management actions will comply with TTOR's Grassland Management Guidelines.[42]

7.3 Summary of Monitoring Plan and Adaptive Management Strategy

Future management actions will be driven by the results of long-term monitoring and adaptive management. Field vegetation and nesting grassland birds will be monitored over the long-term via standardized monitoring and inventory protocol (following TTOR guidelines) within eight grassland

plots. Additional vegetation plots are located within seven experimental mowing plots established in 2002 to analyze the frequency of mowing needed to achieve specific management objectives. Vegetation data will be collected in all plots in 2003 to provide baseline data, and after two growing seasons in fields undergoing active management (e.g., WEi-1) and every three years elsewhere. The experimental mowing plots will be also be inventoried after two cutting cycles.

Once fields are restored to the condition desired in the plan, they will be inventoried at least every three years or visually assessed at least every year to ensure that our management objectives are being achieved. The plan includes a contingency for adapting management practices if the monitoring data (and visual assessments) indicates the need to shift management practices to attain our management goals and conservation targets.

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