

New England Plant Conservation Program

Muhlenbergia capillaris (Lamark) Trinius
Hairgrass

Conservation and Research Plan
for New England

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SUMMARY

Muhlenbergia capillaris (Lamark) Trinius, commonly known as hairgrass, is a perennial grass (Poaceae) found primarily in the southeastern United States and rarely as far north as southern New England. It is a clump-former with very narrow leaves and flowering stems up to one meter tall. The species has a diffusely branching, reddish inflorescence that stands out when in flower during autumn. The small lemmas of its single-flowered spikelets typically have long awns. When viewed at a distance, these inflorescences create a colorful “mist,” hence its popularity in commercial horticulture.

Though the species name has been in regular use since 1824, there has been taxonomic confusion throughout the 20th century about what is included in the species. While as recently as 1989 the species included three varieties, the most current treatment of the genus has *Muhlenbergia capillaris* without any varieties, and two closely-related species taking the place of former varieties.

As with many cespitose grasses, *Muhlenbergia capillaris* reproduces primarily via seed. Pollination is assumed to be by wind. It is a fall-flowering species, with flowering/fruitlet dates in New England ranging from September 10-October 26. At least two studies have shown seed germination success ranging from 0-20%. The best germination results occurred using fresh seed with a 12-week cold period. It is a C₄ grass.

In general, *Muhlenbergia capillaris* occurs at low elevations in open woodlands and savannahs with soils ranging from acidic to basic, and from clay to sand, or rocky, in texture. In New England, *Muhlenbergia capillaris* is mostly restricted to dry, rocky woodlands or openings on trap rock (basalt) ridges. Burning, especially in the early spring versus dormant season, has been shown to greatly increase flower stem production in a closely-related species. Fire also appears to facilitate population growth.

In New England, *Muhlenbergia capillaris* is a Division 2 taxon in *Flora Conservanda* (Regionally Rare). At present, there is only one extant occurrence with only six genets in Connecticut, and seven occurrences are believed to be extirpated. Quarrying and residential development are two known threats to the species in New England. Hiker traffic, competition by woody plants, and inbreeding depression are potential threats to the species. Conservation objectives for *Muhlenbergia capillaris* in New England are to have three occurrences, each with at least 20 genets, displaying a 75% annual flowering rate. Conservation actions include dedicated searches for the species at historical sites, annual surveys of the extant site, land protection (one site), and habitat management, including cutting woody plants to reduce shading and conducting highly localized prescribed burns. If dedicated searches do not reveal other extant occurrences, then *ex situ* activities, including both propagation and seed banking, will be important for reintroductions at two sites.

PREFACE

This document is an excerpt of a New England Plant Conservation Program (NEPCoP) Conservation and Research Plan. Because they contain sensitive information, full plans 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.

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. If you require additional information on the distribution of this rare plant species in your town, please contact your state’s Natural Heritage Program.

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I. BACKGROUND

INTRODUCTION

Muhlenbergia capillaris (Lamark) Trinius, a species of grass (Poaceae), is the focus of this conservation plan. It is found most commonly in the southeastern United States, and rarely as far north as the southern portions of midwestern states (Illinois, Indiana, and Ohio) and southern New England. The plan is presented in two major sections: background and conservation. Based primarily on literature review, the background section provides summary information on the species' taxonomy, biology, ecology, distribution, and status throughout its range. It also contains information on the species' status in New England, including detailed information on all extant and historical occurrences, plus current conservation measures. The second section focuses on conservation of the species in New England, including objectives and general actions, as well as prioritized actions for each occurrence.

While roughly two days were spent in the field surveying and searching for *Muhlenbergia capillaris* in Connecticut, the great bulk of information contained in this plan comes from secondary sources. Much of the occurrence data were obtained from the Massachusetts and Connecticut Natural Heritage Programs, and specimen data from the Herbarium Recovery Project (Arthur Haines, New England Wild Flower Society, unpublished data). Academic literature review, web searches, and personal communications provided the rest of the information.

By all accounts, *Muhlenbergia capillaris* is a striking and beautiful grass when observed in flower or fruit. It is a perennial that grows in dense tufts with narrow leaves and flower stalks up to a meter tall. Its delicately branched and spreading inflorescence is reddish, containing numerous single-flowered spikelets with long-awned lemmas. Taxonomically, there has been some confusion about what to include in the taxon, even though the name *Muhlenbergia capillaris* came into existence in 1824 (Hitchcock 1971). The most recent treatment of the genus describes *Muhlenbergia capillaris* with no varieties (Peterson 2003). Other than basic characteristics typical of many cespitose grasses, little biological information on the species is available. It is a perennial grass that reproduces sexually and is presumably pollinated by the wind. Limited germination trials using New England seed show that the highest germination (20%) occurred when fresh seed had a 12-week cold treatment (New England Wild Flower Society, unpublished data).

Throughout its range, *Muhlenbergia capillaris* is primarily an upland species of open woods and savannahs, growing in soil of a variety of pHs and textures (Peterson 2003). In New England, it primarily occurs in dry, rocky, openings on the trap rock (basalt) ridges of Massachusetts and Connecticut. As with many upland grasses, *Muhlenbergia capillaris* reacts favorably to fires, both in flower stalk production and in regeneration (Bittner and West 1994, Snyder 2003).

Muhlenbergia capillaris is extremely rare in New England, with only one extant (with six genets) and seven historical/extirpated occurrences known. It is a Division 2 (Regionally Rare) taxon in *Flora Conservanda* (Brumback and Mehrhoff et al. 1996). Residential development and quarrying are two known threats to the species in New England, while hiker traffic, competition by woody plants, and inbreeding depression are potential threats. Conservation measures taken to date include seed banking and propagation, and regular surveys of the extant occurrence. A dedicated search has been conducted at almost all the historical occurrences.

DESCRIPTION

Muhlenbergia capillaris is a perennial grass that typically forms large, discrete clumps (Hitchcock 1971, Peterson 2003). Its erect leaf blades are involute to flat, 1-4 millimeters wide and 10-35 (and up to 80) centimeters long. They are smooth abaxially and scabrous adaxially. In New England, leaves of living plants are light green with a slightly bluish cast (Engstrom, personal observation). Its glabrous to puberulous sheaths often become fibrous with maturity, but are not generally curled (Peterson 2003). Basal sheaths are never spirally coiled as in the closely related *Muhlenbergia expansa*. The 60 to 100-cm tall culms are erect with mostly glabrous internodes.

The inflorescence of *Muhlenbergia capillaris* is a diffuse panicle with capillary branches. It is longer than wide, ranging from 15-50 cm in length and 5-30 cm in width. Its panicles are colorful: reddish-purple in life (Engstrom, personal observation), or purple as described in the literature (Hitchcock 1971, Peterson 2003). When abundant, these handsome flowering stems form a reddish-pinkish haze (Engstrom, personal observation). Steyermark (1977: 161) has this engaging description of *Muhlenbergia capillaris*: “This is a handsome grass with its graceful rosy-purple panicle of hair like delicate branches and pedicels, and is conspicuous when encountered in the fall.” It is used horticulturally for this reason. Numerous images of the species, often provided by commercial growers, can be found on the World Wide Web. In New England, there is no other grass that it can be confused with when in flower or fruit.

The single-flowered spikelets are 3-5 mm in length, and are usually purple (or reddish), though they can be green, brown, or straw-colored (Peterson 2003). The 1-1.5 (2)-mm glumes are subequal and usually awnless. The narrow lemmas are 3-5 mm and have short hairs at their bases (calluses). Disarticulation (how the seed falls off the inflorescence) is presumed to be below the lemmas, as is the case with most of the genus. While Hitchcock (1971) describes the lemmas as awned, Peterson (2003) describes them as having awns or not. If present, the awns are from 2-13 (18) mm in length. Paleas are narrower than the lemmas, and nearly of the same length. The brown seed (caryopsis) of *Muhlenbergia capillaris* is elliptic and 2-2.5 mm long.

TAXONOMIC RELATIONSHIPS, HISTORY, AND SYNONYMY

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

Muhlenbergia is a large genus of grasses containing roughly 155 species distributed throughout the Western Hemisphere for the most part, and has its center of distribution in Mexico (Reeder 1975, Peterson 2003). The genus is diverse in growth habits, morphology, and ecological relations. One subgenus (*Muhlenbergia* subgenus *Muhlenbergia*) is clearly segregated based on its scaly rhizomes (Pohl 1969). *Muhlenbergia capillaris* is not in this subgenus.

In the most recent synoptic work of *Muhlenbergia* Schreb. in North America north of Mexico, Peterson (2003) places *Muhlenbergia capillaris* (Lamark) Trinius (Poaceae) as a species with no varieties. This stands in contrast with some earlier works that included up to two varieties beyond the nominative. Vasey (1892) included *M. expansa* (DC) Trin. as *M. capillaris* var. *trichopodes*, and Beal (1896) reduced *M. filipes* M. A. Curtis to a variety of *M. capillaris*. More recently, Morden and Hatch (1989) retained the two aforementioned closely related taxa as varieties of *Muhlenbergia capillaris* (var. *trichopodes* and var. *filipes*) based on the continuum of morphological variation they found in the complex. Peterson (2003) rejected Morden and Hatch's taxonomy and retained both *M. expansa* and *M. filipes* as distinct species, though he changed the latter to *M. sericea* (Michx.) P. M. Peterson because of the priority of an older name. In retaining three distinct species within the complex, Peterson is in keeping with treatments of the genus in most major floras (Fernald 1950, Radford et al. 1968, Reeder 1975), though Gleason and Cronquist (1991) went along with Morden and Hatch's taxonomy and Hitchcock (1971) retained *M. expansa* as a species, but included *M. sericea* (*filipes*) as *M. capillaris* var. *filipes*. In their grass systematics text, Gould and Shaw (1983) note that *Muhlenbergia capillaris* is one of several closely related species with large, open inflorescences.

As described above, there has been taxonomic confusion regarding what to include in *Muhlenbergia capillaris*, though the species name has been taxonomically stable for the most part since Trinius first used it in 1824 (Hitchcock 1971). Synonyms, dating from 1788 to 1841, include *Stipa diffusa* Walt., *Stipa capillaris* Lam., *Podosaemum capillare* Desv., *Tosagris agrostidea* Beauv., *Podosemum agrostideum* Beauv., *Trichochloa capillaris* DC., *Trichochloa polypogon* DC., *Muhlenbergia polypogon* Kunth, and *Agrostis setosa* Willd (Hitchcock 1971).

Using Peterson's (2003) taxonomy, closely related species to *Muhlenbergia capillaris* include *M. expansa* (Poir.) Trin., *M. sericea* (Michx.) P. M. Peterson, *M. reverchonii* Vasey & Scribn., and *M. rigida* (Kunth) Trin. *Muhlenbergia expansa* is separated from *M. capillaris* primarily by its awnless, or nearly awnless, lemmas, and its glumes that are more than half as long as lemmas (Peterson 2003). *Muhlenbergia expansa* is a southeastern United States coastal plain species found in bogs, pine

savannahs, and flatwoods, ranging as far north as southeastern Virginia. *Muhlenbergia sericea* differs from *M. capillaris* by its awned glumes (up to 25 mm), and lemmas with setaceous teeth and larger glumes (8-35 mm). It is largely restricted to sandy coastal habitats in southeastern United States, especially Florida. *Muhlenbergia reverchonii* differs from *M. capillaris* primarily by its shiny, less scabrous, and shorter-awned lemmas, and its shorter and relatively broader panicles. It is restricted to calcareous habitats, rocky or otherwise, in central Texas and Oklahoma (Peterson 2003). *Muhlenbergia rigida* is not easily separated from *M. capillaris*, though it is believed to be a distinct species and the ranges of the two species do not overlap (Paul Peterson, Smithsonian Institution, personal communication). *Muhlenbergia rigida* is a species of the mountains of southwestern United States, Middle America, and South America.

The genus *Muhlenbergia* is named for Rev. Gotthilf Heinrich (Henry) Ernst Muhlenberg, a pioneer American botanist from Pennsylvania active circa 1800 (Hitchcock 1971). The species epithet “*capillaris*” means “hair-like” (Fernald 1950). The most frequently used common name for *Muhlenbergia capillaris* is “hairgrass” (“hair grass” or “hair-grass”) (Gray 1867, Fernald 1950, Radford et al. 1964, Gleason and Cronquist 1991), which should not be confused with the other “hairgrass” — *Deschampsia flexuosa*. Other common names seen in the botanical literature include “hairy-awn muhly” (Reeder 1975, Peterson 2003) and “long-awned smokegrass” (Dodge 1997). In commercial information (Floridata 2003), common names such as Gulf muhlygrass, mist grass, and pink muhlygrass are given. “Regal Mist” is a trademarked cultivar.

SPECIES BIOLOGY

Muhlenbergia capillaris is a perennial grass that forms dense clumps (Peterson 2003). Since it is neither rhizomatous nor stoloniferous, the species must reproduce via seed. Like most grasses, pollination is presumably by wind. Throughout its range, *Muhlenbergia capillaris* flowers in September and October (Fernald 1950, Radford et al. 1964, Gould 1975). In the Florida panhandle, it flowers as late as November (Clewall 1985). In New England, Seymour (1989) gives September 10 to October 5 for flowering dates. Eleven nonduplicate specimens noted as flowering in the Herbarium Recovery Project database (Haines, unpublished data) and from the Connecticut Geological and Natural History Survey, or CTGNHS (unpublished data) give dates ranging from September 10 to October 26; fruiting dates from three different collections from the same sources range from September 11 to September 25. Notes on phenology have been taken several times in recent years at the only extant New England occurrence (CT .002 [New Haven]). Plants were all in fruit on October 19, 1994 (CTGNHS, unpublished data). On September 17, 2002, most inflorescences were $\leq 50\%$ emerged from their sheaths and none of the spikelets had flowered (Engstrom, personal observation). At the same place on the same date a year later, the inflorescences were further emerged from their sheaths, but still had yet to flower (Engstrom, personal observation).

Seed trials of *Muhlenbergia capillaris* from two sources show germination rates ranging from 0 to 20%. Five treatments were used in trials of seed collected from wild Connecticut plants (New England Wild Flower Society, unpublished data). One hundred seeds were tried with each treatment. For fresh seed sowings, germination results were as follows: 20% (12 weeks cold), 12% (warm), and 2% (cold out for winter). For dried seed sowings, germination results were as follows: 17% (warm, moist) and 0% (12 weeks cold), plus 1% in another 12 weeks cold, moist stratification using seed collected from offspring of a plant grown from original seed collection. In a study using *Muhlenbergia capillaris* seed of the offspring of plants grown from seed collected from various locations in Florida, very low (0-1%) germination rates were obtained in laboratory trials, with only one trial as high as 5% (USDA, NRCS 1997). Apparently, very little viable seed was produced even though the accessions (plants grown from wild seed) flowered profusely. Accessions are being maintained at the Plant Materials Center in Brooksville, Florida.

Although no source is provided, summary information on *Muhlenbergia capillaris* provided by the Natural Resources Conservation Service on-line states that no cold stratification is needed for germination (USDA, NRCS 2004). According to an online commercial plant database (Floridata 2003), *Muhlenbergia capillaris* is easy to start from seed, and divisions can be used in propagation.

According to Gould and Shaw (1983), all the members of the Chloridoideae subfamily, including *Muhlenbergia*, have the C₄ photosynthetic pathway. A specialized cell anatomy in combination with this chemical pathway allows C₄ plants to more efficiently utilize carbon dioxide. C₄ grasses are adapted to hotter, drier, sunnier conditions than counterpart C₃ species.

Although no direct references were found on the subject, seed dispersal for *Muhlenbergia capillaris* is likely via large mammals. The long awn on the lemma would appear to easily catch in the fur of a large mammal, especially those with longer hair, such as canids or sheep.

The chromosome number for *Muhlenbergia capillaris* is unknown (Peterson 2003).

HABITAT/ECOLOGY

In general, *Muhlenbergia capillaris* is a grass of open woodlands and savannahs that grows in acidic to calcareous soils of clay, sandy, or rocky textures (Hitchcock 1971, Peterson 2003). It occurs at elevations ranging from sea level to 500 meters. Throughout its continental range, it is mostly an upland species (USDA, NRCS 2004), receiving a “facultative upland” classification in the National Wetlands Inventory. This ranking means that it usually (67-99%) occurs in non-wetlands. Only in Puerto Rico is it classified as a “facultative wetland” species.

In New England, *Muhlenbergia capillaris* is mostly restricted to dry, rocky woodlands or openings on trap rock ridges. In Connecticut, where the only extant population occurs, the species is and was associated with the subacidic rocky summit outcrop, or cedar glade, natural community at elevations under 150 meters (CTGNHS, unpublished data). These particular trap rock ridges are composed of 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. Where the species was historically known in the Holyoke Range in Massachusetts, the soils on basalt bedrock have a higher pH (mean of 4.68) compared to adjacent soils on arkose sandstone and siltstone (mean of 4.06) (Searcy et al. 2003). The two other habitats for *Muhlenbergia capillaris* (of two historical Massachusetts occurrences) include a small arkose mountain with open, rocky habitat, and sea shoreline habitat adjacent to salt marsh. Arkose is a feldspar-rich sandstone.

The following species are associated with *Muhlenbergia capillaris* at two trap rock ridge sites (extant and one believed extirpated) in Connecticut: *Juniperus virginiana*, *Quercus stellata*, *Carya glabra*, *Fraxinus americana*, *Schizachyrium scoparium*, *Carex pensylvanica*, *Tridens flavus*, *Helianthus divaricatus*, *Solidago nemoralis*, *Hypericum punctatum*, *Viburnum rafinesquianum*, *Eupatorium sessilifolium*, *Potentilla arguta*, *Pycnanthemum incanum*, *Paronychia canadensis*, *Dryopteris marginalis*, *Asplenium trichomanes*, and *Polypodium virginianum*.

Elsewhere in northeastern United States (where it is also rare or uncommon), both extant and historical *Muhlenbergia capillaris* occurrences are known from a variety of habitats. In New York, there is a single confirmed record (specimen) of the species from a coastal plain pondshore on Long Island (Zaremba and Lamont 1993; New York Natural Heritage Program, unpublished data). There are also reports of it occurring on exposed glacial sand and gravel deposits on Long Island (Conrad 1923), and in talus at Niagara Falls (New York Natural Heritage Program, unpublished data). In New Jersey, *Muhlenbergia capillaris* occurs in a trap rock glade/outcrop community, apparently similar habitat to the New England occurrences, in the northeastern part of the state (Dodge 1997). There, it occurs with other rare plants (of New Jersey) such as *Scutellaria leonardii*, *Pycnanthemum torreyi*, and *Carex deweyana*. In southern Ohio, it was found in rocky ridge habitat (Ohio Department of Natural Resources 1985). In Illinois, it occurs mostly in sandy woodlands (Mohlenbrock 2001). In southern Illinois, it is considered an indicator species of the globally rare (G2) shale barrens natural community (Bittner and West 1994).

Where it occurs more commonly in southeastern and south central states, *Muhlenbergia capillaris* can be found in an even greater array of habitats. In Missouri, it is found in “upland prairies, glades, tops of bluffs, savannas, and openings of dry upland forests, often on acidic substrates, sometimes in areas of cherty dolomite; also roadsides” (Yatskievych 1999: 720). In his early description of flora of the Ozark region of Missouri, Steyermark (1934) listed *Muhlenbergia capillaris* as a typical oxylophyte, i.e., a species favoring areas of acidic rocks. In the Ozarks, these rocks would be sandstone, chert, granite, and porphyritic trachyte (fine-grained volcanic rock). In the southeastern

Great Plains, it is noted in open woods, prairies and pastures (Great Plains Flora Association 1986).

In Texas, Reeder (1975: 258) gives a very generic description of *Muhlenbergia capillaris* habitat: “rocky or sandy woodlands.” A more vivid picture of the species in the state is gained through the descriptions found on a sampling of specimen labels (Flora of Texas Database 2004):

- “Frequent in loose dry sand hummocks in seacoast bluestem grassland, vegetated flats” (Nueces County)
- “Soil gravelly clay loam; range site Adobe or clay loam” (Lampasas County)
- “Rare in deep sandy loam in loblolly pine – post oak forest on well-drained terraces along tributary stream” (Bastrop County)
- “Rare in slightly acid fine sandy loam Alfisols (Freestone Series) in shortleaf pine-oak savanna on level upland. Associates include *Schizachyrium scoparium*, *Andropogon* spp., *Rudbeckia hirta*, *Lechea mucronata*, *Helianthus mollis*, *Tridens flavus* ...*Eragrostis spectabilis*” (Lanos County)
- “...rare in sandier part of *Iva*- dominated blackland prairie on heavy clay Vertisols (Ferry Series), large opening in loblolly pine forest on midslope. Associates include *Iva angustifolia*, *Grindelia squarrosa*, *Andropogon glomeratus*, *Sporobolus asper*...” (Walker County)
- “...forming clumps 2 ft. in diameter, rare in Wiergate clay (Vertisols) over Willis formation, loblolly pine forest” (San Jacinto County)

Likewise, data from collection labels provide additional insight into the species’ habitat preferences in the heart of the species’ range in Louisiana (Herbarium of Louisiana State University 2004):

- “Secondary growths of Slash Pine mixed with Longleaf Pine with open understory. Soil: Brimstone silty soil underlain by clay pan” (Calcasieu County)
- “Fourchon Beach and associated dunes” (Lafourche County)
- “Common in longleaf pine flatwoods” (St. Tammany County)
- “Calcareous prairie opening ... Ca. 0.5 m tall. Common grass” (Winn County)
- “Common in pine grassland, sandy loam with *Andropogon*, *Paspalum*” (Grant County)
- “Common on older spoil near canal with *Eragrostis*, *Chloris*, and *Paspalum repens*, saline marsh” (Terrebonne County)

Habitats of similar character are described for *Muhlenbergia capillaris* in coastal plain states on the Atlantic seaboard, such as North Carolina and South Carolina, where Radford et al. (1964: 107) summarizes the species’ habitats as “Dry woods and savannahs; chiefly piedmont and coastal plain.” On North Carolina’s Outer Banks it is frequent in dry sands and protected dunes (Stalter and Lamont 1997).

Based on the preceding biological and habitat information, *Muhlenbergia capillaris* can be characterized as an upland, woodland or prairie/savannah species. Furthermore, as a grass, its growth pattern is such that it annually produces dead leaves and fruiting stems that translate into fine fuels. Fine fuels can quickly dry out and burn. Both its dry habitat in conjunction with its production of fine fuels, make it a species likely adapted for fire. Three studies involving prescribed burns suggest it is a fire-adapted species. In a restoration study of the rare shale barrens in southern Illinois, *Muhlenbergia capillaris* was found to be ten times more abundant in the restored (cleared and burned) plots than in the control plots (Bittner and West 1994). In south Florida, the closely-related *Muhlenbergia capillaris* var. *filipes* (*M. sericea* [Peterson 2003]) in a “muhly prairie” of the greater Everglades ecosystem showed a much greater flowering response when burned, versus when clipped but not burned (Snyder 2003). However, in this comparison of burned versus clipped plants, the vegetative growth was the same. The researchers in this experiment found that a 55-gallon metal drum could be used effectively to burn individual plants, thus avoiding the cost and time of a typical prescribed burn over a larger area. In another study of grasses in the wet prairies of south Florida, *Muhlenbergia capillaris*, as well as two other dominant grasses, responded with significantly greater flowering effort with early growing season (May) burns compared to dormant (January) season burns (Main and Barry 2002). This strong positive effect of early growing season burns decreased, however, after the first growing season.

While no direct studies have been conducted, *Muhlenbergia capillaris* is probably a salt-tolerant species given its coastal habitats in the southeastern United States. It is reported as salt-tolerant in commercial horticultural literature (Floridata 2003).

THREATS TO TAXON

Quarrying of trap rock, and residential and other developments, are two threats that have almost indisputably affected New England occurrences of *Muhlenbergia capillaris*. Both destroy habitat for the species, as well as other rare species associated with the trap rock ridges. Quarrying has eliminated a large section, including most of the summit, of the ridge that historically supported CT .004 (Hamden). It also may have affected CT .001 (Cheshire), depending on the actual location of the 1910 specimens. Residential housing has destroyed other parts of CT .004 (Hamden), as well as a large portion of the most promising landscape positions at CT .003 (Hamden). Construction of a large public water supply tank has also destroyed potential habitat for the species at CT .003 (Hamden). Both of these threats, as well as construction of cell towers, have been identified as primary threats facing trap rock ridge natural communities in Connecticut (Fitzgerald 2002).

In addition to these identified threats, several potential threats exist. Because they occupy summit openings that offer expansive views of the surrounding landscapes, several occurrences are threatened by recreational hiker traffic. CT .002 (New Haven), MA .001 (South Hadley), and MA .002 (Deerfield) have summit openings that would attract hikers. The cliff-brow opening of CT .002 (New Haven) has a renegade path

running down through it. While not a problem as of 2003 (Engstrom, personal observation), increased use of this path would have a detrimental effect on the *Muhlenbergia capillaris*.

Shading by woody plants is another potential threat to these sun-loving plants. It has been mentioned as a threat with respect to both CT .001 (Cheshire) and CT .002 (New Haven) occurrences, as well as a general trend at openings along the entire ridge where CT .001 (Cheshire) occurs (William Moorhead, Consulting Botanist, personal communication). Although not documented for *Muhlenbergia capillaris* 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 in canopy cover. The land in southern Connecticut and southern New England in general, was seriously impacted by settlement activities starting in the 17th century and extending through the 18th and 19th centuries (Whitney 1994). The city of New Haven was settled by 500 English Puritans in 1638, at which time there was already a settlement of the native Quinnipiack tribe (City of New Haven Online 2003). Competing invasive species, such as the privet and honeysuckles seen on trap rock ridges near the Connecticut occurrences, and herbs, such as *Centaurea maculosa* and *Vincetoxicum nigrum*, are yet more threats that could impact the *Muhlenbergia capillaris* populations in New England (Engstrom, personal observation).

With such few plants persisting, inbreeding depression and genetic drift are other potential threats to the species' viability in the region. While no genetic studies have been done on *Muhlenbergia capillaris*, genetic studies and theory suggest that selection may work against self-pollinated individuals and homozygotes derived from selfing in small populations of outcrossing species (Neel et al. 2001).

DISTRIBUTION AND STATUS

General Status

Muhlenbergia capillaris is primarily a species of the southeastern United States (Barkworth et al. 2000, Peterson 2003). It rarely, however, reaches into the northeastern states (Table 1, Figure 1). Its northernmost extant station is New Haven, Connecticut, though historically it reached as far north as Franklin County, Massachusetts (42° 28' north). While no specimen has been found, there is a report in literature of *Muhlenbergia capillaris* in Niagara County, New York, which is a bit further north (at least 43° north) (Smith 1965, Young and Weldy 2003). The species is rare in the Midwest, where it ranges as far north as the southern parts of Ohio, Indiana, and Illinois. In Missouri, *Muhlenbergia capillaris* is largely restricted to the southern half of the state, south of the Missouri River (Yatskievych 1999). Excepting its few New England stations, the species' northern boundary roughly approximates the southern boundary of Pleistocene glaciation (Brouillet and Whetstone 1993). The range of *Muhlenbergia capillaris* extends as far west as eastern Kansas, central Oklahoma, and central Texas. Within the

southeastern United States, its occurrences appear to be concentrated along the coast, both the Atlantic seaboard and the Gulf of Mexico. The concentration of occurrences in the southern half of Missouri appears anomalous for the interior, though this might be a function of inconsistent distribution data (Barkworth 2003, Peterson 2003).

Table 1. Occurrence and status of <i>Muhlenbergia capillaris</i> in the United States and Canada based on information from Natural Heritage Programs and the PLANTS Database (2004).			
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, E): 1 extant and 3 likely extirpated	Illinois (S2S3): known from 7 counties (Mohlenbrock 2001)	Alabama (SR)	Delaware (SH)
Indiana (S1, E)	Kentucky (S3S4): 14 counties	Arkansas (SR): occurs in 8 counties	District of Columbia (SH)
Maryland (S1, E)	Louisiana (S?): many specimens (Herbarium of Louisiana State University 2004)	Florida (SR): occurs in 33 counties (USF database)	Massachusetts (SX): 4 historic occurrences
New Jersey (S1, E): known from 7 counties	North Carolina (S3): 35+ counties	Georgia (SR): 22 counties	New York (SX)
West Virginia (S1): 1 county	Virginia (S?): 20 counties	Kansas (SR): 8 counties	Ohio (SH): presumed extirpated (Ohio DNR 1985)
		Mississippi (SR)	Pennsylvania (SX)
		Missouri (SR): occurs in 31 counties	
		Oklahoma (SR)	
		South Carolina (SR): 35+ counties	
		Tennessee (SR): occurs in 10 counties	
		Texas (SR): numerous specimens from different counties (Flora of Texas Database 2004)	

Outside the United States, *Muhlenbergia capillaris* occurs in the Bahamas and possibly other Caribbean islands (Peterson 2003). Kartesz and Meacham (2001) list the species as rare in Puerto Rico. The Missouri Botanical Garden Specimen Database (2004) includes records of *Muhlenbergia capillaris* specimens from the mountains of southern Mexico and adjacent Guatemala, as well as from the Yucatan peninsula. In a recent query of these Mesoamerican specimens, Peterson (personal communication)

stated that he believes the Mexican and Guatemalan specimens are *Muhlenbergia rigida* (Kunth) Trin., though *Muhlenbergia capillaris* may occur along the Caribbean coast in Mexico as far south as Vera Cruz. While believing the presence of two distinct species, he does note, however, that he has no good characteristics to separate *Muhlenbergia capillaris* from *M. rigida*. The latter is a species of southwestern United States, Mexico, and South America.

As shown in Table 1 and Figure 1, *Muhlenbergia capillaris* is rare in the states at the northern edge of its range, including all the northeastern states. In fact, it is historical or extirpated in most of these northern states. Connecticut has the only extant occurrence in all the northeastern states north of New Jersey.

According to The Nature Conservancy's (2001) ecoregional map, the distribution of *Muhlenbergia capillaris* is concentrated mostly in the coastal plain ecoregions, including the Chesapeake Bay Lowlands, Mid-Atlantic Coastal Plain, South Atlantic Coastal Plain, Florida Peninsula, Tropical Florida, East Gulf Coastal Plain, and Gulf Coast Prairies and Marshes ecoregions. Interiorly, it ranges into the Piedmont, Cumberlands and Southern Ridge and Valley, Interior Low Plain, Upper East Gulf Coastal Plain, Mississippi River Alluvial Plain, Piney Woods, Upper West Gulf Coastal Plain, Ozarks, and the Crosstimbers and Southern Tallgrass Prairie. It also ranges into the Osage Plains/Flint Hills and (rarely) into North Atlantic Coastal Plain. It occurs incidentally in the Lower New England/Northern Piedmont ecoregion.

Status of All New England Occurrences — Current and Historical

Muhlenbergia capillaris is a Division 2 species in *Flora Conservanda* (Brumback and Mehrhoff et al. 1996), i.e., a rare taxon in the New England region. Of the eight known occurrences in the region, only one is extant. Hence, the species appears to be declining throughout the region. Information from historical, recent, and extant occurrences suggests that populations have always been small. “Rare” and “not common” were terms used on specimen labels to describe two occurrences (MA .001 [South Hadley] and MA .003 [Hingham]), and population figures from only 8 to 18 genets are known from two extant/recent occurrences (CT .002 [New Haven] and CT .001 [Cheshire], respectively).

The lone extant occurrence (CT .002 [New Haven]) has been known for at least 128 years (since 1875), and possibly as many as 165 years, or more (pre-1835). The report of an 1818 collection (MA .002 [Deerfield]) is the oldest date for the species in New England. Of the 36 specimen records entered in specimen data sets (CTGNHS, unpublished data; Haines, unpublished data), all except three (one 1931 and two undated) were positively collected prior to 1910. All except two occurrences (CT .001 [Cheshire] and CT .002 [New Haven]) are known only from pre-1900 specimens, though one other (MA .003 [Hingham]) might have persisted into the early 1900s. Based on the negative results of dedicated searches of historical occurrences, plus obvious habitat destruction

(CT .004 [Hamden]), all except one of the New England occurrences is believed extirpated.

Abbreviated herbarium names used below follow those of Index Herbariorum (2003). See Appendix 3 for list of herbaria abbreviations used in this plan. Figures 2 and 3 show the distribution of extant and historical occurrences of *Muhlenbergia capillaris* in New England.

Table 2. New England Occurrence Records for <i>Muhlenbergia capillaris</i>. Shaded occurrences are considered extant.			
State	EO #	County	Town
MA	.001	Hampshire	South Hadley/ Hadley
MA	.002	Franklin	Deerfield
MA	.003	Plymouth	Hingham
MA	.004	Hampshire	Amherst
CT	.001	New Haven	Cheshire
CT	.002	New Haven	New Haven
CT	.003	New Haven	Hamden
CT	.004	New Haven	Hamden

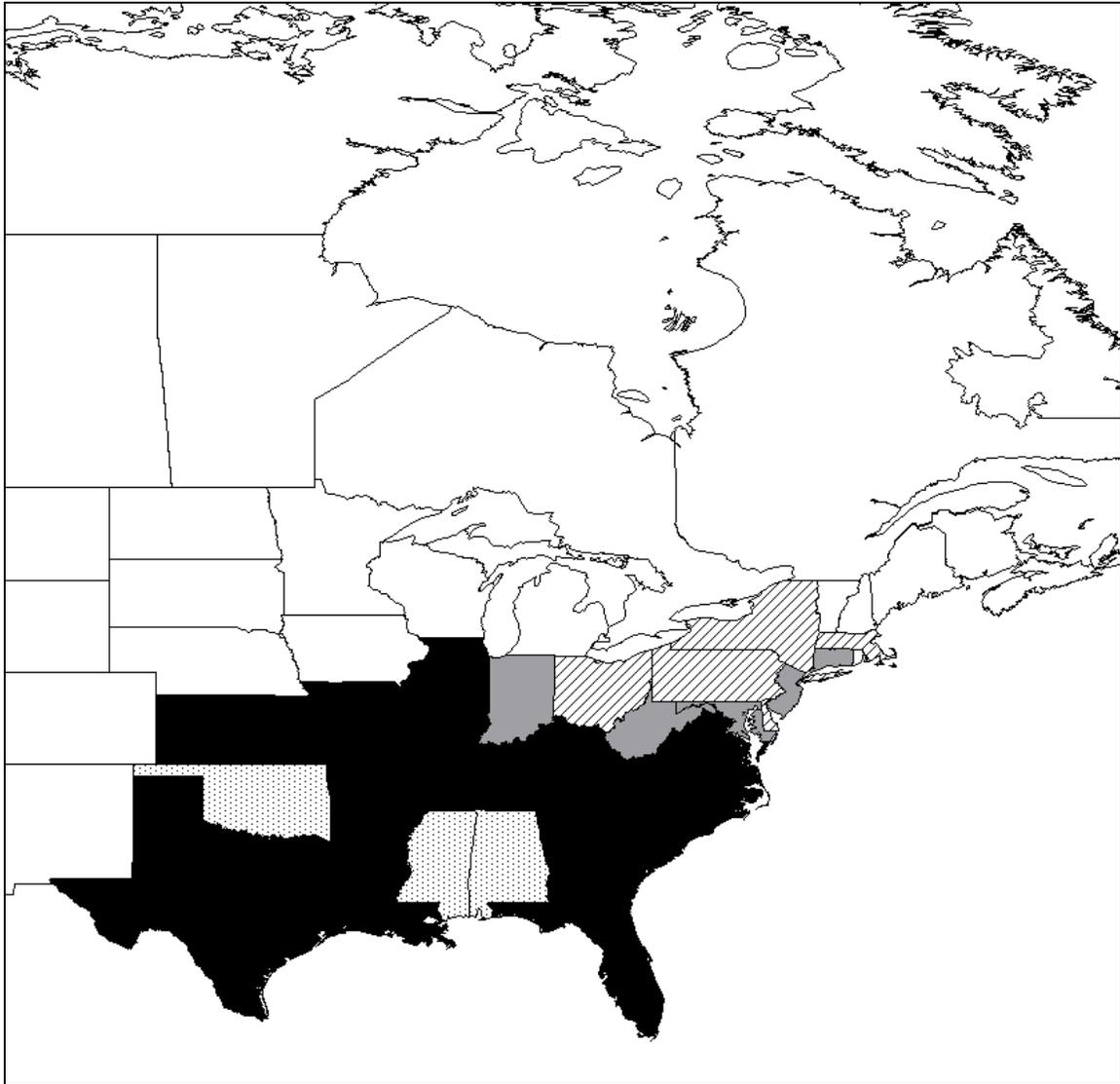


Figure 1. Occurrences of *Muhlenbergia capillaris* in North America. States shaded in gray have one to five (or an unspecified number of) current occurrences of the taxon. Areas shaded in black have more than five confirmed occurrences. States with diagonal hatching are considered "historic," where the taxon no longer occurs. Areas with stippling (Alabama, Mississippi, Oklahoma) are ranked "SR" (status "reported" but not necessarily verified or without further information). See Appendix for explanation of state ranks.

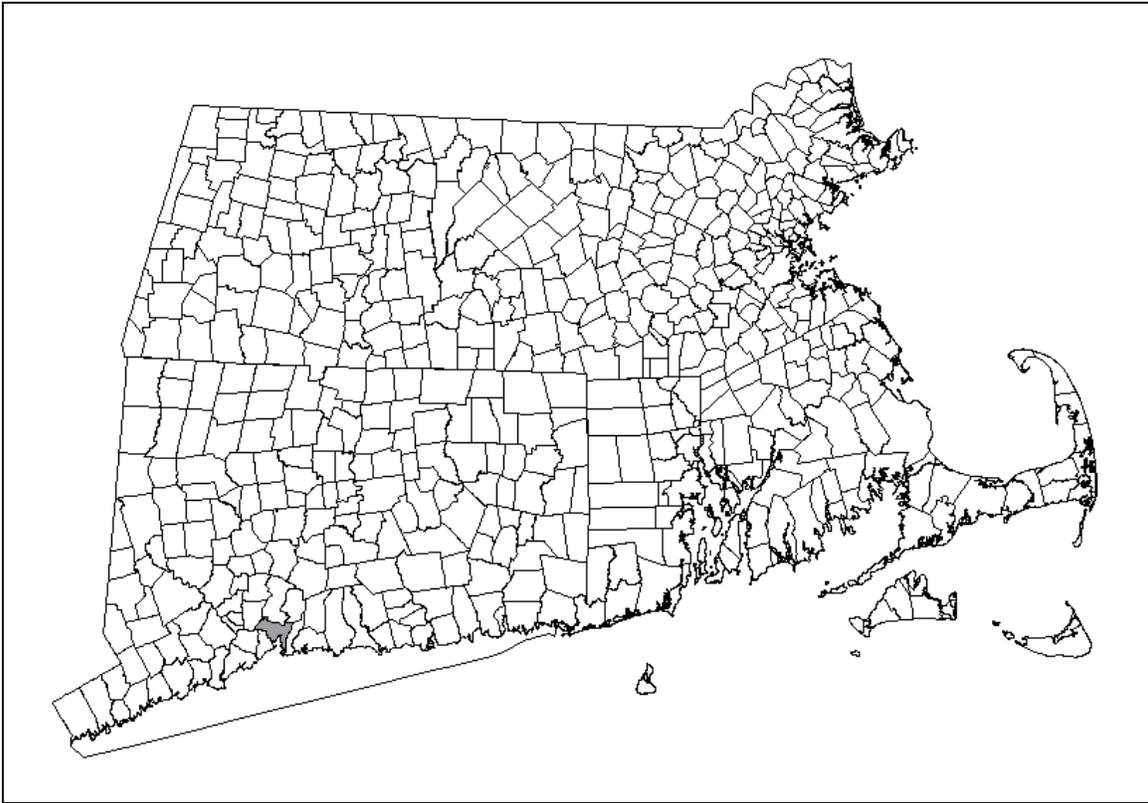


Figure 2. Extant occurrence of *Muhlenbergia capillaris* in New England. Town boundaries for southern New England states are shown. The town shaded in gray (New Haven) has one extant occurrence of the taxon.

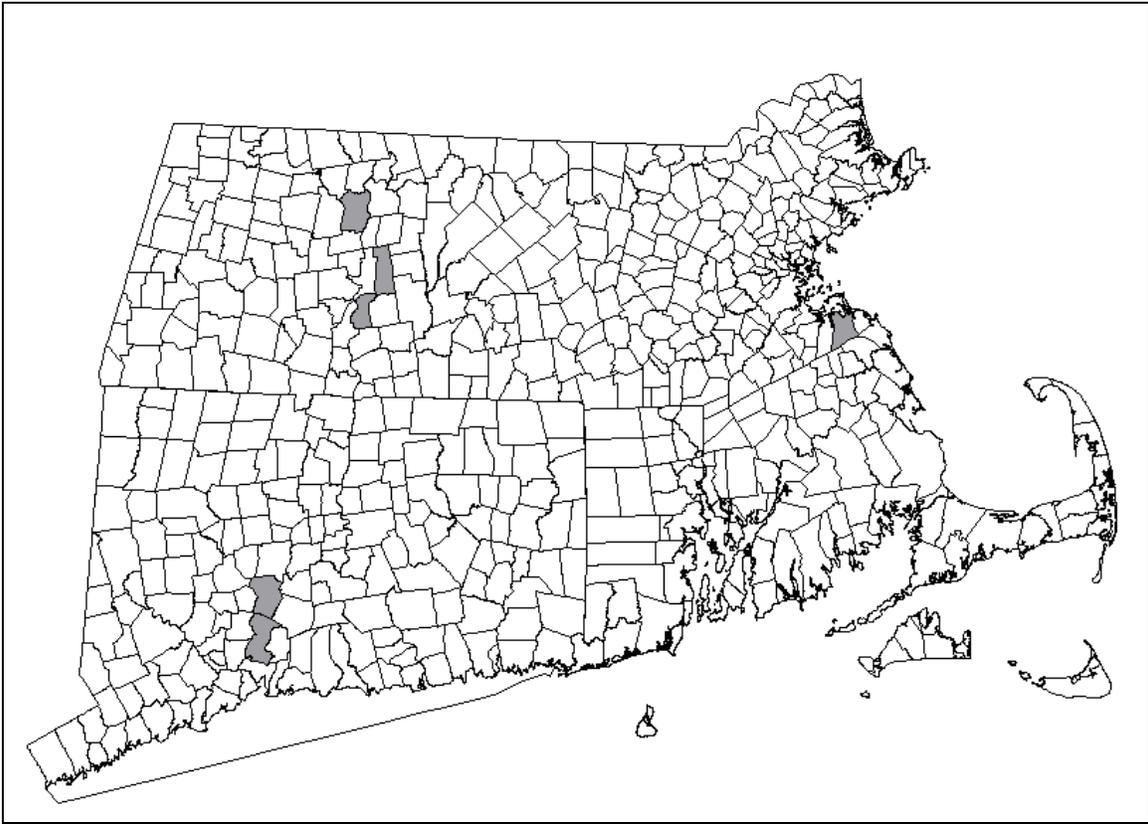


Figure 3. Historic occurrences of *Muhlenbergia capillaris* in New England. Towns shaded in gray have one to five historic records of the taxon.

II. CONSERVATION

CONSERVATION OBJECTIVES FOR THE TAXON IN NEW ENGLAND

The primary conservation objective for *Muhlenbergia capillaris* in New England is to have three occurrences distributed in Massachusetts (one occurrence) and Connecticut (two occurrences) at extant and historical sites for the species. A minimum of 20 genets per occurrence, of which at least 75% flower each year, is set as a goal in order to increase viability of populations at each site. While representing a decrease over a documented eight occurrences ever known in New England, the three occurrences proposed represents a realistic goal for the species in the region over the next 20 years. Lacking robust historical data, the general picture is that the species has always been rare in New England. Since only one occurrence is extant, two more occurrences will need to be rediscovered, or reintroduced, in order to reach this objective. Both the dedicated searches needed for rediscovery, and reintroduction, are time-consuming actions; the latter is costly as well. Dedicated searches should take place within the next five years, and reintroduction, if necessary, within the next 10 years. No expansion from the species' historical and extant sites is recommended, based on the belief that introduction of a species at a new site is a biological gamble at best, and ecologically destabilizing at worst. The 20 plants per occurrence is based on the highest population figure recorded from the two New England occurrences with population data. Having 75% of the plants of each occurrence flowering each year is a conservative objective given that records over a number of years of the extant occurrence (CT .002 [New Haven]) show that (when recorded) 100% of the plants had flowering/fruited stems.

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IV. APPENDICES

- 1. Abbreviations for Herbaria (Index Herbariorum 2003)**
- 2. An Explanation of Conservation Ranks Used by The Nature Conservancy and NatureServe**

1. Abbreviations for Herbaria (*Index Herbariorum* 2003)

AC = Amherst College, Amherst, Massachusetts

CCNL = Connecticut College, New London, Connecticut

CONN = Torrey Herbarium at University of Connecticut, Storrs

GH = Gray Herbarium at Harvard University, Cambridge, Massachusetts

NEBC = New England Botanical Club at Harvard University, Cambridge, Massachusetts

NCBS = Connecticut Botanical Society at Yale University, New Haven, Connecticut

NHA = University of New Hampshire, Durham

NHES = Connecticut Agricultural Experiment Station, New Haven, Connecticut

NY = New York Botanical Garden, New York

SCHN = Smith College, Northampton, Massachusetts

YU = Yale University, New Haven, Connecticut

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 been 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.