New England Plant Conservation Program

Sporobolus heterolepis (A. Gray) A. Gray
Prairie Dropseed

Conservation and Research Plan
for New England

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SUMMARY

Sporobolus heterolepis (A. Gray) A. Gray, commonly known as prairie dropseed, is a member of the grass family (Poaceae) that is rare in New England, but common in the prairie country of the central United States and adjacent Canada. It is a globally secure (G5) taxon. With six extant and three historical occurrences in New England, it is a regionally rare (Division 2) species according to the New England Plant Conservation Program (NEPCoP). Adapted to the dry and sunny conditions of the prairie, *Sporobolus heterolepis* is a perennial C_4 grass that forms dense tussocks and has an extensive root system that runs deep into the ground. Reproduction is sexual and pollination is by the wind. It is a grass that is easy to propagate by seed and also can be propagated by division. Because of its use in prairie restoration and in horticulture, there is ample literature on its propagation and there are many commercial seed sources. Fire, cutting, and grazing, are known to stimulate reproduction, though excess of these will have the opposite effect.

In the plains country of central North America *Sporobolus heterolepis* tends to favor dry positions in the various prairie communities, yet in the Great Lakes region, it is known from wet prairie fens and from seasonally wet alvar communities. In the forests that naturally dominate the landscapes of eastern North America, the species favors openings, or glades, associated with serpentine, limestone, and trap rock (basalt/diabase) outcrops. In New England, all but one of the *Sporobolus heterolepis* occurrences is found in subacidic rocky summit/outcrop natural communities located on the brows of mostly south and west-facing cliffs of trap rock ridges. All but the single Massachusetts occurrence are clustered in New Haven County of south-central Connecticut. Herbarium specimens document the species in Connecticut back to 1835. While long-term data are sparse, populations of *Sporobolus heterolepis* appear to be in decline due to habitat change. Shading by woody plants, including invasives in some instances, is believed to be the major reason for the apparent decline. In addition to decreasing the numbers of plants, shading is probably responsible for the relatively low flowering effort noted in 2002 surveys. Other threats to the species include park recreation development (roads, parking lots, picnic areas), hiking trails, and housing development.

To date, no conservation action has been done specifically for *Sporobolus heterolepis*. Fortunately, all six extant occurrences, plus one presumed extirpated occurrence, are on public or conservation lands. Conservation objectives for *Sporobolus heterolepis* in New England are to have one occurrence with 200 genets, two occurrences with one hundred or more genets, and three occurrences with twenty or more genets. In all the occurrences, the goal is to have 50% or more of the genets flower and set fruit. In addition to relocating historical occurrences, priority conservation actions include more careful surveys, seed collection, and notification of landowners about the plants. Secondary actions are proposed for stimulating flowering, seed production, and seedling regeneration. These include cutting of woody plants around *Sporobolus heterolepis* plants, cutting back the grass plants themselves, and controlled burns. If not found at historically known sites, reintroduction should be considered using seed collected from nearest neighbor plants.

PREFACE

This document is an excerpt of a New England Plant Conservation Program (NEPCoP) Conservation and Research Plan. Full plans with complete and sensitive information are made available to conservation organizations, government agencies, and individuals with responsibility for rare plant conservation. This excerpt contains general information on the species biology, ecology, and distribution of rare plant species in New England.

The New England Plant Conservation Program (NEPCoP) of the New England Wild Flower Society is a voluntary association of private organizations and government agencies in each of the six states of New England, interested in working together to protect from extirpation, and promote the recovery of the endangered flora of the region.

In 1996, NEPCoP published "*Flora Conservanda*: New England." which listed the plants in need of conservation in the region. NEPCoP regional plant Conservation Plans recommend actions that should lead to the conservation of *Flora Conservanda* species. These recommendations derive from a voluntary collaboration of planning partners, and their implementation is contingent on the commitment of federal, state, local, and private conservation organizations.

NEPCoP Conservation Plans do not necessarily represent the official position or approval of all state task forces or NEPCoP member organizations; they do, however, represent a consensus of NEPCoP's Regional Advisory Council. NEPCoP Conservation Plans are subject to modification as dictated by new findings, changes in species status, and the accomplishment of conservation actions.

Completion of the NEPCoP Conservation and Research Plans was made possible by generous funding from an anonymous source, and data were provided by state Natural Heritage Programs. NEPCoP gratefully acknowledges the permission and cooperation of many private and public landowners who granted access to their land for plant monitoring and data collection.

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I. BACKGROUND

INTRODUCTION

The focus of this conservation and research plan is *Sporobolus heterolepis* (A. Gray) A. Gray, or prairie dropseed, a perennial grass family (Poaceae) member native to North America. The purpose of the plan is twofold: 1) to provide background information on the species in general, including its description, taxonomy, biology, ecology, threats and distribution; and 2) to provide information on the conservation of the species specifically in New England, including its status, conservation actions to date, and proposed conservation actions. The background research on the species is used to inform conservation actions for the species in New England.

As with many, if not most, of the conservation plans for rare plants in New England being written for New England Plant Conservation Program (NEPCoP), background information on *Sporobolus heterolepis* comes from disparate sources, no biological monograph having been written for the species. It is a rewarding experience to pull it together, however. It might be viewed as a tribute to the species – its uniqueness as an organism and its ecological place in nature.

With its center of distribution in Iowa, *Sporobolus heterolepis* is principally a tall and mixed grass prairie species (citations provided in appropriate sections below). Adapted to the open country of central North America, with that landscape's attendant ecological processes of fire and grazing, the species in the forested eastern North America shows a very spotty distribution, relegated to small natural openings associated with serpentine, limestone, and trap rock (basalt) outcrops, or rarely in fen-like wetlands.

In New England, *Sporobolus heterolepis* has been known since at least 1835. It is currently, and likely was historically, a rare species in the region. NEPCoP has listed it as a Division 2 taxon; and it is currently listed as Endangered in Connecticut and Extirpated in Massachusetts. While the species appears to have undergone decline in terms of number of occurrences, more inventory work is needed to confirm its status and population sizes. Surveys associated with this plan have confirmed the need for management for the species at sites where the species is extant or historical. Threats to the species include woody plant encroachment (shading), park recreation development, hiking trails, and housing development. Conservation objectives include enhancing the numbers of plants, as well as their flowering and fruiting effort, at all six extant occurrences through a combination of management techniques. Reintroduction at the three sites where the species is presumed extirpated is proposed for consideration after populations at extant occurrences have been increased.

DESCRIPTION

Sporobolus heterolepis is a perennial grass that forms dense tussocks. As such, it is a classic bunch grass. Bunches of a single plant (genet) are typically 10-17 cm in diameter at the base, with larger ones ranging up to 45 cm. The spreading nature of its predominantly basal leaves, however, can produce an apparent vegetation cover of nine times the basal cover (Weaver 1931). In Connecticut, an exceptionally large *Sporobolus heterolepis* bunch had a basal diameter of 30 cm (Engstrom, personal observation). The bunches of this dropseed are formed of numerous, gracefully arching leaves which reach a height of 25 to 45 cm. The light green leaf blades are typically 2 mm wide or less towards the base, and then become almost thread-like in their long attenuate tips. Leaf sheaths are pilose at the throat and can be sparsely pilose on the backs (Hitchcock 1971). Several specimens examined at the Pringle Herbarium (VT) show individual culms with their associated leaf sheath bases forming swollen lateral shoots, up to 1 cm thick (Engstrom, personal observations). The flattened sheaths of specimens are mostly straw-colored and 5 mm wide or wider. Sometimes the sheaths are purplish-brown.

The flowering culms are erect and slender, 30 to 70 cm in height (Hitchcock 1971). In the field in Connecticut, culms 40-85 cm tall were observed, 50 cm being average size at one site, while at another site culms were generally 25-35 cm and the tallest 40-45 cm (Engstrom, personal observation). Inflorescences are panicles, 5-20 cm long, with ascending to spreading branches, 3-6 cm long (Hitchcock 1971). The panicle branches have relatively few spikelets clustered toward the branch tips. Spikelets are grayish and single-flowered with acuminate, unequal glumes 2-6 mm in length. Lemma and palea are of intermediate length between the glumes, with the latter slightly longer than the former. The grain is round, shiny, smooth, and nutlike (indurated), almost 2 mm in diameter, splitting the palea in maturity (Dore and McNeil 1980, Hitchcock 1971). At maturity, grain color varies from a golden-green (Engstrom, personal observation), to greenish-gray or purplish-splotched (Colbry 1957). Like all the members of its genus, the grain is not a true caryopsis because the seed coat (pericarp) is not fused to the ovary wall (Gould 1975). However, *Sporobolus heterolepis* is unique in its genus in having a firm seed coat that does not break apart, even when moistened (Colbry 1957, Chase 1959).

Gray (1857: 542) makes this note about the smell of *Sporobolus heterolepis*: "Plant exhaling an unpleasant scent (Sullivant)." In a recent horticultural description of the species Springer (2001: 38) describes the scent emitted by the inflorescence as a "strong fragrance reminiscent of Juicy Fruit gum."

The root system of *Sporobolus heterolepis* includes masses of roots and fine rootlets. In the deep soils of prairies in central North America, the root masses spread 30-60 cm horizontally and downward 1.2-1.5 m, with the great majority of the roots found in the top 15 cm of soil (Weaver 1958). Weaver found the root masses of *Sporobolus heterolepis* comparable to little blue stem (*Schizachyrium scoparium*), with which it frequently grows. However, in western North Dakota, *Sporobolus heterolepis*

had very large root masses compared to other prairie grasses, including cool-season species (Redman 1975).

Although there are congeners which resemble *Sporobolus heterolepis* vegetatively, and even in spikelet size and parts, the grain of *S. heterolepis* is distinctive (Colbry 1957). While no taxonomic sources mention closely related species, *S. interruptus* Vasey runs closest to *S. heterolepis* in the most recent keys for *Sporobolus* in North America north of Mexico (Peterson et al. 2003). They are apparently similar based on the descriptions. However, since *Sporobolus interruptus* is restricted to Arizona, the ranges of these species do not overlap. There are also a suite of species (*S. teretifolius, S. curtissii, S. silveanus, S. floridanus,* and *S. pinetorum*) from southeastern United States that have a lot of similarities with *Sporobolus heterolepis,* yet their ranges do not overlap, except for *S. silveanus* which occurs in southern Oklahoma.

In the field, clumps of *Sporobolus heterolepis* usually have an abundance of dead leaves that almost form a mat on the ground beneath the plant (Redman 1975; Engstrom, personal observation). The species is not easily mistaken for any other species when in flower or seed; the inflorescence and shining, golden-green spherical grains are distinctive. In vegetative condition, however, it can be easily mistaken for blackseed needlegrass (*Piptochaetium avenaceum*, formerly known as *Stipa avenacea*), with which it frequently grows at a few Connecticut sites (Engstrom, personal observation). The two species form similar dense tussocks with leaves of similar width and length. A few characteristics that are useful for differentiating the two species in the field include the hairs (sometime sparse) on sheath and sheath summits found on *Sporobolus heterolepis* and lacking on *Piptochaetium avenaceum*, and the leaf color, which in *Sporobolus heterolepis* is light green on both surfaces, versus the slightly blue-green upper (adaxial) surface and shiny green lower (abaxial) surface of *Piptochaetium avenaceum*. Because *Piptochaetium avenaceum* flowers early, its fruiting culms are usually on the ground by September, when *Sporobolus heterolepis* is in the height of flowering/fruiting. These old fruiting stalks of *Piptochaetium avenaceum*, however, can usually be found late in the growing season. Glume length and overall inflorescence pattern can readily differentiate the two species. *Sporobolus heterolepis* can also be mistaken for other grasses, especially *Danthonia spicata*, and some clump-forming *Carex* sp., though these species are readily separated from *Sporobolus heterolepis* when closely inspected.

TAXONOMIC RELATIONSHIPS, HISTORY, AND SYNONYMY

A member of the grass family (Poaceae), *Sporobolus heterolepis* (A. Gray) A. Gray appears to be a relatively stable taxon with no varieties described. Synonymy described below is from Hitchcock (1971). The species was originally described by Asa Gray (1835) as *Vilfa heterolepis*. Its type locality is Watertown, Jefferson County, New York, based on a specimen by Dr. Crawe. This collection by Crawe, which is thought to be the holotype for the species, is found in the New York Botanical Garden herbarium (New York Botanical Garden 2003). *Sporobolus heterolepis* is first used in Asa Gray's first (1848) *Manual of the Botany of the Northern United States*. The only synonym is

Agrostis heterolepis Wood, used in Alphonso Wood's *Class-book of Botany*, Second Edition, 1847.

The genus name *Sporobolus* is derived from Greek *spora* (seed) and *ballein* (to throw), referring to freely detaching grains (a characteristic of all *Sporobolus* is that the spikelets disarticulate above the glumes). The specific epithet *heterolepis* refers to the glumes' unequal lengths (Fernald 1950).

Within the grass family – one of the largest in the world for number of species – *Sporobolus* now falls within the subfamily Chloridoideae. In North America north of Mexico this subfamily is almost entirely composed of a single large tribe – the Cynodonteae. *Sporobolus*, along with *Eragrostis* and *Muhlenbergia*, are some of the more diverse genera in the Cynodonteae (Barkworth et al. 2003).

There is no mention of hybridization in *Sporobolus heterolepis* in the literature reviewed. Congeners that are known to grow with *Sporobolus heterolepis* in New England include *Sporobolus compositus* (Poiret) Merrill var. *compositus* (Engstrom, personal observation), and *Sporobolus clandestinus* (Biehler) Hitchcock. The *Sporobolus clandestinus* is a historical record based on specimens collected at one site in New Haven, Connecticut, nearly a century ago (Haines, unpublished data).

The chromosome number for *Sporobolus heterolepis* is 2*n*=72 (Peterson et al. 2003).

SPECIES BIOLOGY

Because *Sporobolus heterolepis* lacks rhizomes or stolons, reproduction is predominantly sexual. It is wind-pollinated like all grasses, and flowers late in the growing season, primarily August-October (Fernald 1950, Steyermark 1977, Great Plains Flora Association 1986).

The seeds of *Sporobolus heterolepis* are quite large and hard. Horticultural literature (Springer 2001) notes that the seeds are short-lived and highly palatable, presumably by rodents and insects. However, there was no documentation of seed herbivory of *Sporobolus heterolepis* in the literature reviewed. The short-lived nature of the seeds is partly corroborated by seedbank work done in an Illinois prairie (Johnson and Anderson 1986). While *Sporobolus heterolepis* dominated the groundcover at the site, it was much less frequent in the seedbank than the seed from weedy herbs. The weedy herbs were relatively unimportant as groundcover. In this same study, it was also noted that the seeds of *Sporobolus heterolepis* emerged mostly from the upper 2 cm of soil. Others suggest that the species should be a good seed banker, based on their hard, shiny nature (William Brumback, New England Wild Flower Society, personal communication).

Germination tests show that seeds stratified in dry soil for a total of ten weeks began germinating in seven days and had peak germination in 25 days (Nuzzo 1978). The species has poor establishment when direct-seeded. In another study, only slightly more seeds germinated when stratified than when unstratified (Greene and Curtis 1950). Propagation literature (Rock 1977) notes that no pretreatment is needed for this species.

There is substantial knowledge about the propagation of this species since it is now used horiculturally as an ornamental. It is also used in prairie restoration and roadside revegetation projects (Nuzzo 1978). A web search for *Sporobolus heterolepis* in 2003 using the Google search engine revealed numerous sites housing information and pictures of the species. Detailed information on greenhouse propagation protocol is provided in Flood et al. (2001). Additional information is available from commercial sources.

Given that it forms large, densely cespitose clumps, *Sporobolus heterolepis* is presumed to be a relatively long-lived perennial. In the horticultural literature, one article notes that plants reach maturity in 4-5 years and live normally 15-20 years (Springer 2001). Perhaps *Sporobolus heterolepis* plants can get much older. While Springer states that the species does not die back in the center, as some cespitose grasses do, Weaver (1931) observed that *Sporobolus heterolepis* in its native prairie habitat does die in the center with age, eventually breaking up into separate tufts that appear as a discontinuous sod. Such a dieback progression might lead to questions about genet distinction. No growth rates were found in the science literature. However, with bunches getting as large as 45 cm in diameter and dying in the center it might be that *Sporobolus heterolepis* genets can reach ages significantly older than 20 years.

While predominately a species associated with full-sun settings, such as prairies, *Sporobolus heterolepis* does occur in woodland settings in central North America (Great Plains Flora Association 1986, Yatskievych 1999). Also, in Connecticut, it occurs in woodlands where it tolerates some shade, though the shade appears to be suppressing its flowering abilities (Engstrom, personal observation). Horticultural literature notes that the species needs at least six hours of sun, but prefers full sun (Springer 2001).

According to Gould and Shaw (1983) all the members of the Chloridoideae subfamily, including *Sporobolus*, have the C_4 photosynthetic pathway. A specialized cell anatomy, in combination with this chemical pathway, allows C_4 plants to more efficiently utilize carbon dioxide. C_4 grasses are adapted to hotter, drier, sunnier conditions than counterpart C_3 species. Ode et al. (1980) make the assumption that *Sporobolus heterolepis* is a C_4 grass based on its warm-season character, i.e. greatest photosynthetic activity in midsummer.

Sporobolus heterolepis is a mycorrhizal grass. While the grass may benefit from this fungal relationship, as mycorrhizal studies have shown for some species, *Sporobolus heterolepis* does not appear to be limited by mycorrhizal fungi, at least in some prairie situations. At two remnant prairie sites in Illinois, Ebbers et al. (1987) found that vesicular-arbuscular mycorrhizal fungal colonization was widespread and not limiting,

while soil moisture-nutrient gradients were the important factors delimiting the distribution of *Sporobolus heterolepis*. The relationship of *Sporobolus heterolepis* with mycorrhizal fungi has not been studied, however, in the eastern United States where the species is rare.

HABITAT/ECOLOGY

While its habitat varies throughout its range, *Sporobolus heterolepis* is a quintessential tallgrass prairie species of the central plains of North America (Weaver 1968). It also occurs in the mixed grass prairie, which dominates the northern Great Plains (Redman 1975). A comparison of the range map of *Sporobolus heterolepis* (Peterson et al. 2003) and a grassland types map (Sims and Risser 2000) shows a very good overlap with much of the tallgrass and mixed grass prairies, but the species is largely absent from the shortgrass prairie that dominates the southwest third of the Great Plains region. This distribution corresponds ecologically with the more mesic portion of the Great Plains, i.e. the more eastern and northern plains. North of the Missouri River deposits associated with late Wisconsian glaciation are the parent materials of the flat and rolling plains landscape. These include till, outwash, lake bottom sediments and loess. Mollisols are the soils largely associated with the tallgrass and mixed grass prairies. The vegetation of these prairies is largely free of woody plants and dominated by grasses (Sims and Risser 2000).

Within the tallgrass prairie of eastern Nebraska and adjacent states, *Sporobolus heterolepis* is most abundant in the driest uplands (Weaver and Fitzpatrick 1934). It is widely distributed but not found in many prairies. While it may be dominant locally on the dry ridges, xeric slopes, or in thin soil areas, it most frequently intermingles with the predominant little bluestem (*Schizachyrium scoparium*), or porcupine grass (*Stipa spartea*) to the north. In contrast, in mixed grass prairie of western North Dakota, *Sporobolus heterolepis* occupies the lower positions in the landscape where soils are finer textured and moister (Redman 1975).

Sporobolus heterolepis is a species described in a variety of plant associations of the Great Plains. In Kuchler's (1964) map of potential natural vegetation of the United States it is mentioned as an "other species" in Bluestem Prairie (*Andropogon-Panicum-Sorghastrum*) and Oak Savannah (*Quercus-Andropogon*) plant associations. The following descriptions excerpted from floras in the central and western portion of the species' range give an indication of the variety of habitats the species can be found in:

- "Open woods and upland or lowland prairies" (Great Plains Flora Association 1986: 1227, referring to the Great Plains region)

- "Dry soil, often on prairies" (Mohlenbrock 2001: 275, referring to Illinois)

- "Upland prairies, dry upland forests, savannahs, glades, and ledges and tops of bluffs, usually on dolomite or chert substrates, rarely fens; occasionally

also railroads and open, disturbed areas" (Yatskievych 1999: 733, referring to Missouri)

- "In the southwestern half of the state...; usually an indicator of original prairie" (Fassett 1951: 60, referring to Wisconsin)

In his classic study of the vegetation of Wisconsin, Curtis (1959) found *Sporobolus heterolepis* was present most frequently in dry and dry-mesic prairies, less frequently in mesic and wet-mesic prairies, and not at all in wet prairies. Based on his sampling, *Sporobolus heterolepis* was considered one of the top ten indicator species for dry-mesic prairie. Other indicator species in this prairie type include *Anemone cylindrica, Asclepias verticillata*, *Helianthus occidentalis, Linum sulcatum, Panicum oligosanthes*, *Petalostemum candidum*, *Potentilla arguta, Scutellaria leonardi*, and *Stipa spartea*. The xeric prairies (dry and dry-mesic) are described as predominantly steep, southwest-facing slopes with thin, organic-rich loess soils over limestone and other bedrock types. These sites have very calcareous soils with pH values rarely less than 8.0 and calcium values of 5000 ppm or greater.

Further east, out of the main prairie belt, *Sporobolus heterolepis* becomes restricted to specialized habitats. In Ontario, it is found in "moist to dry limestone plains and calcareous shores" (this would include alvar) in the southern portion of the province (Reznicek 1984), and prairie/savannah areas in the northwestern portion (Oldham 1999). On Michigan's Upper Peninsula and on Drummond Island, *Sporobolus heterolepis* is a dominant in alvar communities where its associates include *Carex scirpoidea*, *Eleocharis compressa*, *Senecio pauperculus*, and *Schizachyrium scoparium* (Higman and Penskar 2000). In northern Lower Michigan, it is found in prairie-like wetlands in a pro-glacial lake plain, where its associates include rarities such as *Solidago houghtonii*, *Scirpus clintonii*, *Juncus vaseyi*, and *Viola novae-angliae*, as well as shore species like *Deschampsia cespitosa*. In southern Michigan, *Sporobolus heterolepis* occurs primarily in prairie fens where it is often an important species along with *Andropogon gerardii*, *Sorghastrum nutans*, *Muhlenbergia richardsonis*, and *Carex stricta*. In Indiana, *Sporobolus heterolepis* is sometimes a dominant in mesic prairies that once were prevalent in the northwestern part of the state (Jaquart et al. 2002). It also occurs as a dominant in fens, along with other prairie grasses (*Andropogon gerardii*, *Schizachyrium scoparium*, and *Sorghastrum nutans*), plus a variety of species more typically found in wetlands, such as *Carex sterilis, Carex hystricina, Lobelia kalmii*, *Muhlenbergia glomerata*, *Parnassia glauca*, *Solidago ohioensis*, and *Sarracenia purpurea*. In Ohio, it is known only from remnant prairies in dry to moist calcareous soils receiving full sun (Ohio Department of Natural Resources 1984). In Kentucky, *Sporobolus heterolepis* grows in the limestone/dolomite barrens of Bullitt County (The Nature Conservancy 2004a). These are open woodlands with a prairie-like groundcover. Other prairie species, such as *Spiranthes magnicmporum*, *Aster sericeus*, and *Linum sulcatum* grow with the *Sporobolus heterolepis* in these barrens.

In southeastern United States and the mid-Atlantic states, where *Sporobolus heterolepis* is very rare, it is known from "pine barrens over olivine" in western North

Carolina (Radford et al. 1968). This is a serpentine pine savannah with pitch pine (*Pinus rigida*) as an important canopy species (Mansberg and Wentworth 1984). Other herbaceous species in this serpentine barren include *Agropyron trachycaulum, Castilleja coccinea* (another prairie species), and *Sanguisorba canadensis.* In northwest Georgia, it occurs in calcareous glades and barrens (Georgia Natural Heritage Program 2003). In Maryland, it can be a dominant along with *Schizachyrium scoparium* in serpentine openings and adjacent *Pinus virginiana* woodlands (Tyndall 1992). Likewise, it occurs in grasslands and stunted woodlands associated with the State-Line Serpentine Barrens in Chester and Lancaster counties of southeastern Pennsylvania (Dann 1988, The Nature Conservancy 2004b). Here the *Sporobolus heterolepis* grows with other prairie grasses, such as *Sorghastrum nutans, Aristida purpurascens,* and *Bouteloua curtipendula* (also rare), as well as the serpentine endemic *Aster depauperatus*.

In northeastern North America outside of New England, *Sporobolus heterolepis* is rarely found in New York and Quebec. It occurs as a co-dominant with *Deschampsia cespitosa* in the moist zone of the rare alvar grassland community of western New York (Reschke 1990). Alvar grasslands occur in shallow soil over level limestone outcrops that are seasonally flooded, then dry. Sedges such as *Carex crawei, C. molesta,* and *C. castanea,* plus grasses such as *Agropyron trachycaulum, Bromus kalmii* and *Muhlenbergia glomerata,* are characteristic of these alvars. Dicots such *Senecio pauperculus, Solidago ptarmicoides, Castilleja coccinea,* and *Geum triflorum* are other characteristic species. In New York, it also occurs in "cobbly ice meadows, dominated by diverse herbs and low shrubs" along the shore of the Hudson River in Warren County, as vouchered by a 1991 specimen at the New York State Museum in Albany (Dr. Charles Sheviak, New York State Museum, personal communication). In Quebec, *Sporobolus heterolepis* is only known from the Montreal region (Marie-Victorin 1995) where it occurs "on lately emerging trapp rocks in the St. Lawrence" (Bro. Marie-Victorin No. 8124 collection at VT), and from calcareous rocks and wet/moist sands/gravels along the Ottawa River (Bro. Marie-Victorin, et al. collection # 30501 and 43715 at PH). Herbaria abbreviations follow Index Herbariorum (2003).

Excepting the extirpated Massachusetts occurrence, in New England *Sporobolus heterolepis* is restricted to trap rock ridges within which it appears to be tied to subacidic rocky summit outcrops, or cedar glades (Ken Metzler, Connecticut Geological and Natural History Survey, personal communication; Engstrom, personal observation). These particular trap rock ridges are dolerite, or diabase, an intrusive rock similar compositionally to basalt (Rodgers 1985). Notably, diabase contains sufficient calcium to enhance soil pH above acidic conditions typical of silica-rich bedrock areas. On the rocky summits where *Sporobolus heterolepis* grows, the natural community is a fairly narrow band of sparse to moderately treed woodlands perched at the top of cliffs or excessively steep slopes rising 30-200 meters above surrounding lowlands (Engstrom, personal observations; Connecticut Geological and Natural History Survey [CTGNHS], unpublished data; Ronald Rozsa, Connecticut Department of Environmental Protection, personal communication). The *Sporobolus heterolepis* occurrences are on convex to smooth, south to west facing slopes in general, though one site has an east aspect. Most sites are 60-100 meters above sea level; one site is at 207 meters. Soil in these

communities is very rocky and often gravelly loam or sandy loam. In places the soil has a black, humus-rich surface (A) layer at least nine centimeters deep. Field pH readings of 5.0 using a Cornell soil kit are probably low given the soil characteristics (Engstrom, personal observation).

These small outcrop communities are woodlands with anywhere from 40-75% cover of stunted (4-5 meter) *Juniperus virginiana*, *Quercus stellata*, *Carya glabra*, *Prunus serotina*, *Celtis occidentalis* and *Fraxinus americana* (Engstrom, personal observation). Both scrub oaks, *Quercus ilicifolia* and *Quercus prinoides*, are present in some places, as well as an alien privet (*Ligustrum* sp.). *Sporobolus heterolepis* often occurs in the grassy groundcover where other species such as *Schizachyrium scoparium*, *Danthonia spicata*, and *Carex pensylvanica* occur. Other common species include *Solidago nemoralis*, *Aster undulatus*, *Helianthus divaricatus*, and *Aristida dichotoma*. Other species occurring with *Sporobolus heterolepis* include *Asclepias verticillata*, *Aster linariifolius*, *Trichostema dichotomum*, *Hypericum gentianoides*, *Aster undulatus*, *Deschampsia flexuosa*, *Tridens flavus*, and *Lespedeza* sp.

While no ecological monograph exists for *Sporobolus heterolepis*, there is a wealth of literature dealing with prairie ecology where *Sporobolus heterolepis* is often mentioned. Prairie ecology cannot be translated directly to New England. However, *Sporobolus heterolepis*' responses to ecological processes associated with prairies are likely to be similar regardless of geographic location. After all, these responses are based on innate biological characteristics of the species. In a sense, the sites for *Sporobolus heterolepis* in New England and elsewhere in the forested eastern United States are "mini-prairies;" that is, small areas that are prone to droughty and sunny conditions, and the accompanying process of fire, so as to favor growth of grasses and herbs, including species typically found in the true prairies. Therefore, the prairie literature regarding *Sporobolus heterolepis* should be viewed as an important ecological background to help inform the direction of management for the species in New England.

Primary ecological processes associated with prairie vegetation include grazing, fire, and drought (Sims and Risser 2000). Adaptations of many grasses in particular to these processes include proportionally large underground parts, early spring structural development (when moisture is most available), closing stomata and curling leaves during drought, C_4 photosynthetic pathways that contribute to efficient use of water, seeds that can germinate in relatively dry soils, and basal meristems. Compared to forested or other terrestrial ecosystems, grasslands have a large proportion of materials and energy flowing through grazing pathways. This is especially true in the prairies where ungulates such as bison were an important part of the ecological equation. It is noted that *Sporobolus heterolepis* affords excellent forage during spring and summer, though the species' cover decreases under heavy grazing (Weaver 1968).

Fire is another important ecological force in the structuring and maintenance of grasslands. Summaries of the literature covering fire ecology in grasslands include Wright and Bailey (1980) and Collins and Wallace (1990). It is now recognized that Native Americans widely used fire, as well as accidentally ignited fires, in the central

North American grasslands and woodlands (Higgins 1986, Ladd 1991), and even in southern New England (Russell 1983). These human-ignited fires occur in addition to lightning-strike fires, which are relatively frequent in the northern Great Plains (Higgins 1986). Regardless of ignition source, grasslands are fire-prone for several reasons. In the central North American prairie, drought, high temperatures, and strong winds are ideal conditions for fire. Furthermore, grasses produce fine fuels that can dry out quickly and burn readily.

It is generally acknowledged that fire stimulates grassland production (Glenn-Lewin et al. 1990). The immediate effects on the grass plants, however, are generally restricted to one or two years. Fire also has the important effect of removing woody vegetation, thereby reducing competition for light by a potentially taller plant. In terms of flowering, warm-season (C_4) grasses showed increased production of flowering culms after spring burns; in five studies, *Sporobolus heterolepis* showed a 1000 to 2900% increase in flowering culms (Glenn-Lewin et al. 1990)! Late-spring burns compared to early spring burns produced twice as much flowering of some prairie grasses in Wisconsin. In contrast, results of post-fire seed production (number of seeds/culm), seedling establishment, and seedling density and survival were equivocal, some increases attributable to variations in climate (moisture) more than fire. Because of the removal of standing dead stems and litter, late spring burns result in increased useable solar energy as well as an increased efficiency of carbon fixation (Seastedt and Ramundo 1990). Frequent burning, however, can result in severe nitrogen limitations and a reduction in plant productivity. Burning also results in greater soil temperatures (by blackening soil and thatch reduction) and increased phosphorus content, thereby initiating earlier vegetative growth (Ehrenreich and Aikman 1963).

Horticulturalists also find that fire greatly enhances flower production in *Sporobolus heterolepis* (Springer 2001), though cutting back hard in the early spring has similar effects.

The tolerance of *Sporobolus heterolepis* to drought is generally inferred from the locations where it occurs, both in New England and the Great Plains. While it, along with many of the other perennial grasses, was shown to suffer in Nebraska during the extreme droughts of the 1930's, its productivity was only reduced, not eliminated (Robertson 1939). In the moister climate of Connecticut, the species occupies perhaps some the most xeric places in New England: south and west-facing convex slopes above cliffs at low elevations. And there is an intriguing thought that trap rock is an especially good heat sink (because of mineralogy and dark color), which might add to its warm, droughty conditions (Fitzgerald 2002).

THREATS TO TAXON

In the heart of its range in the prairie states, habitat destruction through conversion to agriculture was, and probably still is, the biggest threat to *Sporobolus heterolepis*. On the ecosystem level, the prairies (particularly the tallgrass prairie and the prairie-forest border (savannah) ecoregions of central North America) have nearly disappeared, with loss figures generally ranging from 90 to 99+% (Noss et al. 1995). For more on this see the discussion of the species' status throughout its range.

In prairie country not suitable to row crop agriculture, threat comes in the form of competition with woody plants. In northeast Iowa hill prairies, the elimination of prairie species, including *Sporobolus heterolepis*, comes as a result of fire suppression that allows the encroachment of woody species such as *Rhus copallina* and *Juniperus virginiana* (Ugarte 1987). Woody plant encroachment is also seen as a threat in the maintenance of serpentine openings supporting *Sporobolus heterolepis* in Maryland (Tyndall 1992) and adjacent Pennsylvania (The Nature Conservancy 2004a).

In New England, habitat change is probably the biggest threat to *Sporobolus heterolepis* (Metzler, personal communication). Recent field observations seem to corroborate this perception (Engstrom, personal observation). Although poorly documented for *Sporobolus heterolepis* in particular, changes in land use and disturbance mechanisms over the last 200-300 years have most likely led, and continue to lead, the species into decline. A major reduction in both grazing of domestic livestock and the cutting of trees, as well as fires (both naturally and human ignited), has led to an increase of woody plant growth that shades out the *Sporobolus heterolepis*. Such encroachment appears to depress flowering effort as inferred from observations at two Connecticut occurrences. Alien woody plants, such as the privet seen at one Connecticut occurrence, add to the encroachment threat (Engstrom, personal observation).

Seven of the Connecticut occurrences are on public or conservation organization land and face varying degrees of impact by recreation. Roads, parking lots, and picnic shelters have heavily impacted some public sites where *Sporobolus heterolepis* occurs. Hiker traffic along trails and at viewpoint openings where *Sporobolus heterolepis* occurs on these public lands may also negatively impact the species, though such foot traffic may also be beneficial to the species. The species' dense tussocks appear quite hardy to at least a light to moderate amount of trampling (Engstrom, personal observation), and the foot traffic may arrest woody plant succession. The net effect of foot traffic on the species is unknown.

Other threats to the species in New England are more generic to the trap rock ridges of the region. Housing development, cellular phone tower construction, and quarrying for aggregate are identified threats to the trap rock ridges in Connecticut (Fitzgerald 2002). Of these generic threats, housing development and quarrying have impacted *Sporobolus heterolepis* habitat at three or more sites where the species occurs, or historically occurred.

DISTRIBUTION AND STATUS

General Status

Though rare in eastern North America where forests dominate the landscape, *Sporobolus heterolepis* is quite common in prairie lands of the continent's center and hence is considered a G5 species (NatureServe Explorer 2002). To the north, *Sporobolus heterolepis* ranges from southern Quebec west across southern Ontario to southeast Saskatchewan (Figure 1). It reaches its northern-most point at roughly 53° north latitude in Saskatchewan. In the west, it ranges from southeast Saskatchewan south through the eastern portions of Wyoming and Colorado, and then cuts south to northeastern New Mexico and southern Oklahoma (Barkworth et al. 2000). In the eastern United States, it is much more localized, ranging from northwest Georgia northeast to south-central Massachusetts. It should be noted that the distribution map for *Sporobolus heterolepis* used in the recently published *Flora of North America North of Mexico* (Peterson et al. 2003) is the same map presented for the species in the on-line *Manual of Grasses for North America North of Mexico* (Barkworth et al. 2000).

According to the most recent synoptic work on the species (Peterson et al. 2003), *Sporobolus heterolepis* reaches its southernmost location in south Texas, and does not reach into Mexico. The *Catalogue of New World Grasses* (Peterson et al. 2001) also excludes the species from Mexico, though there is mention of it occurring in Sonora, Mexico on NatureServe Explorer (2002), referenced to Kartesz 1999 (with no citation given). A more recent version of Kartesz, however, does not include Mexico in its distribution (Kartesz and Meacham 2001). According to Brown (1993), as well as Stephan Hatch, curator of S. M. Tracy Herbarium, Texas A&M University (personal communication) *Sporobolus heterolepis* is not part of the Texas and Louisiana floras. All the specimens attributed to *Sporobolus heterolepis* in these states have been subsequently identified as *Sporobolus silvaneus*, *Sporobolus junceus*, *Sporobolus jacquemontii*, or an *Eragrostis*. Therefore, the distribution maps in the *Manual on the Web* (Barkworth et al. 2000) and *Flora of North America* (Peterson et al. 2003), as well as information in the *Grasses of Texas* (Gould 1975), incorrectly show the species occurring in Texas and Louisiana. The southernmost location for the species now appears to be in southern Oklahoma (Choctaw and Bryan counties) at roughly 34˚ north latitude (Barkworth et al. 2000).

While its range includes better than half of the United States plus adjacent Canada, its distribution can be better understood as almost continuous throughout the mid to northern plains states and provinces of central North America, then becoming very rare in eastern United States and adjacent Canada. From a biogeographical perspective, its distribution might be better viewed in relation to ecoregions of North America (The Nature Conservancy 2001). Comparing the Grass Manual on the Web map for *Sporobolus heterolepis* (Barkworth et al. 2000) with the ecoregional map leads to a better sense of the species' status throughout its range. While the Web map does not equate to population size, it does give an indication of ecologically based patterning rather than the arbitrary configurations imposed by state boundaries. The listing below is divided into

three categories. Ecoregions where the species is "widespread" is where the species is spread mostly throughout the area; these regions are likely the strongholds for the species. Ecoregions where the species is "scattered" suggests that the species occurs in several locations and might fall into the uncommon category for the ecoregion as a whole. The "local and rare" ecoregions are the periphery for the species, where it can get by for the most part in very restricted habitats. The state information in parentheses is added for convenience. Included are only the states or parts of states in the ecoregion where *Sporobolus heterolepis* occurs, not necessarily a description of the entire region.

Widespread

Northern Tallgrass Prairie (n. Minnesota, e. North Dakota and South Dakota, n. Iowa)
Central Tallgrass Prairie (n. Iowa, e. Nebraska, ne. Kansas, n. Missouri, central Illinois, nw. Indiana)
Prairie-Forest Border (central Minnesota, sw. Wisconsin, ne. Iowa, n. Illinois)
Northern Mixed-Grass Prairie (n. Nebraska, e. South Dakota and North Dakota)
Osage Plains-Flint Hills (e. Kansas, w.-central Missouri, n. Oklahoma)
Ozarks (s. Missouri, n. Arkansas)

Scattered

Aspen Parkland (s. Manitoba, n. North Dakota)
Palouse-Mixed-Grass Prairie (se. Saskatchewan, s. Manitoba)
Northern Great Plains Steppe (w. North Dakota and South Dakota, ne. Wyoming, nw. Nebraska)
Central Mixed Grass-Prairie (central Nebraska, Kansas)

Local and Rare

Central Shortgrass Prairie (e. Colorado)
Cross Timbers & Southern Tallgrass Prairie (s. Oklahoma)
Ouachita Mountains (w.-central Arkansas)
Interior Low Plateau (s. Illinois and Indiana, nw. Kentucky)
North Central Tillplain (s. Michigan, w. Ohio)
Great Lakes (Upper Peninsula of Michigan, s. Ontario, w. New York)
Cumberlands & Southern Ridge and Valley (nw. Georgia)
Southern Blue Ridge (w. North Carolina and Virginia)
Lower New England/ Northern Piedmont (se. Pennsylvania, central Maryland, Connecticut, e. New York)
St. Lawrence/ Champlain Valley (s. Quebec and adjacent Ontario)

What this distribution shows is how limited the species becomes in the moist, forested eastern United States and adjacent Canada, and how it gradually disappears in the drier climate to the west and south. In the broadest of ecological terms, it is an ecotonal species, straddling the parklands and moist end of the prairie lands between the dry steppe/desert (and high mountains) to the west and the moist forests to the east.

The status of *Sporobolus heterolepis* as viewed by the political units of North America is presented in Table 1 (Natureserve Explorer 2002). In all the eastern states and Quebec (the left column), the species is rare and restricted to unusual habitats: serpentine, alvar glades, trap rock outcrops, and others. It appears to be naturally rare because of habitat limitations, not because of its being destroyed by human activities. It is also listed as rare in Wyoming where the high and dry climate might be restrictive. In the Midwest (Ontario, Michigan, and Illinois) it is uncommon (S3), partly because of habitat restrictions (still a mostly forested landscape) and partly due to habitat destruction, especially in Illinois where the prairie country was converted to agriculture in the 19th century. It is also uncommon in Saskatchewan at the northwest extreme of its range. The many states and provinces where it is only reported (SR) probably have variable status ranks: those in the center of its range might likely rank it S4/S5, while those on the periphery might be more in the S2-S4 range.

What this table does not include is the extreme decline the species has undoubtedly undergone in the prairie states. In these states, which are biogeographically central to the species, the landscape has essentially been converted to agricultural fields. In major tallgrass prairie states, such as Illinois and Iowa, less than two-tenths of one percent of the original prairie – once covering millions of acres – remains (Whitney 1994), and in adjacent states scant more prairie remains. While the species is generally not threatened in these states, it has undeniably undergone a huge population decline.

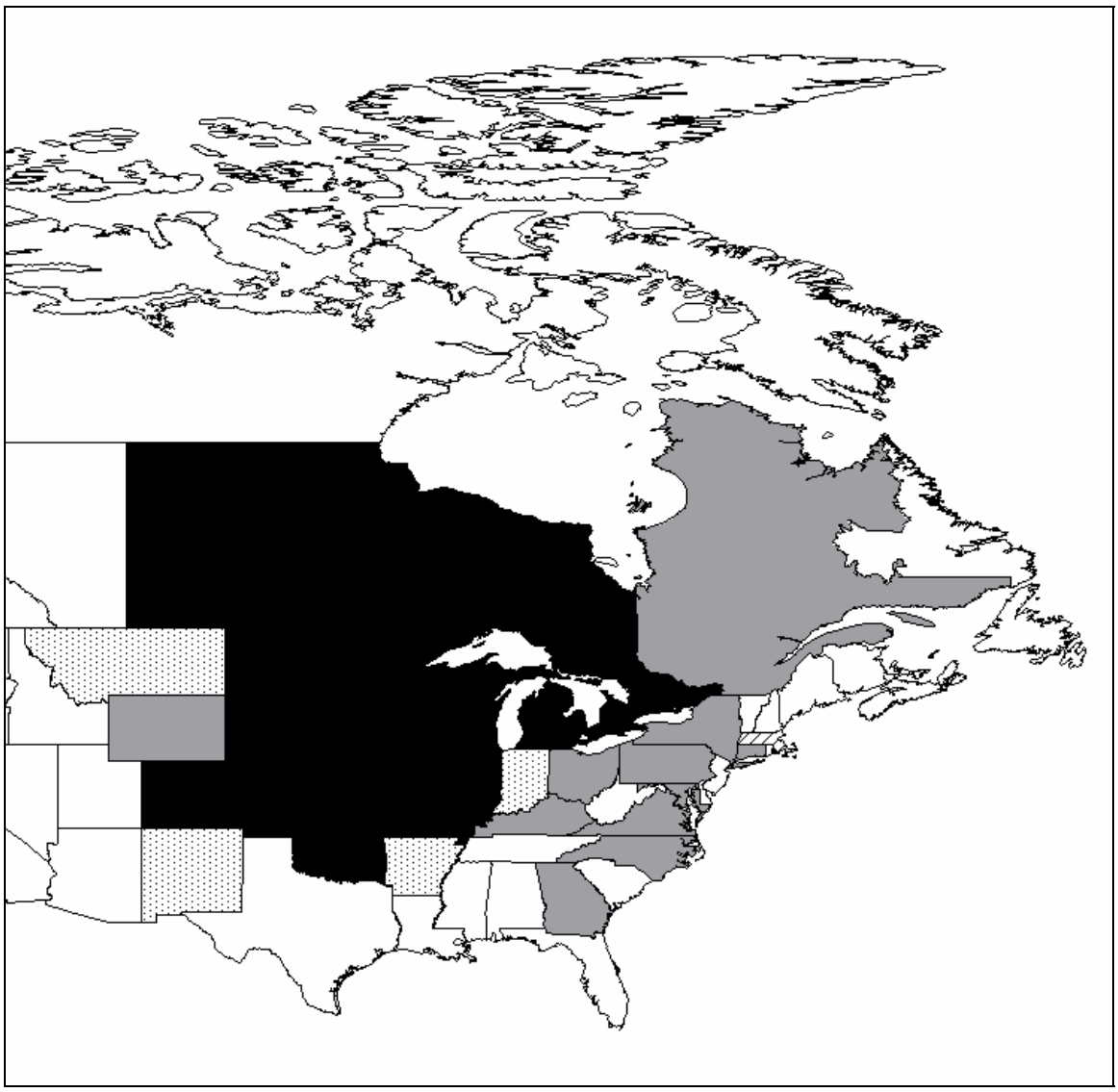

Figure 1. Occurrences of *Sporobolus heterolepis* in North America. States and provinces shaded in gray have one to five (or an unspecified number of) current occurrences of the taxon. Areas shaded in black have more than five confirmed occurrences. The state (Massachusetts) with diagonal hatching is designated "historic," where the taxon no longer occurs. States with stippling are ranked "SR" (status "reported" but without additional information). See Appendix for explanation of state ranks.

Table 1. Occurrence, status, and distribution notes of *Sporobolus heterolepis* in the United States and Canada based on information from Natural Heritage Programs and other sources.

OCCURS & LISTED (AS S1, S2, OR T &E)	OCCURS & NOT LISTED (AS S1, S2, OR T & E)	OCCURRENCE REPORTED OR UNVERIFIED	HISTORIC (LIKELY EXTIRPATED)
Connecticut (S1): 6 extant and 2 likely extirpated	Iowa (S4): throughout, almost every county (Barkworth et al. 2000)	Arkansas (SR): 4 counties in northwestern portion of state (Barkworth et al. 2000)	Massachusetts (SX): known only from single occurrence
Georgia (S1): species of Special Concern (Georgia Natural Heritage Program 2003); extreme norhtwest portion of state (Barkworth et al. 2000)	Illinois (S2S3): Occasional in northern half; rare in southern half (Mohlenbrock 2001); distributed throughout the state, but present in more northern counties (Barkworth et al. 2000)	Colorado (SR): 6 counties in central CO east of the Rockies, plus one county in the northeast (Barkworth et al. 2000). Specimens from Jefferson Co. (W. A. Weber #15537, 1979) at Pringle Herbarium (VT).	
Kentucky (S1): couple counties along the Ohio R. (Barkworth et al. 2000)	Michigan (S3): 3 counties in Upper Peninsula; 10 in Lower Michigan, primarily south (Higman and Penskar 2000)	Indiana (SR): shown only in far northwestern corner of state (Barkworth et al. 2000)	
Maryland (S1): in serpentine barrens (Tyndall 1992)	Ontario (S3): 11 southern counties, plus one recent discovery in Keno County, northwestern Ontario (Oldham 1999); widespread but local, except on Manitoulin and associated islands (Reznicek 1984)	Kansas (SR): scattered in east half of state (Great Plains Flora Association 1986; Barkworth et al. 2000)	
New York (S2): Seven occurrences (5 extant and 2 historical) (New York Natural Heritage Program, unpublished data)	Saskatchewan (S3): scattered in southeastern portion of province, s. of Saskatchewan R. (Barkworth et al. 2000)	Manitoba (S5?): south portion of province, primarily south of Lake Winnepeg and Lake Manitoba (Barkworth et al. 2000)	
North Carolina (S1): Clay Co. in w. NC (Radford et al. 1964; Barkworth et al. 2000)		Minnesota (SR): throughout southwestern half of state (Barkworth et al. 2002)	

Table 1. Occurrence, status, and distribution notes of *Sporobolus heterolepis* in the United States and Canada based on information from Natural Heritage Programs and other sources.

OCCURS & LISTED (AS S1, S2, OR T &E)	OCCURS & NOT LISTED (AS S1, S2, OR T & E)	OCCURRENCE REPORTED OR UNVERIFIED	HISTORIC (LIKELY EXTIRPATED)
Ohio (S2): recent records in 3 west-central counties; historical in Franklin County (Columbus area) (Ohio Department of Natural Resources 1984)		Missouri (SR): throughout the state except absent in southeast (Mississippi lowlands) (Yatskievych 1999)	
Pennsylvania (S1): Chester and Lancaster counties, southeast part of state (Barkworth et al. 2000); proposed endangered (PA NHP)		Montana (SR)	
Quebec (S1): Known from one site adjacent Montreal (Marie-Victorin1995) and 3 sites along the Ottawa R. (Dore and McNeil 1980; collections at PH		Nebraska (SR): scattered in eastern and northern portions of the state (Barkworth et al. 2000)	
Virginia (S1): Franklin County in the west (Barkworth et al. 2000)		New Mexico (SR): northeast (Colfax County) (Barkworth et al. 2000)	
Wyoming (S1): northeast-most 2 counties (Barkworth et al. 2000)		North Dakota (SR): distributed throughout (Barkworth et al. 2000)	
		Oklahoma (SR): mostly southern counties (Barkworth et al. 2000)	
		South Dakota (SR): especially Black Hills region and eastern part of state (Barkworth et al. 2000)	
		Wisconsin (SR): almost every county in southern half of state; rare in north (Barkworth et al. 2000)	

Status and Distribution of All New England Occurrences — Current and Historical

Sporobolus heterolepis is a regionally rare taxon in New England (Division 2 in *Flora Conservanda;* Brumback and Mehrhoff et al. 1996). While the statuses of some of the New England occurrences have changed over the last century, the species has always been rare in the region (Table 2). Three of the nine occurrences, including the lone Massachusetts occurrence, are considered by Massachusetts Natural Heritage and Endangered Species Program (MANHESP) and the CTGNHS to be extirpated. This has led to the species being listed as Endangered in Connecticut, and Historical or Extirpated in Massachusetts. All of the current occurrences are small (less than fifty plants), though data are incomplete for two occurrences. One occurrence (CT .008 [Hamden]), discovered as a result of field work for this plan, has only a single plant. Another occurrence (CT .003 [Guilford]) appears to have drastically declined in numbers (from 700 to 50 or less) over the last fifteen years.

Within New England, the distribution of *Sporobolus heterolepis* is very restricted (Figures 2 and 3). Outside the lone historical occurrence in south-central Massachusetts, the eight occurrences of *Sporobolus heterolepis* in Connecticut are all from New Haven County. Furthermore, seven of the eight are concentrated in the city of New Haven and adjacent Hamden, i.e., within a thirteen-kilometer diameter circle. And even though these seven occurrences may be separated by a distance of 2-4 kilometers, physiographically they are divided into only three or four macrosites. Interestingly, while trap rock ridges – *Sporobolus heterolepis*' principal habitat – extend for one hundred miles to the north, eight of the nine occurrences are clustered at the trap ridge system's extreme south end. The two historical occurrences of the species in Connecticut are located very close to extant occurrences; one, possibly two, could be considered part of a macrosite with two extant occurrences.

Table 2. New England Occurrence Records for *Sporobolus heterolepis.* Shaded occurrences are considered extant.

State	EO #	County	Town
MA	.001	Worcester	Webster
CT	**.001**	**New Haven**	**Hamden**
CT	**.002**	**New Haven**	**New Haven**
CT	**.003**	**New Haven**	**Guilford**
CT	.004	New Haven	New Haven
CT	.005	New Haven	Hamden
CT	**.006**	**New Haven**	**New Haven**
CT	**.007**	**New Haven**	**Hamden**
CT	**.008**	**New Haven**	**New Haven**

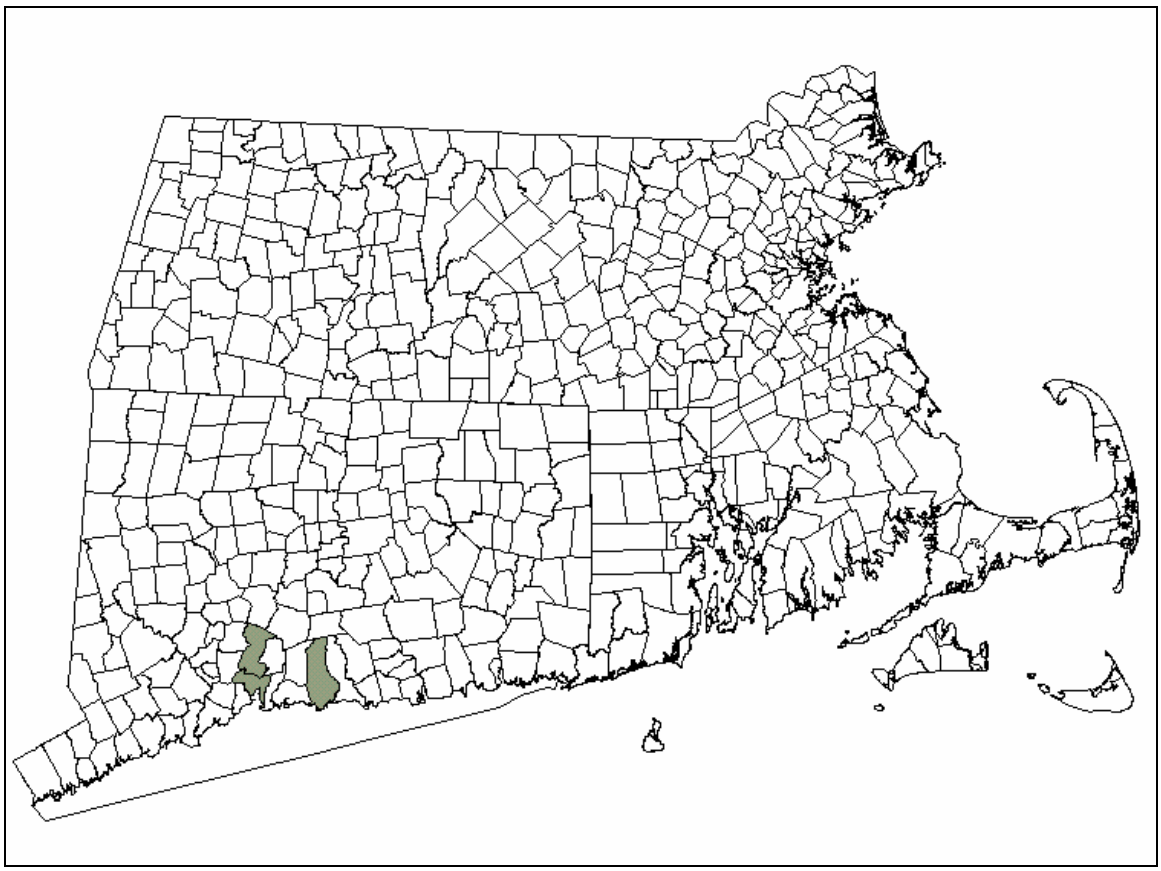

Figure 2. Extant occurrences of *Sporobolus heterolepis* in New England. Town boundaries for southern New England states are shown. Towns shaded in gray have one to five confirmed, current occurrences of the taxon.

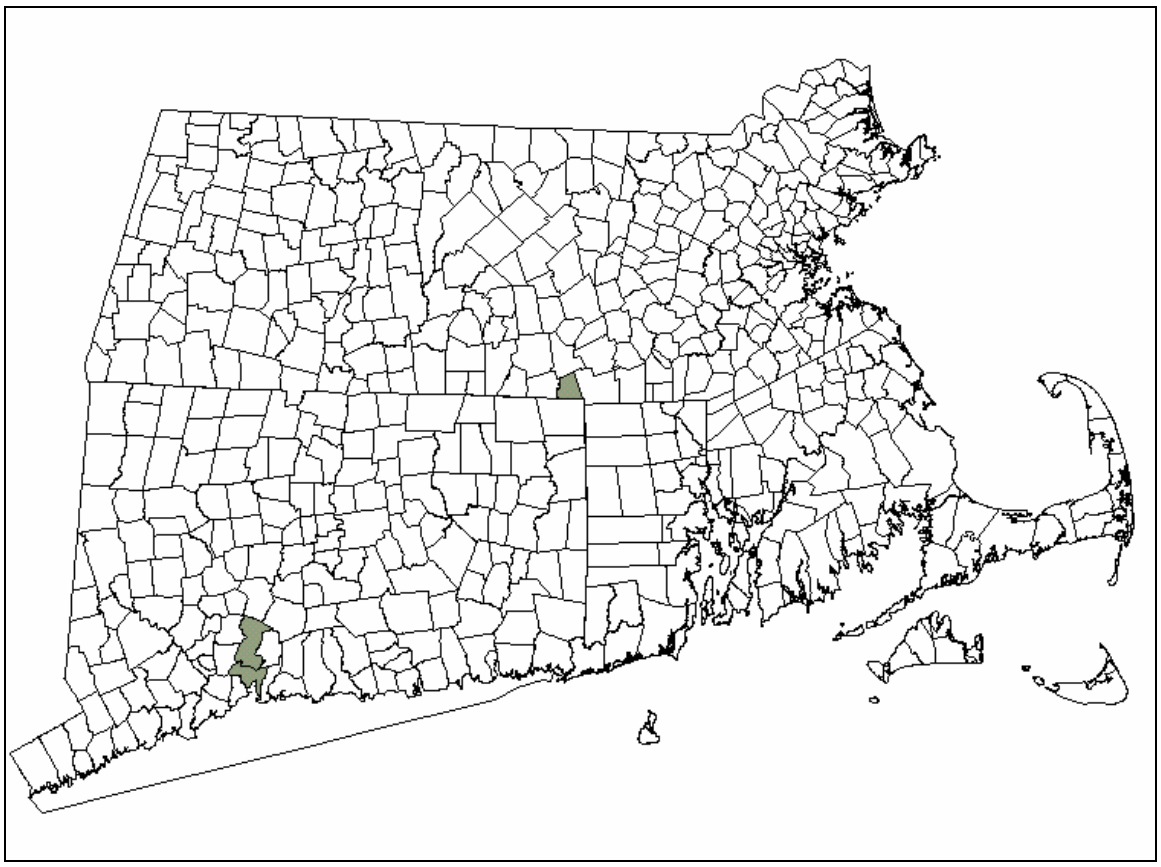

Figure 3. Historical occurrences of *Sporobolus heterolepis* in New England. Towns shaded in gray have one historical record of the taxon.

II. CONSERVATION

CONSERVATION OBJECTIVES FOR THE TAXON IN NEW ENGLAND

Conservation objectives for *Sporobolus heterolepis* in New England are to have one occurrence with 200 or more genets, two occurrences with 100 or more genets, and three occurrences with 20 or more genets. In all the occurrences, the goal is to have 50% or more of the genets flower and set fruit. Also, additional effort should be put into relocating the historical (and presumed extirpated) occurrence in Massachusetts.

My rationale for these objectives is that it is reasonable to have nearly the same number of occurrences as was known historically. Due to unknown biogeographical factors, at least eight occurrences are the natural endowment of the species in Connecticut, both historically and now. In Connecticut, fairly explicit locations are given for all occurrences. The reason for six instead of eight occurrences in Connecticut is because one occurrence appears irrevocably lost largely due to development and the other lost probably to habitat change. Conservation of the lone Massachusetts occurrence is problematic due to vague location information provided for this historical population. This makes relocating the species difficult, and reintroduction a matter of guesswork.

The six extant occurrences in Connecticut should be maintainable given that at least one of them has been in existence for well over 150 years. Three of these occurrences have, or have had, 40 to 700 genets. Furthermore, habitat is available at all six of these sites, and land for all six (plus one of the extirpated occurrences) is publicly or land trust owned. Since such numbers already exist in nature, we can strive for the doubling or better of current numbers of the larger occurrences (CT .003 [Guilford], CT .006 [New Haven], and CT .007 [Hamden]), and building to a minimum of 20 genets the smaller occurrences. In all occurrences, the application of management techniques used for the species in prairie and horticultural settings will be needed to increase populations.

Setting the objective of 50% sexually reproductive plants per occurrence is a logical first step towards expanding the currently low population numbers and thereby reducing the threat of extirpations. This is especially true since sexual reproduction is the primary means of regeneration. Extant occurrences show 25 to 70% of the genets flowering, and even less fruiting. To maintain and expand current numbers, more fruiting effort would be advantageous. The 50% figure is midway between known high and low flowering figures. Higher flowering effort, as well as flowering culms per genet, should be obtainable with management, particularly fire, given that studies have shown tenfold or greater flowering stem production for the species after fire (Glenn-Lewin et al. 1990). Obtaining 50% or greater fruiting effort will require active management in some cases.

Augmentation and reintroduction should be considered only if management of existing occurrences is unsuccessful. If needed, only genetic material from New England populations should be used for the work.

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IV. APPENDICES

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1. **Unpublished Data References**

2. **An Explanation of Conservation Ranks Used by The Nature Conservancy and NatureServe**

1. Unpublished Data References

Connecticut Geological and Natural History Survey (CTGNHS)
Department of Environmental Protection
79 Elm Street
Hartford, Connecticut 06106 USA

Arthur Haines
Herbarium Recovery Project (as of Dec. 23, 2002)
New England Wild Flower Society
180 Hemenway Road
Framingham, Massachusetts 01701 USA

Massachusetts Natural Heritage and Endangered Species Program (MANHESP)
Division of Fisheries and Wildlife
Rt. 135, One Rabbit Hill Road
Westborough, Massachusetts 01581 USA

New York Natural Heritage Program
625 Broadway, 5th Floor
Albany, New York 12233-4757 USA

2. An Explanation of Conservation Ranks Used by The Nature Conservancy and NatureServe

The conservation rank of an element known or assumed to exist within a jurisdiction is designated by a whole number from 1 to 5, preceded by a G (Global), N (National), or S (Subnational) as appropriate. The numbers have the following meaning:

1 = critically imperiled
2 = imperiled
3 = vulnerable to extirpation or extinction
4 = apparently secure
5 = demonstrably widespread, abundant, and secure.

G1, for example, indicates critical imperilment on a range-wide basis -- that is, a great risk of extinction. S1 indicates critical imperilment within a particular state, province, or other subnational jurisdiction -- i.e., a great risk of extirpation of the element from that subnation, regardless of its status elsewhere. Species known in an area only from historical records are ranked as either H (possibly extirpated/possibly extinct) or X (presumed extirpated/presumed extinct). Certain other codes, rank variants, and qualifiers are also allowed in order to add information about the element or indicate uncertainty.

Elements that are imperiled or vulnerable everywhere they occur will have a global rank of G1, G2, or G3 and equally high or higher national and subnational ranks (the lower the number, the "higher" the rank, and therefore the conservation priority). On the other hand, it is possible for an element to be rarer or more vulnerable in a given nation or subnation than it is range-wide. In that case, it might be ranked N1, N2, or N3, or S1, S2, or S3 even though its global rank is G4 or G5. The three levels of the ranking system give a more complete picture of the conservation status of a species or community than either a range-wide or local rank by itself. They also make it easier to set appropriate conservation priorities in different places and at different geographic levels. In an effort to balance global and local conservation concerns, global as well as national and subnational (provincial or state) ranks are used to select the elements that should receive priority for research and conservation in a jurisdiction.

Use of standard ranking criteria and definitions makes Natural Heritage ranks comparable across element groups; thus, G1 has the same basic meaning whether applied to a salamander, a moss, or a forest community. Standardization also makes ranks comparable across jurisdictions, which in turn allows scientists to use the national and subnational ranks assigned by local data centers to determine and refine or reaffirm global ranks.

Ranking is a qualitative process: it takes into account several factors, including total number, range, and condition of element occurrences, population size, range extent and area of occupancy, short- and long-term trends in the foregoing factors, threats, environmental specificity, and fragility. These factors function as guidelines rather than arithmetic rules, and the relative weight given to the factors may differ among taxa. In some states, the taxon may receive a rank of SR (where the element is reported but has not yet been reviewed locally) or SRF (where a false, erroneous report exists and persists in the literature). A rank of S? denotes an uncertain or inexact numeric rank for the taxon at the state level.

Within states, individual occurrences of a taxon are sometimes assigned element occurrence ranks. Element occurrence (EO) ranks, which are an average of four separate evaluations of quality (size and productivity), condition, viability, and defensibility, are included in site descriptions to provide a general indication of site quality. Ranks range from: A (excellent) to D (poor); a rank of E is provided for element occurrences that are extant, but for which information is inadequate to provide a qualitative score. An EO rank of H is provided for sites for which no observations have made for more than 20 years. An X rank is utilized for sites that are known to be extirpated. Not all EOs have received such ranks in all states, and ranks are not necessarily consistent among states as yet.