New England Plant Conservation Program

Conservation and Research Plan

Liatris borealis Nuttall ex MacNab
(Northern Blazing Star)

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SUMMARY

Northern Blazing Star (*Liatris borealis* Nuttall ex MacNab [Asteraceae]) is a NEPCoP Division 1 species with a global rank of G5?T3. It has a rank of S1 in Maine, New Hampshire, and Rhode Island, S3 in Connecticut, and S3 in Massachusetts. *Liatris borealis* is an herbaceous perennial endemic to the northeastern United States, and is the only member of its genus native to New England. Of the 82 extant occurrences in New England, 15 are in Connecticut, four in Maine, 44 in Massachusetts, five in New Hampshire, and 14 in Rhode Island. Only four of these occurrences consist of over 1000 plants; 65% have fewer than 100 plants, and 36.5% have fewer than 25 plants and must be considered at high risk of extirpation. Over the last 20 years, six known populations (6.8%) have been extirpated.

Liatris borealis grows in coastal sandplain grasslands. It is an early-successional species that responds well to disturbance events. Fire, in particular, seems to have a positive effect on establishment and reproduction of this species. The taxon does not compete well in shade, and populations decline when later successional species colonize. *Liatris borealis* is often found on roadsides and other disturbed areas.

The major threat to *L. borealis* is habitat loss due to development and succession. Fire may be an important disturbance for maintaining habitat of this taxon. Other threats include destructive mowing regimes, extensive deer grazing, seed predation, herbicide use, collection, and lack of public awareness. Conservation efforts to date include habitat protection, managing for *L. borealis* habitat, controlled burning, constructing deer exclosures, establishing *ex situ* seed banks, and propagation of the taxon.

Objectives for protection of *L. borealis* in New England include 1) habitat protection; 2) maintaining or increasing size of extant element occurrences; and 3) increasing the number of element occurrences.

Actions that should be taken to protect *L. borealis* in New England include: 1)habitat protection and maintenance; 2) population monitoring; 3) excluding herbivores; 4) searching for new and historic sites; 5) possible augmentation and reintroduction; 6) seed collection in threatened populations; 7) educating landowners and the public; and 8) conducting research on species biology.

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) 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

Northern blazing star (*Liatris borealis* Nuttall ex MacNab [Asteraceae]) has a NEPCoP rank of Division 1, meaning that it is a regionally rare species in need of conservation (Brumback and Mehrhoff et al. 1996). The global rank of G5?T3 represents inexact ranking due to uncertainty over the taxonomic status of the plant. It is unclear whether the taxon is a subspecies of *Liatris scariosa* or a distinct species, *Liatris borealis*. There are 82 extant occurrences of the species in New England. There are 125 known historic occurrences, indicating that Northern blazing star is not as widespread as it once was. Over the last 20 years, six known populations (6.8%) have been extirpated.

Liatris borealis is a member of the composite (Asteraceae) family. *Liatris* is a genus of North American herbs, found largely in the Midwest. Members of the genus are found east of the Rockies, from southern Canada to northern Mexico. There are 32 *Liatris* species and approximately 10 hybrids (Gaiser 1946).

This species of *Liatris* is endemic to the northeastern United States, and its global range is limited to Connecticut, Massachusetts, Maine, New Hampshire, New Jersey, New York, Pennsylvania, and Rhode Island (Hamilton 1991). As shown in Table 2, Northern blazing star is listed as an S1 (Threatened or Endangered) species in Maine, New Hampshire, and Rhode Island, and as a species of special concern in Connecticut and Massachusetts (S2 and S3, respectively). It is the only species of *Liatris* native to New England. Northern blazing star may no longer be present in Pennsylvania and all reports of the plant in Canada appear to be misidentifications.

DESCRIPTION

Liatris borealis is an herbaceous, iteroparous perennial, meaning that it is able to reproduce for multiple successive years. It over-winters as a corm, comes up in May or June, and flowers in August and September. Mature *L. borealis* plants produce one to several flowering stems that extend from a root-like corm. Stems reach 0.25-1 m in height, and are sparsely pubescent, or hairy. The stem, or cauline, leaves are narrow to lance-shaped, and numerous. The plant produces three to 60 rose-purple, thistle-like flower heads arranged in a spike-like cyme (Fernald 1950).

The hemispheric flower head is two to three centimeters wide and surrounded with many blunt-tipped dark green bracts, or phyllaries. Each inflorescence produces up to 100 small, tubular, five-lobed flowers. The plant blooms in August and early September, after which fruiting plants develop achenes, which are six to seven millimeters in length. The achene is tipped with white to purple pappus, which aids in wind dispersal of the seed.

Liatris borealis can be distinguished from similar species and subspecies by its restricted distribution, slightly hairy leaves, flat-tipped phyllaries, and larger achene size (Hamilton 1991). Refer to Table 1 for characteristics that can aid in identification of *L. borealis* and in differentiating this taxon from similar species of the same genus.

Table 1. Ranges and distinguishing characteristics of *L. borealis* and similar species reported in the northeastern United States.

	L. borealis	***L. scariosa* var. *nieuwlandii***	***L. scariosa* var. *scariosa***	***L. spicata***	***L. pycnostachya***
Northeastern states where species has been reported	CT, MA, ME, NH, NJ, NY, PA, RI	CT, NJ, NY, PA	DE (State Historic), NJ, PA	CT (Fairfield County), DE, MA (Middlesex County), NJ, NY, PA	MA, NJ, NY, PA
Habitat	Coast dry woods and clearings	Inland dry woods and clearings	Mountains, especially shale barrens	Wet meadows and ditches	Fields and barrens
Plant Height	30-100 cm	30-80 cm	30-80 cm	30-120 cm	50-150 cm
Leaf number	Numerous cauline leaves (20-60 leaves below inflorescence)	Numerous cauline leaves (20-60 leaves below inflorescence)	Few cauline leaves (8-25 below inflorescence)	Numerous	Numerous
Leaf width	Lower leaves narrow (1-2.5 cm)	Lower leaves wide (2-5 cm)	Lower leaves wide (2-5 cm)	Lower leaves usually >1.5 cm wide	Lower leaves narrow (0.3-1.3 cm wide)
Inflorescence size, shape, and arrangement	Hemispheric heads; heads 1.8-3 cm wide; spike arrangement	Hemispheric heads; spike arrangement	Hemispheric heads; spike arrangement	Cylindrical or bell-shaped heads; heads twice as long as wide; crowded spike	Crowded spike arrangement
Flower number	Up to 100 per head	Up to 100 per head	Less than 40 per head	5-14 per head	5-12 per head
Achene size	6-7 mm	4-5 mm			

Sources: Natureserve (2001), Gleason and Cronquist (1991), Magee and Ahles (1999), Hamilton (1991) Newcomb (1977).

TAXONOMIC RELATIONSHIPS, HISTORY, AND SYNONYMY

Liatris scariosa, the species complex with which Northern blazing star has been grouped in the past, occurs as far south and west as Arkansas. From 8000 to 5000 years before present, there was a period of warm, dry climatic conditions during which many Midwestern grasslands expanded eastward. These grasslands reached the Appalachians and western Pennsylvania, and grassland species were able to spread to the northeastern coastal plain. Following this hypsithermal interval, these eastern grasslands were overgrown with forest, but the coastal plains remained along the Atlantic (Mehrhoff 1997). Today, the remaining grasslands and heathlands on northeastern coastal plains provide much of the habitat for Northern Blazing Star, a presumed relict species from the grassland that spread during the hypsithermal interval.

Several synonyms exist for Northern Blazing Star, including *Liatris scariosa* (L.) Willd. var. *novae-angliae* Lunnell, *Liatris borealis* Nuttall ex Macnab, and *Liatris novae-angliae* Lunnell (Magee and Ahles 1999). Gleason and Cronquist (1991) and Magee and Ahles (1999) use *L. scariosa* (L.) Willd., and describe three regional varieties: *novae-angliae* Lunnell, of northeastern coastal plains in New England, New Jersey, and New York; *scariosa,* of the Appalachian shale barrens; and *niewlandii* Lunnell, of inland areas from Michigan to Arkansas and east to New York. Fernald (1950) and others have considered the plant a distinct species, *Liatris borealis* or *Liatris novae-angliae*, while some taxonomists consider it a subspecies (Gleason and Cronquist1991). However, *Liatris scariosa* (L.) Willd. var. *novae-angliae* Lunnell is not a validly published name (Paul Somers, Massachusetts State Botanist, personal communication). The International Plant Names Index, a collaboration of The Royal Botanic Gardens, Kew, The Harvard University Herbaria, and the Australian National Herbarium, lists two names for the species: *Liatris borealis* Nutt. *ex* Macnab, published in 1835 and 1838, and *Liatris borealis forma albiflora* (Shinners) Fernald, published in 1949 (International Plant Names Index 1999).

There are numerous synonyms for Northern blazing star due to the tremendous confusion and disagreement over the taxonomic status of the plant. Gaiser (1946) wrote of the genus *Liatris*, "variability in and inter-gradations between the species are undoubtedly responsible for the bewildering problems in specific determination." *Liatris borealis* was found in the Herbarium of Nuttall, but no published description or type specimen was given. It was later included in Gaiser's description of the genus *Liatris* (Gaiser 1946) and Fernald (1950) follows Gaiser in using *Liatris borealis* Nutt.

Kesseli et al. (1998) used RAPD DNA markers to characterize genetic divergence within and between New England populations (*L. borealis*) and Indiana populations (*L. scariosa* var. *niewlandii*). They found that New England populations of *L. borealis* are genetically distinct from Indiana populations of *L. scariosa* var. *niewlandii*. Interestingly, a New York population of *L. borealis* variety did not fit into this distinct cluster and was more closely related to the Indiana populations. This suggests that the New England taxon is more restricted in its range than previously thought.

Kesseli et al.'s (1998) study is only a beginning in determining the taxonomic relationships between varieties of *L. scariosa* and *L. borealis*. Their dendrogram, based upon genetic distances, rather than cladistic analysis, cannot provide the phylogenetic information necessary to determine whether the recognized varieties constitute monophyletic taxa. More sampling is needed for all *Liatris scariosa* varieties in the Mid-Atlantic and Midwest to explore genetic relationships. Because the designation of Northern blazing star as a subspecies of *Liatris scariosa* does not appear to be valid, we follow the International Plant Names Index, Gaiser, and Fernald and refer to the plant as *Liatris borealis*.

SPECIES BIOLOGY

Liatris borealis seeds germinate in May in Maine (Vickery et al. 1999). Seeds used for *ex situ* propagation by NEWFS germinate readily, suggesting that they do not possess innate dormancy. However, little is known about dormancy or longevity of buried seeds or seed bank dynamics in natural populations.

Seedlings develop quickly and, by September, can have a corm 8 mm in diameter (Vickery et al. 1999). Vickery et al. (1999) reported seedling mortality to be high in the first summer. Kane (2001) observed seedling mortality rates of nearly 80% on Block Island. Vickery et al. further discovered that *L. borealis* seedlings can go dormant following extended periods of drought, and rejuvenate to produce a second round of shoots later in the same season. This was termed the "Lazarus" effect (Vickery et al. 1999). Kane (2001) observed this phenomenon among seedlings on Block Island as well.

Liatris borealis is insect pollinated. Bees, flies, butterflies, and moths have been observed visiting the flowers (personal observation; Sawyer 1996). This taxon may have been a nectar plant for the regal fritillary butterfly (*Speyeria idalia*: F. Nymphalidae), a rare species once found in Massachusetts and Rhode Island (Hamilton 1991).

Reproduction

Little is known about the breeding system of *Liatris borealis*. This is important information for conservation of rare species because of the different threats associated with different mating systems. Reproduction of self-incompatible species can be threatened by pollen-limitation, or loss of incompatibility alleles in small populations. Plants that are able to self-fertilize may not experience pollen-limitation, but fitness may decrease due to inbreeding depression.

It is not known for certain whether *Liatris borealis* is able to self-fertilize, or whether it possesses self-incompatibility mechanisms that prevent fertilization from genetically similar pollen. Godt (1995) found a member of the same genus, *L. helleri*, to be self-incompatible. Furthermore, multiallelic sporophytic incompatibility is common in members of the Asteraceae (Richards 1986). Although Kesseli et al. (1998) did not study the breeding system of this taxon directly, their data indicate that populations of *Liatris borealis* in New England are probably outcrossing. They suggest that the high genetic diversity observed within populations may indicate low levels of self-fertilization. (However, RAPDs cannot be used to measure heterozygosity directly, and it is possible that some inbreeding combined with restricted gene flow may have contributed to the genetic substructure they observed within some populations.) They also found no evidence for asexual reproduction.

Kane (2001) observed no difference in seed set of bagged and unbagged flower heads, suggesting that *Liatris borealis* is capable of self-fertilizing. These results are not conclusive because viability of the seeds has not yet been tested, but the data suggest that self-fertilization can occur. This differs from the self-incompatibility that Godt found in another *Liatris* species. However, self-fertilization is common in rare plant species, such as Northern blazing star. Rare plants have disproportionately high levels of self-compatibility or asexuality when compared with abundant species (Gaston and Kunin 1997). Self-fertilization can result in inbreeding depression, the loss of fitness due to extensive mating with close relatives, in small populations (Barrett and Kohn 1991). Thus, inbreeding depression could be a threat to small patches of *Liatris borealis*, especially if pollinators are limited, and should be considered in management strategies. Small population size remains a concern if, contrary to the evidence of the preliminary seed set data, *L. borealis* is self-incompatible. In this case, small patches may experience a lower degree of pollinator visitation, and therefore may not receive enough pollen from genetically different individuals. This pollen limitation could result in reduced seed set (Groom 1998). Moreover, loss of self-incompatibility alleles in small populations could result in failure to set seed due to an increase in the proportion of incompatible matings (Byers and Meagher 1992, Byers 1995).

Response to fire

Fire may be important to the biology and reproductive success of *L. borealis*. At NH .014 (Portsmouth), Peteroy (1997) found that a controlled burn treatment increased the number of flowering individuals by 294% in *Liatris borealis*. In Maine (ME .001 [Kennebunk]), Vickery (1997) studied seed set, seed germination, and seedling establishment of *L. borealis* in sites with one, two, and five years since a burn. He found increased seed set and germination rates in sites burned within 1 or 2 years compared with sites five years previously.

In Vickery's study, fire had differing effects on seedling establishment, depending on the time since the most recent burn. No seedlings were observed in sites burned 48 or more months prior to the study. Seedlings were most abundant among sites burned 20 months before the study, suggesting that fire may temporarily improve conditions for seedling establishment. However, no seedlings were found among sites burned one or eight months before the survey, which was conducted in June. This suggests that timing of the burn is important, and that burning may limit population size during some years by killing seeds from the burn year. However, over several growing seasons, seedling recruitment is likely to increase with fire, due to the rises in both seed set and germination rate within one to two years following a burn.

Fire may further benefit *L. borealis* by reducing seed predation by insect larvae. Vickery (1997) studied this effect in Maine (ME .001) and found that seed predation rates declined by 70% the year following a burn. Several different larvae have been found in seed heads of *Liatris borealis*. Attempts at rearing larvae by Dr. David Wagner, University of Connecticut, have been unsuccessful thus far, making it impossible to identify the seed predator to species (D. Wagner, personal communication). In Kennebunk Plains, Maine, two microlepidopteran moth species have been observed. Although the taxonomy of these moth species remains uncertain, Michael Roberts, an entomologist from Steuben, Maine, in conjunction with taxonomists at the Smithsonian Institute, has determined that one is of the genus *Isophrictis* in the Gelechiidae family (M. Roberts, personal communication). The second species found in Maine was originally identified as *Phalonia hopses* (Vickery 1997) but is now believed to be a previously unidentified species in the Tortricidae family. This species may be an obligate feeder on *L. borealis* (M. Roberts, personal communication). On Block Island, a third microlepidopteran seed predator has been observed (personal observation and Kane 2001). Roberts tentatively identified the specimen as a species of *Idia*, a member of the Noctuidae family (M. Roberts, personal communication).

Population dynamics

What is the limiting life cycle stage?

Without long-term demographic data, it is impossible to determine what life cycle stage has the greatest impact on population growth rate (or decline) in *L. borealis*. Such information will be critical for management decisions. For example, if seedling establishment is limited by the availability of suitable micro-sites (a likely scenario in sites undergoing succession), management to increase seed set may have little effect on seedling recruitment or population numbers. On the other hand, if the number of seeds dispersed limits population growth, then seed predators (e.g., Louda and Potvin 1995) or Allee effects (Groom 1998) may have an important impact on population dynamics, and appropriate management of these factors should increase seedling recruitment.

We suspect that one of these two stages (limitation of seedling establishment to specific micro-sites or limitation of the seed supply by seed predators or grazers) is likely to be critical for many populations of *L. borealis*. We base this on the apparent dependence of this species on disturbance, and on the apparent impact of seed predation and/or herbivory on the seed supply in some populations, coupled with reports of herbivore-limited population dynamics of other perennial grassland Asteraceae species (Louda and Collinge 1992, Louda and Potvin1995, Bevill et al. 1999). However, other life cycle stages may also be limiting, such as juvenile mortality, adult longevity or seed bank mortality, and the critical life history stage may change over the course of succession or differ among sites with different ecological conditions. To resolve this issue, demographic studies in which individual plants are marked and repeatedly censused over several years to determine longevity, mortality, and the probabilities of transition between each life stage are needed (Schemske et al. 1994).

Metapopulations:

Because it is an early successional species that occupies patches of open habitat, *L. borealis* populations may operate under a metapopulation dynamic. Schemske et al. (1994) argue that "An emphasis on metapopulation dynamics will be particularly important for assessing the status of species with high population turnover, or when colonization is dependent on environmental disturbance." While there are populations of *L. borealis* that have remained stable for 17 years or more, many New England occurrences have declined or been extirpated in association with succession (e.g. RI .009 [New Shoreham], CT.003 [Coventry], and CT .005 [Colchester]).

A metapopulation is a "population of populations," or a patchwork of temporary populations linked by migration. It is generally thought of as many short-lived subpopulations, in which the distribution changes dramatically with each new generation. Two occurrences (NH *015 [Amherst]and CT .002 [New Haven]) exhibit this rapid change in location. However, metapopulations can also exist as sources and sinks, in which there are a small number of core or source populations with stable amounts of the species, and many more transient satellite or sink populations (Primack 1998). This may be the case at RI .001, where one patch consists of 13,000 plants and there are six smaller patches in the surrounding area.

A classic example of a species with a metapopulation structure is the Furbish lousewort (*Pedicularis furbishiae*), which depends on disturbance from the St. John River in Maine to reverse successional changes and open new habitat for the plant (Menges 1990). Menges points out that, in such cases, the classic conservation approach of "protecting the best individual populations while ignoring others will not necessarily ensure species persistence." Rather, "A viable metapopulation…clearly depends on the availability of empty sites for new populations."

Liatris borealis is similar to *P. furbishiae* in that it appears to depend on disturbance to create new, early successional habitat. It may function as a metapopulation in which patches are established in newly disturbed areas and go extinct as succession occurs. However, based on the relatively stable existence of certain sites, *L. borealis* may operate as a source-sink metapopulation. If so, identification and protection of source populations will be critical to conservation of the taxon. The possibility of a metapopulation dynamic must be researched further in this species.

Allee effects:

Populations of *L. borealis* are frequently small and isolated (Hamilton 1991), and are, therefore, at risk for Allee effects: the low per capita reproductive rates found in small, low-density, or isolated patches. Pollen limitation due to decreased visitation by animal pollinators i one cause of reduced per plant reproduction, as discussed above. Inbreeding may also be responsible for Allee effects (Groom 1998). Of the 82 extant element occurrences in New England (see Table 3), 65% of patches contained fewer than 100 *L. borealis* plants, and 47% contained fewer than 50 plants. Allee effects may therefore play a role in the population dynamics of the plant.

Kesseli et al. (1998) found a positive correlation between population size and genetic diversity (measured by RAPD markers) in *Liatris borealis*; small populations of the species had lower levels of molecular diversity than larger populations. Large populations also had a higher proportion of genetically unique individuals. They concluded that the low genetic variation in small populations was due to genetic drift. These data also imply that inbreeding may occur at higher levels in small populations, and suggests that inbreeding depression may be an important consideration in conservation of small patches of *Liatris borealis*.

HABITAT/ECOLOGY

Liatris borealis grows in dry open woods, clearings, and barrens. It is found on coastal plains, morainal grasslands, and roadsides in the northeast. *Liatris borealis* occurs in early-successional habitats, characterized by low herbaceous cover and low-nutrient, sandy soils (Collins 1994). These sandplain grassland communities were never common in New England and are considered globally endangered (Maine Natural Heritage Program 1993 Scorecard in Henderson 1994).

Grassland communities historically existed in large patches of New England. Historical records and observations suggest that native grassland habitat existed along the New England coast hundreds of years before European settlement in this region (Vickery and Dunwiddie 1997). Salt spray, lightning-induced fire, and other natural disturbance events, as well as Native American fire regimes, may have created and maintained these grasslands. The arrival and settlement of Europeans in North America and increased agricultural practices led to the creation of numerous pastures and grazed areas. These land use practices may have expanded the potential habitat for *Liatris borealis* (Henderson 1994; Vickery and Dunwiddie 1997).

Both native and agricultural grasslands have decreased significantly over the past century and a half (Vickery and Dunwiddie 1997), with hayfields and pastures in New England and New York decreasing by 60 percent in the last 60 years (Vickery et al. 1994). One cause for loss of grassland communities over the last century is a decline in agriculture. By the mid-nineteenth century, less than 40 percent of Connecticut, Rhode Island, Massachusetts, and Vermont were forested. As agriculture declined in the early twentieth century, forests reclaimed former pastureland and came to dominate New England (Vickery and Dunwiddie 1997). *Liatris borealis* is thus part of a rare natural community. In conserving this taxon, conservation of entire northeastern grassland ecosystems should be considered.

Liatris borealis seems to be a poor competitor and populations decline when later successional species colonize (Hamilton 1991). The plant appears to be disturbance-dependant, as seed germination and seedling recruitment of the plant are low in absence of disturbance (Vickery 1997). Fire is an important disturbance event for many grassland species. Fire has shaped the landscape of the Northeast at least since the last ice age (Vickery and Dunwiddie 1997) and Northern blazing star seems to be fire responsive, as are other members of the genus *Liatris* (Anderson and Menges 1997; Medve 1987).

THREATS TO TAXON

Below, we describe six major threats to *Liatris borealis,* listed in order of significance for the region. It should be noted that threats to this species vary from occurrence to occurrence. For instance, deer grazing is a more significant threat on RI .001 (New Shoreham), while herbicide is more significant at ME .002 (Wells). See Appendix 5 for a table of threats and their distributions at EOs in different states.

Habitat loss

The most significant threat to *L. borealis* is loss of habitat. A major cause of habitat destruction is development, as the taxon's preferred flat sandplain grasslands and open, grassy hill-tops are often ideal for construction projects such as airports, houses, and golf courses. Furthermore, coastal areas, where *L. borealis* is found, are under tremendous development pressure. Development is the most frequently listed threat in the element occurrence records, with 23 of the 89 extant or recently extirpated sites reportedly experiencing this threat. Many of the element occurrence records do not report threats, so this number could be much higher.

The open grassland habitat of *L. borealis* is also lost through succession. Of the 89 extant or recently extirpated sites in New England, 19 are reportedly threatened by succession, including overgrowth by invasive species. Because it is an early-successional species that seems to thrive off disturbances such as fire, natural succession and human prevention of disturbance are another cause for rarity. While some level of disturbance is needed to maintain the open habitat necessary for *L. borealis* to thrive, the duration and frequency of disturbance must be considered. Severe, frequent or constant disturbances, such as continuous trampling by hikers, all-terrain vehicle traffic, and construction, have led to decline and extirpation of populations. Fire and mowing regimes appear to provide the needed level of disturbance to maintain open habitat, while allowing the plant to persist after the event.

Invasive species are also a potential threat to *L. borealis* habitat. Invasives, such as *Eleagnus umbellata, Vincetoxicum nigrum, Pinus thunbergii,* and *Celastrus orbiculatus*, were observed at sites throughout New England (e.g. RI .004 [New Shoreham], RI .007 [Narragansett}, RI .009 [New Shoreham], MA .016 [Falmouth], CT .008 [New Haven]). *Eleagnus* is a nitrogen fixer, and may make nutrient-poor habitats more suitable for other plants to colonize. Other invasive species may simply shade out *Liatris*. At many sites, invasive species seem to be spreading and may outcompete *L. borealis*.

Destructive mowing regimes

Liatris borealis often grows in disturbed roadside habitats and railroad beds. Twenty-nine extant occurrences are located in this type of habitat in New England. The main threat to the taxon in these habitats, in addition to potential herbicide use and construction events, is the timing of mowing. An additional four occurrences are located on mowed paths, cemeteries, or golf courses threatened by frequent mowing.

While mowing can be a useful tool to maintain the early successional habitats favored by *L. borealis,* the timing of this regime is extremely significant. Road maintenance mowing is often performed vigorously throughout the summer, and this is the season of growth and reproduction for *L. borealis*. Mowing at this time of year prevents flowering and fruiting, thus inhibiting reproduction of the species. Optimal times for mowing are in spring, before plants have grown extensively, and in the fall, after seeds have been dispersed.

Deer grazing

At some sites of *L. borealis,* deer grazing significantly inhibits reproduction of the plant. Twelve extant or recently extirpated occurrences reportedly experience deer grazing. Grazing seems most significant on the two islands where *L. borealis* grows: Block Island, Rhode Island and Nantucket, Massachusetts. Deer grazing was observed at eight of the 12 extant occurrences on Block Island, and three of the 16 extant occurrences on Nantucket. Block Island sustains all except one of Rhode Island's extant occurrences, and Nantucket is home to one fourth of the extant sites in Massachusetts. Because these two locations provide habitat for a significant number of the region's *L. borealis* occurrences, deer grazing appears to be a significant threat to this species.

The Block Island office of The Nature Conservancy found 97% of *L. borealis* stalks to be grazed at RI .001 (New Shoreham) in 1997 (Comings, personal communication). Kane (2001) found the percent of plants with flowering and seed stalks to be significantly lower in an area where grazing occurred than in an adjacent deer-excluded area at this site. Flowering stalks made up 94% of total *L. borealis* within the exclosure, while only 44% of stalks outside the exclosure were flowering. Similarly, 87% of stalks inside the exclosure produced seed heads, while only 26% outside did. Furthermore, the seedling to adult ratio was negatively correlated with deer grazing rates on Block Island (Kane 2001). This probably occurs because deer eat large proportions of the flower heads produced by *L. borealis* on Block Island. This means that seed production is inhibited, and seedling establishment does not occur. The correlation between grazing rates and the seedling to adult ratio suggests the demographic structure of *L. borealis* populations is significantly altered when herbivory rates are high. Thus, deer grazing may be limiting population size at some occurrences.

Seed predation

Seed predation by several microlepidopteran moth species is another potential threat to *L. borealis*. It has not been studied at the majority of sites, but has been observed at ten of the extant or recently extirpated sites in New England. The extent of this predation varies from site to site. In Kennebunk Plains, Maine, units that had not been burned for more than 22 months experienced seed predation rates of more than 90% (Vickery 1997). On Block Island, seed predation rates are positively correlated with patch size, indicating that seed predation is more significant in larger populations (Kane 2001). Seed loss to insect predators may not pose a major threat to all element occurrences. Despite the presence of seed predators on Block Island, seed predation does not appear to be limiting populations there (Kane 2001).

The issue of seed predation of the taxon is complicated by the fact that one species, the tortricid, may be a previously unidentified obligate feeder of *L. borealis*. If this is the case, threats to *L. borealis* also threaten this moth, and the effects of land management must be considered for the moth as well as the plant.

Herbicide use

Many of the element occurrences of *L. borealis* occur on lands owned or managed by railroad companies, utility companies, or highway departments. These land managers often employ herbicide to keep property open and facilitate maintenance of machinery. While *L. borealis* thrives in open habitats, herbicides may damage the plant. Herbicide use has been reported at six of the extant or recently extirpated element occurrences. However, it should be acknowledged that herbicide at ME .001 (Kennebunk), applied for blueberry production, may have resulted in an increase in *L. borealis* plants as competing monocot species were reduced.

Collection and lack of awareness

Other threats to the taxon are collection and lack of public awareness. Collection is reportedly a threat at three of the extant or recently extirpated sites (MA .006 [Dartmouth], CT .028 [Newtown], and RI .002 [Westerly]) in New England. One private landowner (RI*015 [New Shoreham]) confessed to vigorously weeding *L. borealis* from her garden prior to knowing its rare status.

DISTRIBUTION AND STATUS

General status

The reason for Northern blazing star's global heritage status rank of G5?T3 is that, although it is locally common in some areas, it may be declining regionally. The uncertainty of the global rank is due to uncertainty over taxonomic status of the plant.

This species is endemic to the northeastern United States, and its global range is limited to Connecticut, Massachusetts, Maine, New Hampshire, New Jersey, New York, Pennsylvania, and Rhode Island (Hamilton 1991). There are a total of 214 historic and extant occurrences in New England. Of these occurrences, 82 are extant, six have been recently extirpated, and 126 are historic (See Appendix 2 for distributions of occurrence type by state). The fact that there are significantly more historic occurrences than extant occurrences suggests that Northern blazing star is not as widespread as it once was. However, the decline in the number of occurrences has been relatively slow over the last 20 years, as only six of the known populations have been extirpated in that time.

There are four extant occurrences in Maine, five in New Hampshire, 44 in Massachusetts, fourteen in Rhode Island, and 15 in Connecticut. Massachusetts may have the greatest abundance of this species because it possesses a greater area of sandplain grassland habitat than the other New England states.

Most element occurrences consist of small populations. Of the 82 extant occurrences in New England, 30 are populations smaller than 25 plants, and therefore probably at high risk of extinction. Nineteen of the occurrences number between 25 and 99, 21 of the occurrences number between 100 and 499, and only eight occurrences in the region number over 500 plants. See Appendix 3 for a table of occurrence sizes distributions for each state.

Status of All New England Occurrences — Current and Historic

Site descriptions for all New England occurrences of *L. borealis* appear on the following pages. Description of all records are taken from element occurrence records (EORs) maintained by the Natural Heritage Programs of Maine, Massachusetts, New Hampshire, Rhode Island, and Connecticut. Additional descriptive information of ME .001 and all Rhode Island occurrences are based on site visits conducted by the authors.

Table 2. Occurrence and status of *Liatris borealis* in the United States and Canada based on information from Natural Heritage Programs.

OCCURS & LISTED (AS S1, S2, OR T &E)	**OCCURS & NOT LISTED (AS S1, S2, OR T & E**	**HISTORIC (LIKELY EXTIRPATED)**
Maine (S1): 4 extant occurrences	Connecticut (S3): 15 extant occurrences	New Jersey: (SH)
New Hampshire (S1): 5 extant occurrences	Massachusetts (S?): 36 extant occurrences	
Rhode Island: (S1): 13 extant occurrences	Pennsylvania (SU)	
New York (S2): 12 occurrences		

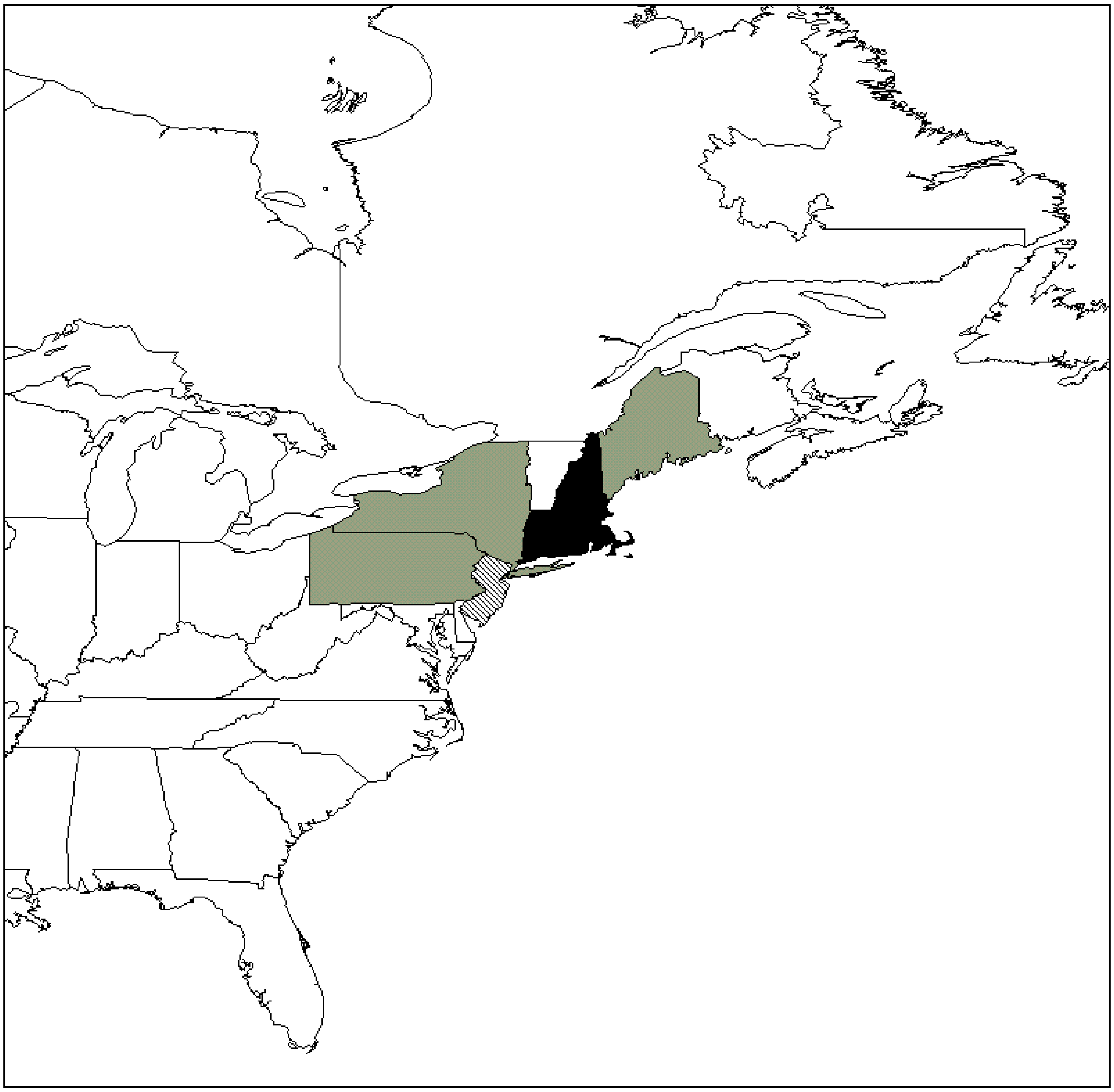

Figure 1. Occurrences of *Liatris borealis* in North America. States shaded in gray have one to five confirmed occurrences of the taxon. States shaded in black have more than five occurrences. Diagonal hatching indicates the state (New Jersey) where *Liatris borealis* is ranked as historic.

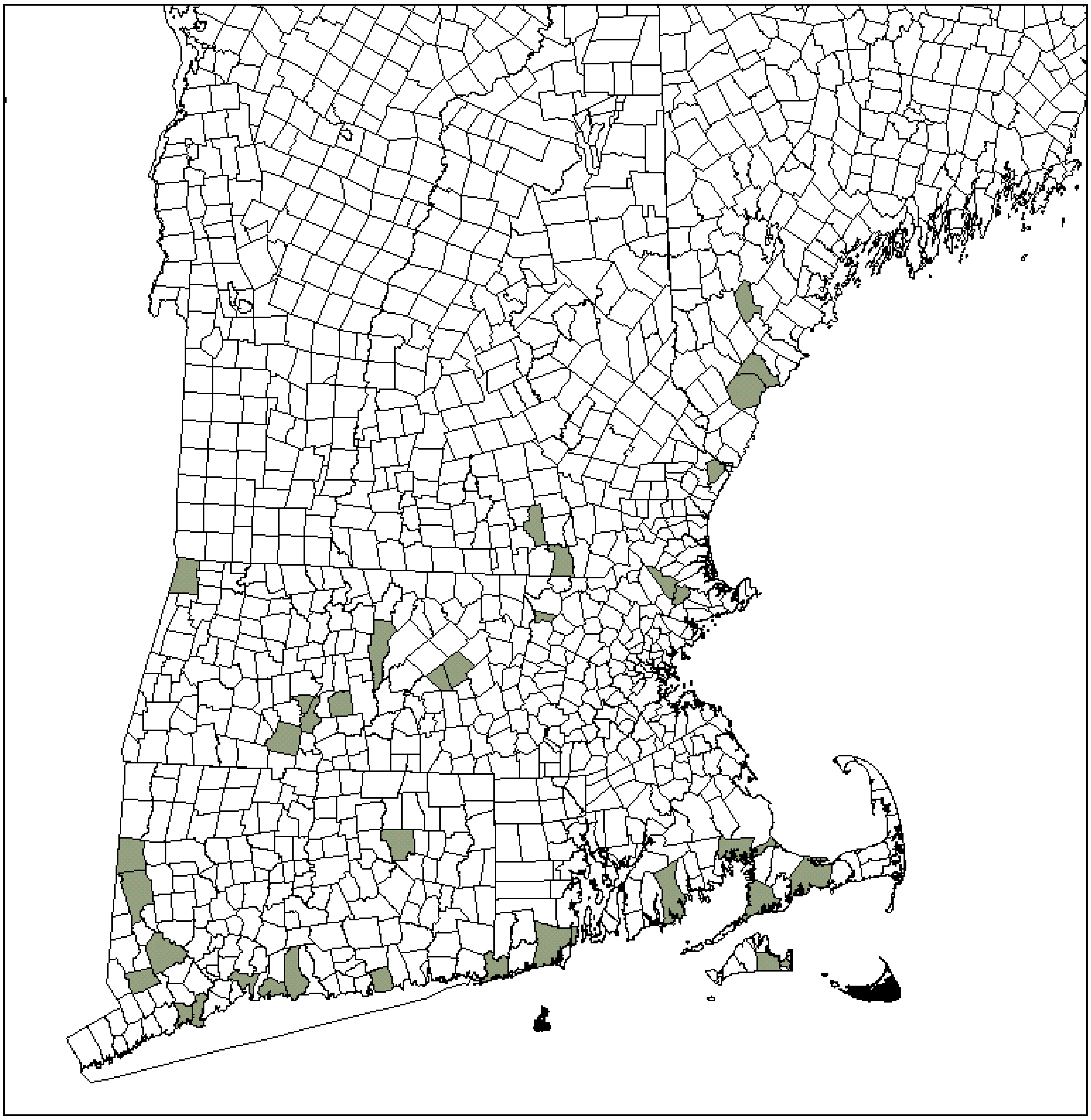

Figure 2. Extant occurrences of *Liatris borealis* in New England. Town boundaries for New England states are shown. Towns shaded in gray have 1 to 5 confirmed, extant occurrences of the taxon. Towns shaded in black (New Shoreham, Rhode Island and Nantucket, Massachusetts) have more than five extant occurrences.

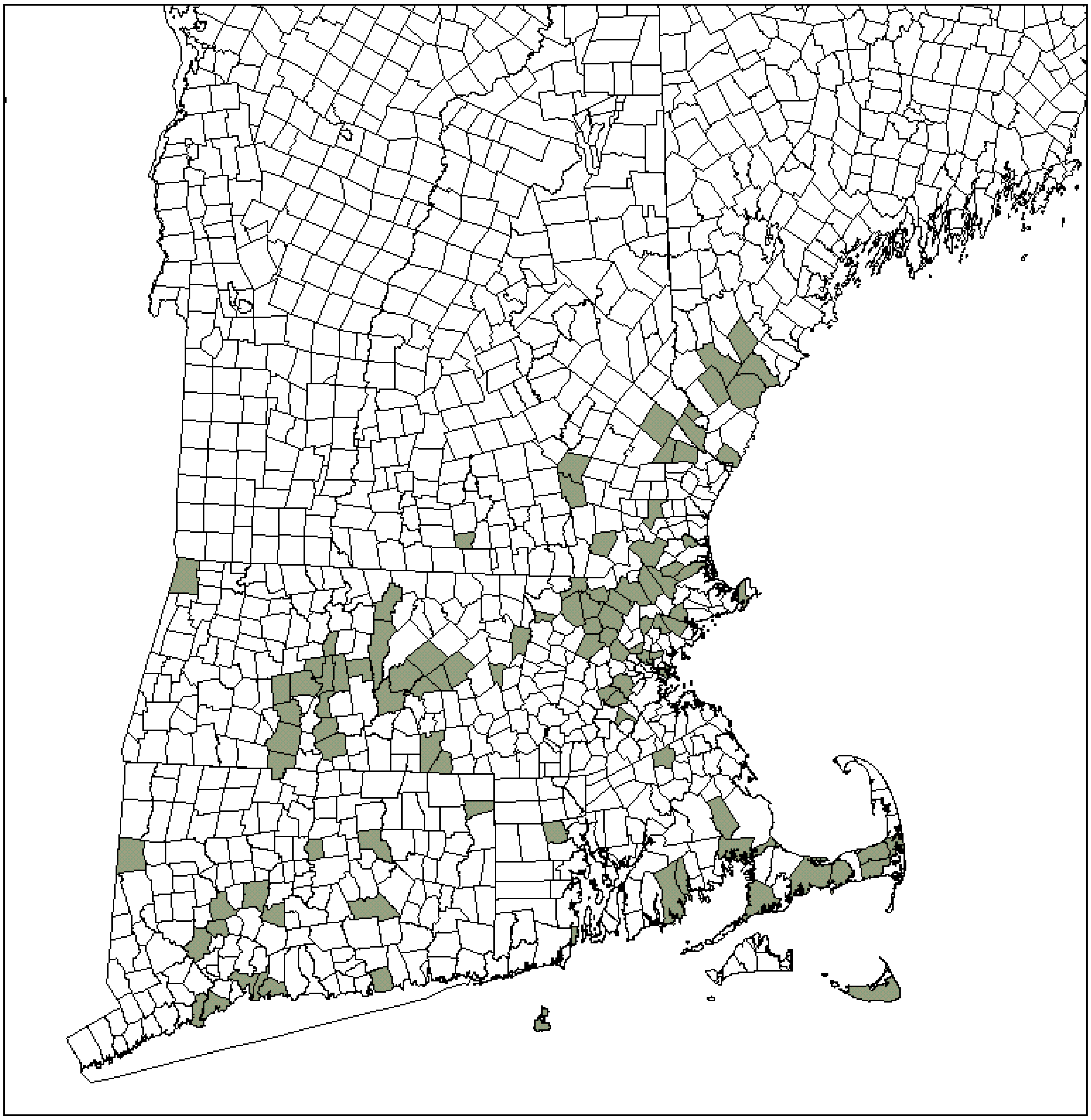

Figure 3. Historic occurrences of *Liatris borealis* in New England. Towns shaded in gray have one to five historic records of the taxon.

Table 3. New England Occurrence Records for *Liatris borealis*. Shaded occurrences are considered extant.

State	Element Occurrence Number	County	Town
ME	**.001**	**York**	**Kennebunk**
ME	**.002**	**York**	**Wells**
ME	.003	York	Lyman
ME	.004	York	Sandford
ME	.005	York	North Berwick
ME	.006	York	Kennebunk
ME	.007	York	Kittery
ME	.008	York	Wells
ME	**.009**	**York**	**Wells**
ME	**.010**	**York**	**Hollis**
NH	**.001**	**Hillsborough**	**Nashua**
NH	**.002**	**Hillsborough**	**Amherst**
NH	.003	Hillsborough	Manchester
NH	**.004**	**Merrimack**	**Hooksett**
NH	**.005**	**Strafford**	**Somersworth/ Dover**
NH	**.006**	**Hillsborough**	**Amherst**
NH	.007	Strafford	Durham
NH	.008	Rockingham	Kingston
NH	.009	Hillsborough	Sharon
NH	.010	Rockingham	Windham
NH	.011	Strafford	Barrington
NH	.012	Strafford	Dover
NH	.013	Strafford	Lee
NH	**.014**	**Rockingham**	**Portsmouth**
NH	***015**	**Hillsborough**	**Amherst**
MA	**.001**	**Barnstable**	**Chatham**
MA	**.002**	**Nantucket**	**Nantucket**
MA	**.003**	**Nantucket**	**Nantucket**
MA	**.004**	**Barnstable**	**Bourne**
MA	**.005**	**Plymouth**	**Wareham**
MA	**.006**	**Bristol**	**Dartmouth**
MA	**.007**	**Middlesex**	**Ayer**
MA	**.008**	**Barnstable**	**Barnstable**
MA	**.009**	**Barnstable**	**Falmouth**

Table 3. New England Occurrence Records for *Liatris borealis*. Shaded occurrences are considered extant.

State	Element Occurrence Number	County	Town
MA	**.010**	**Hampshire**	**Granby**
MA	**.011**	**Barnstable**	**Falmouth**
MA	**.012**	**Barnstable**	**Falmouth**
MA	.013	Barnstable	Bourne
MA	**.014**	**Barnstable**	**Bourne**
MA	**.015**	**Nantucket**	**Nantucket**
MA	**.016**	**Barnstable**	**Falmouth**
MA	**.017**	**Nantucket**	**Nantucket**
MA	**.018**	**Nantucket**	**Nantucket**
MA	**.019**	**Nantucket**	**Nantucket**
MA	**.020**	**Nantucket**	**Nantucket**
MA	**.021**	**Nantucket**	**Nantucket**
MA	**.022**	**Nantucket**	**Nantucket**
MA	**.023**	**Nantucket**	**Nantucket**
MA	**.024**	**Hampshire**	**Holyoke, Easthampton**
MA	**.025**	**Hampden**	**Westfield**
MA	.026	Hampshire	Northampton
MA	**.027**	**Middlesex**	**Stow**
MA	.028	Barnstable	Yarmouth
MA	.029	Barnstable	Yarmouth
MA	.030	Barnstable	Yarmouth
MA	.032	Essex	Haverhill
MA	.033	Hampshire	South Hadley
MA	.034	Worcester	Rutland
MA	.035	Middlesex	Concord
MA	**.036**	**Franklin**	**New Salem**
MA	**.037**	**Nantucket**	**Nantucket**
MA	.038	Barnstable	Barnstable
MA	.039	Barnstable	Barnstable
MA	**.040**	**Nantucket**	**Nantucket**
MA	.041	Middlesex	Concord
MA	.042	Worcester	Boylston
MA	.043	Barnstable	Brewster
MA	**.044**	**Nantucket**	**Nantucket**
MA	.045	Hampshire	Amherst

Table 3. New England Occurrence Records for *Liatris borealis.* Shaded occurrences are considered extant.

State	Element Occurrence Number	County	Town
MA	.046	Essex	Andover
MA	.047	Middlesex	Ayer
MA	**.048**	**Nantucket**	**Nantucket**
MA	**.049**	**Nantucket**	**Nantucket**
MA	**.050**	**Nantucket**	**Nantucket**
MA	**.051**	**Barnstable**	**Bourne**
MA	.057	Barnstable	Barnstable
MA	.063	Barnstable	Barnstable
MA	.065	Worcester	Barre
MA	.067	Middlesex	Billerica
MA	.069	Barnstable	Bourne
MA	.070	Barnstable	Bourne
MA	.073	Suffolk	Boston
MA	.074	Essex	Boxford
MA	.075	Barnstable	Brewster
MA	.076	Plymouth	Brockton
MA	.078	Middlesex	Carlisle
MA	.080	Plymouth	Carver
MA	.081	Barnstable	Chatham
MA	.083	Middlesex	Chelmsford
MA	.085	Hampden	Chicopee
MA	.089	Bristol	Dartmouth
MA	.090	Essex	Danvers
MA	.091	Norfolk	Westwood
MA	.094	Hampshire	Ware
MA	.099	Barnstable	Falmouth
MA	.101	Essex	Gloucester
MA	.103	Essex	Georgetown
MA	.104	Hampshire	Hadley
MA	.105	Barnstable	Harwich
MA	.106	Worcester	Hardwick
MA	.107	Hampshire	Hatfield
MA	.112	Essex	Ipswich
MA	.114	Worcester	Lancaster
MA	.115	Middlesex	Lexington

Table 3. New England Occurrence Records for *Liatris borealis.* Shaded occurrences are considered extant.			
State	**Element Occurrence Number**	**County**	**Town**
MA	.116	Middlesex	Lowell
MA	.117	Essex	Lynnfield
MA	.120	Middlesex	Malden
MA	.122	Middlesex	Medford
MA	.123	Nantucket	Nantucket
MA	.129	Norfolk	Needham
MA	.130	Bristol	New Bedford
MA	.131	Worcester	New Braintree
MA	.132	Essex	Newburyport
MA	.133	Middlesex	Newton
MA	.135	Franklin	New Salem
MA	.136	Franklin	New Salem
MA	.139	Middlesex	Newton
MA	.140	Essex	North Andover
MA	.141	Franklin	Orange
MA	.142	Worcester	Oakham
MA	.143	Essex	Peabody
MA	.144	Hampshire	Pelham
MA	.145	Plymouth	Plymouth
MA	.146	Plymouth	Plymouth
MA	.151	Middlesex	Reading
MA	.152	Essex	Rowley
MA	.153	Worcester	Rutland
MA	.154	Essex	Salem
MA	.155	Barnstable	Sandwich
MA	.159	Worcester	Southbridge
MA	.160	Hampden	Southwick
MA	.161	Hampden	Southampton
MA	.163	Unknown	Stockbridge or Sturbridge?
MA	.164	Hampden	Springfield
MA	.166	Middlesex	Stow
MA	.167	Worcester	Sturbridge
MA	.168	Franklin	Sunderland
MA	.171	Middlesex	Tewksbury
MA	.172	Middlesex	Tyngsborough

Table 3. New England Occurrence Records for *Liatris borealis.* Shaded occurrences are considered extant.			
State	**Element Occurrence Number**	**County**	**Town**
MA	.174	Norfolk	Wellesley
MA	.175	Hampden	Westfield
MA	.176	Middlesex	Westford
MA	.177	No data	Woburn?
MA	.178	Hampshire	Westhampton
MA	.179	Middlesex	Winchester
MA	.183	Essex	Peabody
MA	.184	Barnstable	Orleans
MA	.187	Barnstable	Brewster
MA	.191	Plymouth	Wareham
MA	**.195**	**Essex**	**Boxford**
MA	.196	Essex	Haverhill
MA	.199	Middlesex	Bedford
MA	**.200**	**Dukes**	**Edgartown**
MA	**.201**	**Dukes**	**Edgartown**
MA	**.202**	**Barnstable**	**Barnstable**
MA	**.203**	**Barnstable**	**Bourne**
MA	**.204**	**Essex**	**Topsfield**
MA	**.205**	**Barnstable**	**Barnstable**
MA	**.206**	**Barnstable**	**Bourne**
MA	**.207**	**Barnstable**	**Sandwich**
MA	**.208**	**Worcester**	**Rutland, Oaklham**
MA	**.209**	**Essex**	**Boxford**
RI	**.001**	**Washington**	**New Shoreham**
RI	**.002**	**Washington**	**Westerly**
RI	.003	Providence	Johnston
RI	**.004**	**Washington**	**New Shoreham**
RI	**.005**	**Washington**	**New Shoreham**
RI	**.006**	**Washington**	**New Shoreham**
RI	**.007**	**Washington**	**Narragansett**
RI	**.008**	**Washington**	**New Shoreham**
RI	**.009**	**Washington**	**New Shoreham**
RI	**.010**	**Washington**	**New Shoreham**
RI	*011	Washington	Narragansett
RI	***012**	**Washington**	**New Shoreham**

Table 3. New England Occurrence Records for *Liatris borealis.* Shaded occurrences are considered extant.

State	Element Occurrence Number	County	Town
RI	***013**	**Washington**	**New Shoreham**
RI	***014**	**Washington**	**New Shoreham**
RI	***015**	**Washington**	**New Shoreham**
RI	***016**	**Washington**	**New Shoreham**
RI	*017	Washington	Wakefield
CT	**.001**	**New London**	**Old Lyme**
CT	**.002**	**New Haven**	**New Haven**
CT	.003	Tolland	Coventry
CT	**.004**	**No data**	**Bulls Bridge (New Milford)**
CT	.005	New London	Colchester
CT	**.006**	**Fairfield**	**Stratford**
CT	**.007**	**Fairfield**	**Bridgeport Stratford**
CT	**.008**	**New Haven**	**New Haven**
CT	**.009**	**Tolland**	**Mansfield**
CT	**.010**	**Tolland**	**Coventry**
CT	**.011**	**New Haven**	**Guilford**
CT	**.012**	**New Haven**	**Branford**
CT	**.019**	**Litchfield**	**Kent**
CT	**.027**	**New Haven**	**Branford**
CT	**.028**	**Fairfield**	**Newtown**
CT	**.029**	**Fairfield**	**Redding**
CT	**.030**	**New Haven**	**New Haven**
CT	?	Windham	Putnam
CT	?	New London	Colchester
CT	?	New London	Old Lyme
CT	?	Hartford	East Hartford
CT	?	Hartford	East Hartford
CT	?	Hartford	Southington
CT	?	Hartford	Southington
CT	?	New Haven	Branford
CT	?	New Haven	East Haven
CT	?	New Haven	South Meriden
CT	?	New Haven	Milford
CT	?	New Haven	Naugatuck

Table 3. New England Occurrence Records for *Liatris borealis.* Shaded occurrences are considered extant.

State	Element Occurrence Number	County	Town
CT	?	New Haven	New Haven
CT	?	New Haven	Milford
CT	?	New Haven	Oxford
CT	?	New Haven	Waterbury
CT	?	Litchfield	Kent
CT	?	Fairfield	Stratford

CURRENT CONSERVATION MEASURES IN NEW ENGLAND

Land acquisition and preservation

Of the 82 extant element occurrences of *L. borealis*, 19 are in owned, managed, or in easements with conservation organizations. Thirteen of the 82 occurrences are owned by state or federal organizations, which may facilitate implementation of conservation efforts. Populations on airports (NH .014 [Portsmouth], MA .201 [Edgartown], and RI .004 [New Shoreham]) are relatively well-protected, even though they are not on preserved land, because human activity and development are limited on these lands. The world's largest known population of *L. borealis* (ME .001 [Kennebunk]) is owned by the state and managed by The Nature Conservancy. The largest population in Rhode Island (RI .001 [New Shoreham]) is also on preserved land, managed by The Nature Conservancy and owned by a Land Trust.

Habitat management

Some landowners manage for the early successional habitat preferred by *L. borealis*. Periodic fire and mowing treatments have proved successful at maintaining these open landscapes and preventing extensive growth of shrubs, trees, and other plants from out-competing *L. borealis*. The Kennebunk, Maine site (ME .001) is divided into 18 units, between seven and 78 acres in size, most of which are burned every three to five years (Henderson 1994). As described above, fire, in addition to maintaining habitat, increases flowering rates, seed germination, and seedling establishment, and reduces seed predation (Peteroy 1997, Vickery 1997). Burning has also been used at one New Hampshire occurrence (NH .014) and four occurrences in Massachusetts (MA .009 [Falmouth], MA .048[Nantucket], MA .200 [Edgartown], and MA .201 [Edgartown]). In all cases, populations appeared to increase in the short term following the burn, and declined with time since the burn. This suggests that a regular cycle of burning is necessary to achieve sustained benefits to the taxon.

Other element occurrences throughout New England are mowed to preserve the sandplain grasslands communities where *L. borealis* is found. Like fire, a mowing regime reduces woody plant growth. However, because it increases thatch layers, mowing does not increase seed contact with mineral soil, and thus may not increase seed germination. Mowing also does not have the same dramatic effect of stimulating flowering either. Peteroy (1997) found a 42% increase in flowering plants following a clearing regime, compared with a 460% increase following a prescribed burn. Furthermore, it is unlikely that mowing affects seed predation rates (MA Division of Fisheries and Wildlife 1995). The benefits of mowing are that it requires fewer people, resources, and planning. Furthermore, it can be performed on populations that are small in area and in close proximity to homes or other structures that might preclude the feasibility of performing a prescribed burn for safety reasons.

At other occurrences, managers have removed invasive species or encroaching woody plants. At RI .004 (New Shoreham), TNC periodically removes *Eleagnus umbellata* individuals. In summer 2001, NEWFS plans to remove shrubs and juvenile trees at NH .006 (Amherst) to maintain the open habitat at that site.

Deer exclusion

Significant deer grazing has been observed at three occurrences in Massachusetts (MA .017 [Nantucket], MA .025 [Westfield], and MA .048 [Nantucket]) and five in Rhode Island (RI.001 [New Shoreham], RI.009 [New Shoreham], RI.010 [New Shoreham], RI*012 [New Shoreham], and RI *016 [New Shoreham]). Construction of a deer exclosure at RI .001 has been successful at preventing the grazing that inhibits reproduction of *L. borealis*. Plants in the exclosure, protected from grazing, produce more flower heads and seed heads than those outside the exclosure (Kane 2001) and may increase the seed supply to nearby unprotected patches. Deer exclusion for *L. borealis* is complicated by the fact that constructing an exclosure may hasten successional processes by preventing grazing. It is therefore important to practice burning or mowing within the exclosure to prevent colonization by plants that may outcompete *L. borealis*.

Ex situ ***seed banking and propagation***

New England Wildflower Society (NEWFS) has successfully developed a seed bank and propagated *L. borealis*. Seeds germinated easily, and no special treatment was necessary. Propagation began in 1993, and since then, seeds have been collected from sites in New Hampshire and Rhode Island (NEWFS 2000). *Ex situ* seed banks can be a valuable tool for reintroducing rare and decreasing species to a region. However, this process fails to preserve genetic diversity and may cause genetic changes to stored seeds (Hamilton 1994) and an accumulation of mutational load (Schoen et al. 1998).

Searching for historic occurrences

The Massachusetts Natural Heritage Program has been successful at relocating sites of historic occurrences of *L. borealis* (MA .041 [Concord], MA .042 [Boylston], MA .045 [Amherst]). Unfortunately, none of these searches have yielded findings of the plant, but it is important to continue such practices. Even if searches for historic occurrences do not result to finding plants, they provide an opportunity to study and evaluate previous habitat and potential reintroduction sites.

Education and coordination with landowners

Education efforts by NEWFS include propagating *L. borealis*, displaying it in a rare plant garden, and selling the plant to visitors. In Rhode Island, The Nature Conservancy participates in extensive education and coordination with private landowners, which has resulted in land use changes and management to protect *L. borealis*. Landowners have altered mowing times to manage for the plants at RI .004 (New Shoreham), RI.010 (New Shoreham), RI *015 (New Shoreham), and RI *016 (New Shoreham). A Massachusetts landowner has also expressed interested in maintaining open habitat for the plant (MA .207). Such coordination efforts and education practices are invaluable for protection of *L. borealis* on unprotected sites.

II. CONSERVATION

CONSERVATION OBJECTIVES FOR THE TAXON IN NEW ENGLAND

Liatris borealis is endemic to the Northeast, and, as the only member of its genus native to New England, is an important and exciting part of this region's ecological heritage. Furthermore, it is an important nectar source for numerous insect pollinators, and may be an obligate food source for tortricid moth larvae. Its bright showy flowers have aesthetic value as well, as anyone who has seen the sea of purple created by acres of *L. borealis* blooming in Kennebunk, Maine (ME .001) can attest.

In looking at the number of EOs, the regional population of this species appears to be declining slowly. There are 82 occurrences of this species, a relatively large number. Six small populations have been extirpated in the last twenty years. The species is doing well in Massachusetts, where there are 44 extant occurrences and no known populations have been extirpated in the last 20 years. However, there are only 4 populations with over 1,000 plants in the region, and over half the occurrences number less than 50 individuals in size. Thirty occurrences have less than 25 plants, and must be considered at high risk of extirpation. All extirpated populations had population sizes of 12 plants or less, and the average population size immediately prior to extirpation was six individuals. It is clear that small populations are much more likely to go extinct than large populations. In all cases of extirpation, either construction or succession was listed as the cause.

In addition to the number of occurrences and their population sizes, it is important to look at trends in these numbers. It is impossible to draw conclusive evidence based on the EORs because many do not provide specific information about the number of plants at an occurrence. The populations have also not been observed consistently and for an extended period of time. Furthermore, there may be observed yearly variation in population sizes because sampling of the population was performed by a different person, involved a different surveying technique, or was conducted at a different time of year. This phenomenon was apparent to A. Kane in her studies of Block Island populations. Because she spent the entire summer studying *L. borealis,* she was able to carefully survey and count populations there. She often came up with larger population sizes than had been previously recorded, when surveys gave estimates or were performed more quickly.

Nonetheless, it is useful to look at the population trends as recorded in EO reports. Of the 88 extant and recently extirpated sites, 21 occurrences have declined over the last 20 years, 13 have increased, and 12 have remained stable. A trend could not be detected for 42 of the occurrences, due to insufficient data. Refer to Appendix 4 for a complete table of these trends.

It is encouraging that over 50% of populations for which data are available are increasing or stable, based on the EO records. However, these data also suggest that a significant proportion of the populations have declined over the last 20 years, potentially increasing their risk of eventual extinction.

The overall conservation goal for this species is to protect and maintain the current number of 82 extant occurrences. If any occurrence is extirpated, it should either be restored by augmentation from adjacent populations (if the site itself is not threatened and can be managed appropriately to maintain the population) or replaced by establishment of a new population in the nearest suitable site from *ex-situ* stocks or adjacent populations (if the original site is destroyed or threatened). We further recommend collecting seeds and/or transplanting individuals from sites that are headed for immediate extirpation. Ideally, the number of element occurrences of *L. borealis* should be increased, to safe guard against those occurrences that may be lost in the future, with growing development pressures.

While this plan addresses a single plant species, it is necessary to consider the entire habitat upon which this plant depends. Sandplain grasslands have never been common in New England, but are under tremendous threat currently. In the conservation of *L. borealis*, it is beneficial to broaden the objective to protection of sandplain grassland communities as a whole. Habitat protection is thus the first priority action of this plan. Maintaining and increasing population size and number of occurrences follow as conservation goals.

1. Habitat Protection. The primary conservation prescription of this plan is to protect habitat and ensure the safety of current populations of *L. borealis* in New England. It is unlikely that the plant ever existed on a large scale in New England simply because the sandplain grasslands community is uncommon in this region. However, due to increasing development pressures, decreases in land clearing for agriculture, and suppression of natural disturbance events, these communities are becoming even more rare. The decrease in extant occurrences when compared with historic occurrences of *L. borealis* provide evidence for this trend.

Preservation of habitat type should be the goal, in addition to protection of this specific taxon. Fire may be a necessary element for protection of sandplain grassland communities. It reduces tree and shrub cover, and is successful at maintaining large areas of this open habitat. Fire also reduces litter cover, which is related to nutrient availability, flowering and seed production, species diversity, and biomass production in tall grass prairies (Henderson 1994). The objective of habitat protection is also important because of the possible metapopulation status of *L. borealis*, which would require the preservation of vacant sites to prevent regional decline.

2. Maintain and increase population size of extant occurrences. Even in areas of preserved habitat, populations of *L. borealis* have declined. Populations must be carefully monitored to ensure that recreational and other land uses do not destroy occurrences, on both protected and unprotected lands. Population size is important because small, fragmented populations are subject to rapid decline and are more likely to go extinct than large populations (Menges 1992, Schemske et al.1994, Groom 1998). This occurs through random demographic fluctuations, environmental fluctuations, and loss of genetic variability, which can lead to inbreeding depression and genetic drift (Primack 1998). For these reasons, the size of current *L. borealis* populations must be maintained or increased. If the taxon does operate under metapopulation dynamics, it is particularly important to ensure stability of known source populations of the plant, because destruction of a single source population could lead to the extirpation of numerous satellite populations. Over a third of the occurrences of this taxon consist of fewer than 25 individuals. These population sizes must be increased to ensure their continued existence. Ideally, population viability analyses should be conducted to determine minimum viable population size (MVP). This type of study requires several years of demographic data and may not be feasible for many sites. Furthermore, the estimate of a MVP can vary depending on the chosen survival probability. We have arbitrarily chosen 500 individuals as a starting number, to which populations of *L. borealis* should be increased. As a beginning step, we have prioritized 28 sites based on population size, ownership type, and the feasibility of their protection (See Table 4). These occurrences are those that we assigned first and second priority actions. Because of the large number of occurrences for this taxon, the remaining populations are grouped into three population types, and actions are suggested for each type of population. The suggested increases and prioritized sites are only a starting point. The process of prioritization and evaluation of MVPs should continue and evolve with experience and increased knowledge of *L. borealis*.

3. Increase element occurrences. If maintaining or increasing the size of extant sites is infeasible or insufficient to protect the species, then the number of element occurrences should be increased. Many occurrences of *L. borealis* are extremely small, exist on private property, and are threatened by land use practices and succession. An important long-term goal for the species may therefore be to increase the number of element occurrences in New England, on suitable habitat. Identifying this habitat may be difficult, but a good starting place is using sites where *L. borealis* has historically been found. Preserved land may be well-suited for reintroduction because these areas are more likely to be monitored regularly. Reintroduction strategies should take into account the possible metapopulation dynamics of this species.

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IV. APPENDICES

1. Extant, recently extirpated, and historic element occurrences in each state

2. Population sizes of extant occurrences in each state

3. Population trends of extant occurrences in each state

4. Threats to extant and recently extirpated occurrences in each state

5. An explanation of conservation ranks used by The Nature Conservancy and the Association for Biodiversity Information

Appendix 1. Extant, recently extirpated, and historic element occurrences in each state.

State	Total occurrences	Extant occurrences	Extirpated occurrences	Historic occurrences
CT EOs	35	15	2	18
ME EOs	10	4	1	5
MA EOs	137	44	0	93
NH EOs	15	5	2	8
RI EOs	17	14	1	2
Total EOs	**214**	**82**	**6**	**126**

Appendix 2. Populations sizes of extant occurrences in each state.

State	>1000 plants	500-1000 plants	100-499 plants	50-99 plants	25-49 plants	0-24 plants	Unknown
CT EOs	0	0	4	2	3	5	1
ME EOs	1	1	0	0	0	2	
MA EOs	0	0	13	4	5	20	2
NH EOs	0		2	1	0	2	0
RI EOs	3	3	2	3	1	1	1
Total EOs	**4**	**4**	**21**	**10**	**9**	**30**	**4**

Appendix 3. Population trends of extant occurrences in each state.

State	Increasing	Decreasing	Stable	Not enough data
CT EOs	1	3	3	10
ME EOs	0	1	2	2
MA EOs	7	10	4	23
NH EOs	1	4	1	1
RI EOs	4	3	3	5
Total EOs	**13**	**21**	**13**	**41**

Appendix 4. Threats to extant and recently extirpated occurrences in each state.

State	Mowing	Roadside	Succession	Deer	Development/ construction	Herbicide	Collecting
CT EOs	0	4	2	0	1	0	1
ME EOs	0	1	0	0	1	2	0
MA EOs	8	22	13	3	17	3	1
NH EOs	3	0	0	0	3	1	0
RI EOs	1	2	4	8	1	0	1
Total EOs	**12**	**29**	**19**	**11**	**23**	**6**	**3**

5. An explanation of conservation ranks used by The Nature Conservancy and the Association for Biodiversity Information

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**C**that is, a great risk of extinction. S1 indicates critical imperilment within a particular state, province, or other subnational jurisdiction**C**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**C**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.