Conservation Assessment
for
Mat Muhly (Muhlenbergia richardsonis) (Trin.) Rydb.

Photo: Kevin K. Sedivec and William T. Barker

USDA Forest Service, Eastern Region

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This Conservation Assessment was prepared to compile the published and unpublished information on the subject taxon or community; or this document was prepared by another organization and provides information to serve as a Conservation Assessment for the Eastern Region of the Forest Service. It does not represent a management decision by the U.S. Forest Service. Though the best scientific information available was used and subject experts were consulted in preparation of this document and its review, it is expected that new information will arise. In the spirit of continuous learning and adaptive management, if the reader has any information that will assist in conserving the subject taxon, please contact the Eastern Region of the Forest Service – Threatened and Endangered Species Program at 310 Wisconsin Avenue, Suite 580 Milwaukee, Wisconsin 53203.

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ABSTRACT

This Conservation Assessment provides a review of available information regarding *Muhlenbergia richardsonii* (Trin.) Rydb. (mat muhly) and its distribution, habitat, ecology, and population biology. This species is listed as Threatened in Michigan and Maine and Endangered in Wisconsin. Mat muhly has not been assessed in Minnesota, but it is more common here than other eastern states since western Minnesota is the beginning of the prairie region. It has an S2 ranking (vulnerable) in New Brunswick, Quebec, and Ontario in Canada, yet it is fairly common in the western provinces. It has been extirpated from Nebraska, a state that historically had populations. *Muhlenbergia richardsonii* tends to grow on wet, gravelly soil. It is found from Anticosti Island in Quebec to New Brunswick, south to Michigan; Minnesota west to Washington and New Mexico. It is found throughout Canada from the Yukon to New Brunswick. In the eastern United States, its distribution is limited by the uniqueness and remnant quality of prairie fens, and river-side alvars, its preferred habitat in eastern states. Both prairie fens and riverside habitat have been drained in the past for farmland.

INTRODUCTION

The objectives of this Conservation Assessment are (1) to review and compile currently known information on the biology, status, and distribution of *Muhlenbergia richardsonii* and (2) to identify the information needed to develop a strategy to conserve this species. This is an administrative study only and does not include management direction.

The National Forest Management Act and U.S. Forest Service policy require that Forest Service lands be managed to maintain viable populations of all native plant and animal species. A viable population is one that has the estimated numbers and distribution of reproductive individuals to ensure the continued existence of the species throughout its range within a given planning area. In addition to those species listed as endangered or threatened under the Endangered Species Act, or Species of Concern by the U.S. Fish and Wildlife Service, the Forest Service lists species that are Sensitive within each region. *Muhlenbergia richardsonii* is on the Regional Forester's Sensitive Species (RFSS) list for the Eastern Region within the Hiawatha National Forest. It is not known from any other Eastern Region National Forests (USDA Forest Service, 2000).

The objectives of management for such species are to ensure their continued viability throughout their range on National Forest lands, and to ensure that they do not become threatened or endangered because of Forest Service actions.

NOMENCLATURE AND TAXONOMY

Kingdom:	Plantae
Subkingdom:	Tracheobionta
Supedivision:	Spermatophyta
Division:	Magnoliophyta
Class:	Liliopsida
Subclass:	Commelinidae
Order:	Cyperales
Family:	Poaceae

Tribe: Eragrosteae
Genus: Muhlenbergia Shreb.

Scientific name: *Muhlenbergia richardsonis* (Trin.) Rydb.

Common names: mat muhly (Gleason and Cronquist, 1991)
soft-leaf muhly (Univ. of Wisconsin, Herbarium, 2001)
Richardson's muhlenbergia (Quebec, 2001).

National Plant Database Code: MURI

Synonyms: *Muhlenbergia squarrosa* (Trin.) Rydb. (Kartesz, 1994)
Muhlenbergia squarrosa (Nutt.) Torr. (USDA Plant Database, 2001).

Basionyms: V*ilfa richardsonis* (Trin.)
Mem. Acad. Imp. Sci. Saint-Petersbourg, Ser. 6, Sci. Match., Seconde Pt. Sci. Nat. 4(1).103. 1840.
Sprobolus richardsonis (Trin.) Merr.
Rhodora 4:46. 1902.
Muhlenbergia brevifolia (Scribn.) Jones var. richardsonis (Trin.) M.E. Jones, Contr. W. Bot. 14:12. 1912.
Vilfa squarrosa (Trin.) (Morden and Hatch, 1996).

Note: The genus was named after G.H. Muhlenberg (1753-1815), who was a dedicated grass student (Royal British Columbia Museum 2001).

Protection Status: Currently the official status for *Muhlenbergia richardsonii* with respect to federal, state, and private agencies is: (Rank followed by rank definition)

U. S. Fish and Wildlife Service: Not Listed

The Nature Conservancy Global rank: G5
TNC ELCODE: PMOA481G0
Definition of G5: Species demonstrably secure globally

United States National rank: N?
Definition of N#?: Tentative ranking

U. S. Forest Service Region 9: Regional Forester Sensitive Species
Definition: The Regional Forester has identified it as a species for which viability is a concern as evidenced by: a) significant current or predicted downward trends in population numbers or density, and or b) significant current or predicted downward trends in habitat capability that would reduce its existing distribution.
Found on the Hiawatha National Forest in the Upper Peninsula of Michigan (USDA Forest Service, 2000).

United States (NatureServe 2001, if not indicated otherwise)

Arizona: SR

Definition of SR: Reported – element reported in the nation or subnation but without a basis for either accepting or rejecting the report, or the report not yet reviewed locally. Some of these are very recent discoveries for which the program has not yet received first-hand information; others are old obscure reports.

California: SR

Colorado: SR

Idaho: SR

Maine: S2, state Threatened. (Maine Department of Conservation, 2001)

Definition of S2: Imperiled because of rarity (6-20 occurrences or few remaining individuals or acres) or because of some factor(s) making it very vulnerable to extirpation from the state.

Definition of Threatened: Any species which is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range.

Michigan: S2, state Threatened. (State of Michigan, 1999).

Minnesota: SR

Montana: SR

Nebraska: S1 (NatureServe, 2001) SH (Assoc. for Biological Information, 2001)

Definition of SH: Of historical occurrence in the state, having not been verified in the past 20 years and suspected to still be extant.

Nevada: SR

New Mexico: SR

North Dakota: SR

Ohio: SR

Oregon: SR

South Dakota: SR

Utah: SR

Washington: SR

Wisconsin: S1, state Endangered. (State of Wisconsin, 1998)

Definition of Endangered: Continued existence in Wisconsin is in jeopardy.

Wyoming: S3S4 (NatureServe, 2001)

Definition of S3S4: Between S3 and S4. S3: Vulnerable. Vulnerable in the state because it is uncommon, or found only in a restricted range (even if abundant at some locations). Definition of S4: Apparently secure – uncommon but not rare, and usually widespread in the nation or subnation. Possible cause of long-term concern. Normally more than 100 occurrences and more than 10,000 individuals.

Canada

National Conservation Status Rank: N?

Definition of N#?: Tentative ranking

Canadian Provinces (NatureServe 2001, if not otherwise indicated)

Alberta: S5

Definition of S5: Secure. Common, widespread and abundant in the state or province. Essentially ineradicable under present conditions. Typically with considerably more than 100 occurrences and more than 10,000 individuals.

British Columbia: S? (NatureServe, 2001); S2Q (B.C. Conservation Data Centre).

Manitoba: S4
New Brunswick: S2
Northwest Territories: SR
Ontario: S2
Quebec: S2 (NatureServe, 2001); Likely to be designated as threatened or vulnerable (Quebec, 2001)
Saskatchewan: S?
Definition of S#?: Unranked – rank not assessed yet.
Yukon Territory: SR

SPECIES DESCRIPTION

Muhlenbergia richardsonis is a very slender, wiry perennial warm-season grass that grows in loose clumps to dense tufts or mats, occasionally forming a sod (Chadde 1999, Penskar and Higman 1999). The culms are erect or arise from old decumbent culms, which are sometimes hard and knotty (Voss, 1972). The leaves are upright and slender, usually inrolled. The flowers are in a narrow spike-like panicle (usually maturing in August) and each spikelet has one gray-green flower (Chadde 1999).

Habit: Mat forming or loosely clumped (Chadde 1999).

Underground rooting: Rooting from lower nodes of stem (Chadde 1999) or occasionally stolons (Penskar and Higman 1999); other authors describe as strongly rhizomatous (Hitchcock *et al.* 1969) or widely rhizomatous (North Dakota State University 1998).

Culms (stems): "Culms are erect, or decumbant at base, slender, solid, slightly flattened, nodes minutely rough" (North Dakota State Univ. 1998).

Leaves: Wiry, narrow (1-2mm wide), upright, usually inrolled, 3-6 cm long, Blue green, open leaf sheaths (Gleason and Cronquist 1991, Penskar and Higman 1999).

Ligules: "Membranous, acute to truncate, erose, or shallowly toothed" Morden and Hatch 1996), ragged at its tip (Chadde 1999).

Inflorescence: A narrow panicle, few flowered with short ascending, scarcely overlapping branches (interrupted to continuous), not glomerulate (USGS Northern Prairie Wildlife Research Center 2001).

Spikelets: Uncrowded, 1 flowered, gray-green, 2-3 mm long (Chadde 1999).
Glumes: About equal or second slightly longer, acute, 1/3 to ½ length of floret, broad, unawned, green, normally 2 nerved (Morden and Hatch 1996, Welsh 1974, Chadde 1999).
Lemma: Lance-shaped, smooth, not bearded or hairy at base, 2-3 mm long (Chadde 1998), dark green or mottled, 3-nerves obscure (Morden and Hatch 1996); usually minutely awn-tipped (Hitchcock *et al.* 1969).
Anthers: 1.0-1.6 mm long, yellow, becoming purple at maturity (Morden and

Hatch 1996).

Caryopse (grain): Brown, ellipsoid, 1.2-1.5 mm long USGS Northern Prairie Wildlife Research Center 2001).

Provided by USDA-NRCS, 2001:

Shape and Orientation:	Decumbent
Fall Conspicuous:	No
Foliage Color:	Green
Foliage Texture:	Fine
Foliage Porosity:	Porous
Flower Color:	Green
Flower Conspicuous:	No
Fruit/Seed Color:	Yellow
Fruit/Seed Conspicuous:	No

Similar Species:

In the midwestern United States mat muhly is often confused with *M. cuspidata* (Torr.) Rydb. which differs by lacking rhizomes, has a shorter ligule, and long glumes which are acuminate or cuspidate. *Muhlenbergia filiformis* (Thurb.) Rydb. is an annual or weak perennial resembling *M. richardsonis*, but is distinguishable by its roughened culms and ovate to acute glumes (Morden and Hatch 1996). In Michigan, three other *Muhlenbergia* species are found on alvars and sedge meadows: *M. glomerata, M. mexicana,* and *M. uniflora* (Chadde 1999). "*M. glomerata* and *M. mexicana* spread by an extensive network of rhizomes (absent in mat muhly), and have a tuft of long hairs at the base of the lemma (absent in mat muhly)" (Chadde 1999). Lesica and Kannowski (1998) noted that *M. glomerata* and *M. richardsonis* could not always be distinguished. The spikelets of *M. uniflora* are in an open head and not densely clustered into spikes as in mat muhly (Chadde 1999), also *M. uniflora* is a considerably smaller plant (Penskar and Higman 1999).

Morphological differences within *M. repens* complex:

Morden and Hatch (1986) studied the variation present within leaf anatomical traits and found that all species of this complex were discernible with the exception of *M. richardsonis* and *M. squarrosa*. *M. richardsonis* and *M. squarrosa* have been found throughout North America north of Mexico (including Alaska and the provinces of Canada) except in the southeastern United States. Often they are sympatric in distribution and occasionally grow side by side. They have previously been reported as separate species based on culm morphology or as a single species (under *M. richardsonis*: Cronquist *et al.* 1977). *M. squarrosa* has stout, decumbent, and spreading culms and occupies drier sites with little competition from other species; whereas *M. richardsonis* has more slender, erect culms and is usually growing in moister soils in a meadow-like association (Morden and Hatch, 1996).

Populations of *M. richardsonis* and *M. squarrosa* are not consistently distinguishable from one another on the basis of morphological characters analyzed and are currently considered a single highly variable species. This was corroborated using cluster analysis and MANOVA (Morden and Hatch, 1996) and henceforth will be regarded as a single species, *M. richardsonis*.

Populations of *M. fastigiata* and *M. richardsonis* appear to intergrade in morphological form. Because *M. richardsonis* often occurs at high elevations in the Rocky Mountains and *M. fastigiata* occurs in the South American Andes Mountains it was postulated that *M. fastigiata* might be a smaller form of this species. To investigate this last point in more detail, analyses were performed on populations of *M. fastigiata* and *M. richardsonis* to determine the extent to which these species are similar. The results of analysis of variance and cluster analysis clearly show *M.fastigiata* and *M. richardsonis* to be distinct. "Characters which consistently distinguish these species are plant size (culm height, internode length, and inflorescence length) and floret vestiture (*M. fastigiata* being completely glabrous whereas *M. richardsonis* is usually scabrous or minutely pubescent). Inflorescence length and floret vestiture are particular useful because these characteristics are conservative distinctions between the two species, whereas differences based only on plant size may be environmentally induced" (Morden and Hatch, 1996).

Muhlenbergia richardsonis and *M. squarrosa* are apparently morphologically distinct from others of the complex. They are most similar to and apparently integrating in some regions of their range with *M. repens* (in the southwestern United States) and *M. utilis* (in Texas and California). Cluster analysis depicts *M. richardsonis* as more closely aligned with *M. repens* and *M. utilis* rather than *M. fastigiata* as was previously hypothesized (Morden and Hatch, 1996).

Geographical Distribution

Mat muhly occurs in Alaska and southern Yukon east to New Brunswick and Maine and south to Michigan and Ohio, from North Dakota south to Arizona, west to California, and Baja California (Hitchcock *et al*., 1969). It occurs throughout southern Canada: Alberta, British Columbia, Manitoba, New Brunswick, Ontario, Quebec, Saskatchewan, Yukon (USDA Forest Service, 2001). It is also found throughout most of the prairie region of Minnesota (North Dakota State University, 1998) and west of the Mississippi River in the United States (USDA Forest Service, 2001).

Elevation ranges vary in the western United States as follows (Dittberner and Olson, 1983 *cf* USDA Forest Service, 2001):

6,500 to 9,500 feet (2,000 – 2,900 m) in Colorado
4,800 to 8,000 feet (1,500 – 2,400 m) in Montana
7,000 to 10,500 feet (2,100 – 3,200 m) in Utah
5,000 to 9,900 feet (1,500 – 3,000 m) in Wyoming.

In the western United States, mat muhly typically grows in dry meadows and open flatlands associated with ponderosa pine (*Pinus ponderosa*), lodgepole pine (*P. contorta*), and fir-spruce (*Abies* spp., *Picea* spp.) zones. It occasionally spreads down into the sagebrush (*Artemesia* spp.) flatlands (Reed, 1952 *cf* USDA Forest Service, 2001).

Mat muhly is common on disturbed sites, persisting but becoming less important in late serial stages. Mat muhly often increases in relative abundance with cattle grazing (Zacek *et.al.*, 1977*cf* USDA Forest Service, 2001). For example, relative abundance of mat muhly increased with the deterioration of tufted hairgrass (*Deschampsia caespitosa*) on an overgrazed mountain rangeland in Wyoming and the Sierra Nevada (Beetle 1962, Ratliff 1982 *cf* USDA Forest Service, 2001). Mat muhly is normally a minor constituent of undisturbed mountain meadows in the Sierra Nevada Mountains (Ratliff, 1985 *cf* USDA Forest Service, 2001).

Mat muhly is found north of 60° latitude only on open, warm microsites that receive high insulation and have dry soil that heats up rapidly (Schwarz and Redmann 1988).

Muhlenbergia richardsonis is the most widespread C4 grass in northwestern Canada. It has been collected as far north as Great Bear Lake and is the only C4 grass to occur in the Yukon River drainage. The other five C4 species as well as *M. richardsonis* are found in the upper Mackenzie Basin and its tributaries. A smaller area of warm air in the western Yukon is correlated with the occurrence of *M. richardsonis* (Schwarz and Redmann, 1988).

United States

Note: See Site Appendix 3 for specific site locations

Arizona: Topography in the Elgin Research Natural Area varies from relatively flat ridges to a rolling terrain with slopes up to 35%. Past grazing of this site is evidenced by the presence of species such as mat muhly (*Muhlenbergia richardsonis*) and shrubby cinquefoil (*Potentilla frutiosa*) (USDA FS, Coronado National Forest 2001).

California:. In the White Mountains of California, Sage and Sage (2001) found that the C4 grass *Muhlenbergia richarsonis* commonly occurs in the alpine zone at 3300 to 3800 m, with the highest altitude population observed 3950 m above sea level. This is the highest altitude reported for a C4 plant population in North America. It is near the world altitude limits (4000 to 4200 m) reported for C4 plants in Asia and the Andes. At its highest altitude (3600 to 3950 m), *M. richardsonis* is restricted to southeast and southwest facing slopes, with greatest frequency on southeast faces.

Colorado: Elevational ranges vary 6,500 to 9,500 feet (2,000 – 2,900 m) (Dittberner and Olson, 1983 *cf* USDA Forest Service, 2001).

Michigan: Marshy ground and boggy meadows, said to be common on anthills (Hanes 1947). Moist, open places in alvars and in sedge-dominated fens; often where calcium rich (Chadde, 1999). Approximately seven records for mat muhly are scattered across southern lower Michigan, which were identified within the last two decades. In the Lower Peninsula this species is found primarily within the glacial interlobate region where it forms local groundcover in high quality prairie fens (Penskar and Higman 1999). It is known from Jackson, Kalamazoo, Oakland and Washtenaw Counties. Livingston County has three records from 1928 and there are two 1928 records from Washtenaw County (Farwell at MSC); these are historical collections that have not been revisited (MNFI 2002).

In the Upper Peninsula, *M. richardsonis* is found in localized abundance along portions of the Escanaba River in Delta County, where it occurs on alvar or limestone pavement (5 occurrences). It is also found in a marl fen in Mackinac County (1 occurrence) within an Candidate Research Natural Area (CRNA) on the Hiawatha National Forest. Farwell's Keweenaw County collection (bluffs at Cliffton in 1895) was noted as suspicious by Voss (1972); and later the specimen was identified as *M. cuspidata* (plains muhly) (Penskar and Higman 1999).

Minnesota: *M. richardsonis* occurs throughout the prairie region of the state, from the Canadian border to Iowa, with the exception of the Paleozoic Plateau in the southeastern portion (Ownbey, G.B. and T. Morley 1991).

Montana: Elevational ranges vary 4,800 to 8,000 feet (1,500 – 2,400 m) (Dittberner and Olson, 1983 *cf* USDA Forest Service, 2001). Mat muhly is found in dry lowland areas, alkaline seeps, and intermontane prairie pothole wetlands in the northern Rocky Mountains (University of Montana, 2001).

Pine Butte Fen is a large (450 ha) minerotrophic peatland mosaic of patterned open fen and carr vegetation in north-central Montana (Lesica 1986 in Lesica and Kannowski, 1998). *Muhlenbergia richardsonis* and *M. glomerata* were conspicuous on *Formica* (ant) mounds, but were uncommon elsewhere in the peatland (Lesica and Kannowski, 1998).

Utah: Elevational ranges vary 7,000 to 10,500 feet (2,100 – 3,200 m) (Dittberner and Olson, 1983 *cf* USDA Forest Service, 2001).

Wyoming: Elevational ranges vary 5,000 to 9,900 feet (1,500 – 3,000 m) in Wyoming (Dittberner and Olson, 1983 *cf* USDA Forest Service, 2001).

Canadian Provinces:

Alberta: Mat muhly is a fair forage species and an invader in regards to grazing response meaning that it responds to grazing with new growth (USDA Forest Service 2001). The majority of occurrences are found in the southwestern section of the province, while those scattered in the northeast occur along river drainages exclusively (Moss 1983).

British Columbia: Mat muhly grows on lime-rich sites such as moist meadows and terraces and gravel bars in the steppe and montane zones. In the Columbia Basin it occurs at Armstrong Bay and the terrace adjacent to Findlay Creek (Royal B.C. Museum, 2001).

M. richardsonis is listed in the mineral springs ecosystem in the Mount Edziza Park on extensive calcite formations at Mess Lake (British Columbia Ministry of Environment Lands and Parks, 2000).

Manitoba: Found in the interior Douglas-fir zone within the Columbia Basin Region (University of Manitoba, 2001). Occurs in the Aspen Parkland in southwestern Manitoba (Bird, R. D. 1961). Robert Dana, prairie ecologist MN DNR (pers. comm. 2002) has seen *M. richardsonis* in southeastern aspen parkland below Winnipeg.

Quebec: Since the Bonaventure barachois is periodically inundated with salt water, barachois features vegetation that is well adapted to salinity. Noteworthy plants include three that are likely to be designated as threatened or vulnerable: Macoun's fringed-gentian (*Gentianopsis macounii*), Gaspe′ Peninsula arrowgrass (*Triglochin gaspense*) and Richardson's muhlenbergia (*Muhlenbergia richardsonis*) (Quebec, 2001).

Saskatchewan: Grilz and Romo (1995) reported that mat muhly commonly occurred in a rough fescue (*Festuca altaica*) prairie seedbank in Saskatchewan after a burn (USDA Forest Service, 2001).

Yukon Territory: Takhini Salt Flats is an area with artesian springs, alkaline conditions, and an area infused with sodium sulfates. *M. richardsonis* is on a preliminary list of plants of the Takhini Salt Flats (Botanical Electronic News, 2000).

In the Yukon, one of the most important aspect of sites with *M. richardsonis* is their well-drained open nature. Low moisture is probably a critical factor limiting tree growth, but some of these sites remain susceptible to invasion by aspen (Schwarz and Redmann, 1988).

HABITAT - ECOLOGY

Mat muhly grows from moist lowlands to montane prairies, highland meadows and rocky slopes Hitchcock *et al.*1969. In the Intermountain Region, mat muhly occurs on dry to moist sites. Plants are occasional on open slopes from 5,700 to 11,000 feet (1700-3200 meters) (Welsh, *et al.* 1987 *cf* USDA database 2001).

Mat muhly can be found in a wide variety of soils. Mat muhly grows in shallow, moist, slightly saline soils, as well as on dry uplands. It often grows on alkaline soil with textures ranging from sand or gravel to clay-loam. Mat muhly is one of the more salt-tolerant upland grasses, sometimes forming mixed stands with halophytic species (Coupland, 1992 *cf* USDA Forest Service, 2001).

Several studies were done in Saskatchewan (Dodd & Coupland 1966) and North Dakota (Dix & Smeins 1967, Redmann 1972) to better define the preferred habitat for *Muhlenbergia richardsonis*. The study done by Dix and Smeins in North Dakota (1967) focused on drainage regime gradients. *Muhlenbergia richardsonis* was found at high frequency in four upland types. Though similar in growth form *M. cuspidata* is most abundant on excessively drained sites, while *M. richardsonis* is normally found on moderately drained sites. *Muhlenbergia richardsonis* was either absent or found at very low levels on sandy soils. On the basis of drainage regime alone *Muhlenbergia richardsonis* was not considered to function as an indicator species (Dix and Smeins 1967). In plains grassland communities mat muhly commonly occurs with many flowered aster (*Aster pansus*), purple milkvetch (*Astragalus goniatus*), Kentucky bluegrass (*Poa pratensis*), and slender peavine (*Lathyrus palustris*) (Dix and Smeins, 1967).

Another study done in Saskatchewan by Dodd and Coupland (1966) concentrated on the salinity of grassland soils. An important source of salinity in this strongly rolling topography is ground-water discharge. The dominant grasses in order of decreasing salt tolerance were *Puccinellia airoides, Distichlis stricta, Hordeum jubatum, Muhlenbergia richardsonis* and various *Agropyron* species. Dodd and Coupland (1966) considered *M. richardsonis* to be characteristic of semi-halophytic vegetation. This vegetation zone occurs at the drier periphery of depressions, where saline water reaches only in times of high water levels. The characteristic soils belong to the Saline Calcareous Chernozem and Saline Rego Chernozem subgroups. The predominate cations are sodium and magnesium; while sulfate, bicarbonate, and chloride are the most abundant anions (Dodd *et al.* 1964 cf Dodd & Coupland 1966). *Muhlenbergia richardsonis* is the major grass (up to 73%) growing in coarse-textured Saline Calcareous Chernozem soil. In this setting *M. richardsonis* forms clumps as large as 120 cm in diameter and grows to heights as great as 20 cm by the time of maturity in August. On the downslope side, *Muhlenbergia richardsonis* grows in association with *Distichlis stricta*. On the upslope side, *Muhlenbergia* grows in association with species of *Agropyron*. The *Agropyron-Muhlenbergia* community usually occurs as a transition zone between the *Muhlenbergia*

community and upland grasslands. Often the area occupied by this type is more extensive than the pure *Muhlenbergia richardsonis* community (Dodd & Coupland 1966).

A study done in 1972 on an eastern North Dakota prairie by Redmann benefited from the previous studies. Redmann (1972) found the *Muhlenbergia richardsonis* community type on surface soils that were non-saline; however subsoils were often moderately or strongly saline. Osmotic potentials are negligible in surface horizons, but remain significant at the subsoil level.

Although this community type is dominated by *M. richardsonis*, the community is rather variable in composition. Other common associates include *Distichlis stricta, Sporobolus asper, Melilotus* spp. and *Ambrosia coronopifolia*. Forb species include *Lactuca pulchella*, *Lobelia spicata, Solidago* spp. and *Rudbeckia serotina*. Similar to Saskatchewan, *M. richardsonis* was also an important component of the *Andropogon* community. The *Andropogon* community is found on wet to moist sites, usually with a non-saline surface, and a moderately saline subsoil. At the Oakville prairie in North Dakota, this community might be considered a transitional type between the Low Prairie and Meadow communities. The change is gradual when moving from the *Andropogon* to *Muhlenbergia* community because there is usually not a sharp break in topography or soil characteristics (Redmann 1972).

C4 Grasses

Six C4 grasses (including *M. richardsonis*) were found in grassy openings in the boreal forest of northwestern Canada. High carbon isotope ratios and Kranz anatomy confirmed that these northern populations are functionally C4 grasses. The distribution of these grasses north of 57°N latitude is mainly in areas with a July minimum temperature of 7.5°C or higher. Within these areas, C4 grasses are found on warm microsites with high irradiance and distinctive edaphic characteristics. On the basis of carbon isotope ratios and leaf anatomy, it is a C4 plant, confirming earlier reports (Bender and Smith 1973, Guy *et al.* 1986 *cf* Schwarz and Redmann, 1988).

Soil analysis of sites supporting C4 grasses in northwestern Canada. (Table from Schwarz and Redmann, 1988)

					Water saturated extract	
Site No.	**Soil class**	**Texture class**	**Moisture class**	**pH range**	**Electric conductivity**	**Sodium absorption ratio**
5-7	Orthic Gray Luvisol, Rego Humic Gleysol or Orthic Regosol	Clay loam to sandy loams	Dry	7.7-8.4	1.6±0.2	4.4±2.0
8	Orthic Regosol	Clay loam	Dry	7.3	0.7	0.2

Water-saturated extract (continued)

Na (mg/L)	**Ca (mg/L)**	**Mg (mg/L)**	**K (mg/L)**	**Cl (mg/L)**	**SO24 (mg/L)**	**Organic matter %**	**P (mg/L)**	**NO3-N (mg/L)**
193±82	53±5	92±35	14±2	112±41	287±46	5.7±1.0	8.5±3.8	-
11	108	30	6	25	175	10.8	7.5	-

Soil salinity was low to moderate in soils under stands of *M. richardsonis.* Concentrations of major ions were much lower in these soils as compared with the saline soils of the Salt Plain (Schwarz and Redmann, 1988).

California C4 Grass

C4 plants are uncommon in cold environments at high latitude and altitude, and are not generally thought to occur in the alpine tundra. In the White Mountains of California, Sage and Sage (2001) found that the C4 grass *Muhlenbergia richarsonis* commonly occurred in the alpine zone at 3300 to 3800 m, with the highest population observed 3950 m above sea level. At its highest altitude (3600 to 3950 m), *M. richardsonis* is restricted to southeast and southwest facing slopes, with greatest frequency on southeast faces. *Muhlenbergia richardsonis* plants form low mats with mean height of 2.7 cm, while co-occurring C3 grasses form bunches that are on average two to three times taller (Sage and Sage, 2001).

Muhlenbergia richardsonis leaves are more affected by the boundary layer of the soil than nearby C3 grasses. Temperature of mat muhly leaves was over 20^{o}F above air temperature in full sun and still air, and 10^{o}F above air temperature in full sun and wind. Midday leaf temperatures in *M. richardsonis* were observed to be favorable to C4 photosynthesis. At night, the high boundary layer in the *Muhlenbergia* mats allows for 5 to 15^{o}F reduction of leaf temperature below air temperature, resulting in regular frosting of leaves. These results indicate that mat muhly requires daytime heating for ecological success, and has evolved the capacity to tolerate freezing at night and early in the day (Sage and Sage, 2001).

Pacific Northwest

M. richardsonis is found in "moist to dry, lowland to montane prairies, meadows, and rocky slopes from British Columbia southward on the east side of the Cascade crests to Baja California" (Hitchcock *et al*. 1969).

Western United States

In upland meadows in the western United States mat muhly is commonly associated with needlegrass (*Stipa* spp.), bluegrass (*Poa* spp.), and mountain muhly (*Muhlenbergia montana*) (USDA Forest Service 1937 *cf* USDA Forest Service, 2001). Mat muhly's associates in pinyon-juniper woodlands include predominantly singleleaf pinyon (*Pinus monophylla*) and Utah juniper (*Juniperus osteosperma*) with an understory of big sagebrush (*Artemesia tridentata*) and desert bitterbrush (*Purshia glandulosa*) (Blackburn *et al*., 1975 *cf* USDA Forest Service, 2001).

In the Sierra Nevada, mat muhly dominates on high-elevation sites (10,200 to 11,700 feet or 3200-3658 meters) with very thin soils (Pemble, 1970 *cf* USDA database 2001).
In the Sierra Nevada common associates include western yarrow (*Achillea lanulosa*), northwest cinquefoil (*Potentilla gracillis*), sedge (*Carex* spp.), rush (*Juncus* spp.), and bluegrass (*Poa* spp.) (Boyd, *et al*. 1993 *cf* USDA Forest Service, 2001). In alpine areas of the Sierra Nevada, mat muhly is associated with needlegrass (*Stipa* spp.) and wax currant (*Ribes cereum*), where it is found with the krummholz form of whitebark pine (*Pinus albicaulis*) (Pemble, 1970 *cf* USDA Forest Service, 2001).

Major Associated Ecosystems – Western United States (USDA Forest Service, 2001):

In the Western United States the following ecosystems are the commonly associated grassland and shrub community types for *Muhlenbergia richardsonis*. For the Kuchler Plant Associates, or Forester and Rangland cover types, please see Appendix 1, Community information for *M. richardsonis*.

FRES11	Spruce-fir
FRES17	Elm-ash-cottonwood
FRES21	Ponderosa Pine
FRES26	Lodgepole pine
FRES29	Sagebrush
FRES30	Desert shrub
FRES34	Chaparrel-mountain shrub
FRES35	Pinyon-juniper
FRES36	Mountain grasslands
FRES37	Mountain meadows
FRES38	Plains grasslands
FRES39	Prairie
FRES40	Desert grasslands

Mat muhly is described as a dominant or an indicator species in the following community classifications:

- Classification and dynamics of subalpine meadow ecosystems in the southern Sierra Nevada (Benedict, 1984 *cf* USDA Forest Service, 2001).
- Habitat characteristics of the Silver Lake mule deer range (Dealy, 1971 *cf* USDA Forest Service, 2001).
- Vegetation of saline areas of Saskatchewan (Dix and Smeins, 1967).
- Natural vegetation of Oregon and Washington (Franklin and Dyrness, 1973 *cf* USDA Forest Service, 2001).
- Plant communities and soils of an eastern South Dakota prairie (Redmann, 1972).

Saskatchewan Prairie – Canadian Plains
Kernen's Prairie, a 130 hectare tract of grassland, in central Saskatchewan was spared cultivation or heavy grazing by domestic animals. It is considered to be representative of vegetation that developed on fine textured lacustrine deposits of the former glacial Lake Saskatoon. In late summer, *Muhlenbergia richardsonis* was found to grow best in 20 to 30% soil moisture, but in soils with relatively high water retaining capacity (100 to 140%). Soil pH values of 5.1 to 5.5 were favored and few plants were found above pH 6.0 (Baines 1973).

Slope position has been found to be very determinant in terms of species composition.
A clear relationship was discerned between species distributions and relatively subtle changes in slope position. Part of this difference can be shown to be due to soil temperature and moisture content which varies with slope aspect and position. *Muhlenbergia richardsonis* occurred almost exclusively on the lower slope with a very small number of occurrences in depressions. Dominant grasses in this mesic downslope position are *Festuca scabrella* and *Agropyron trachycaulum.* Soil composition in this lower slope position averaged sand 25%, silt 48%, and clay 27% (Baines 1973).

Western Canada

In western Canada, Mat muhly grows on lime-rich sites such as moist meadows and terraces and wet gravel bars in the steppe and montane zones (Royal B.C. Museum, 2001). Mat muhly is one of the more salt-tolerant upland grasses, sometimes forming mixed stands with halophytic species (Coupland, 1992 *cf* USDA Forest Service, 2001).

Saline and alkaline habitats have very high concentrations of sodium, calcium and magnesium, carbonates, bicarbonates and sulfates. Concentrations can range up to 12,000 micro mhos/cm, and pH can be as high as 9.7 and 10.5. These conditions are toxic to most plants except for a few halophytes (Environment Canada, 1998).

In British Columbia, Canada halophytes from the dry interior include many (1) chenopods: Salicornia rubra, Chenopodium rubrum, C. leptophyllum var. oblongifolium, C. atrovirens, Atriplex argentea, A. subspicata, A. truncata, Suaeda calceoliformis, Monolepis nuttalliana.

(2) A number of specialized grasses: Disticchlis stricta, Puccinellia nuttelliana, P. interior, P. distans, Spartina gracilis, Muhlenbergia asperifolia, M. richardsonis, Poa juncifolia.

(3) Other halophytes such as: Juncus balticus, Scirpus validus, Eleocharis rostellata, E. palustris, Triglochin maritimum, T. palustre, Glaux maritimum, Hutchinsia (Hymenolobos) procumbens, Thellungiella (Arabidopsis) salsuginosa, Spergularia marina, Polygonum ramosissimum, Amaranthus retroflexus, Ruppia maritime (Environment Canada, 1998).

Maine

Muhlenbergia richardsonis is known from small, but persistent populations, on rocky river ledges in northern Maine (Maine Department of Conservation 1998).

Michigan

In the Midwest, mat muhly's associates include shrubby cinquefoil (Potentilla fruticosa), purple pitcherplant (Sarracenia purpurpea), low nutrush (Scleria verticillata), and marsh arrowgrass (Triglochin palustris) (Eddy and Harriman, 1992).

Associates of *M. richardsonis* at a southern Michigan prairie fen include big bluestem (*Andropogon gerardii*), smooth blue aster (*Aster laevis*), fen star sedge (*Carex sterilis*), fringed gentian (*Gentiana crinita*), blazing star (*Liatris spicata*), Kalm's lobelia (*Lobelia kalmii*), shrubby cinquefoil (*Potentilla fruticosa*), and Riddell's goldenrod (*Solidago riddellii*)
(Bess and Hamilton, 1999).

Associates at other southern Michigan fens (alkaline peatlands) often include other prairie grasses such as *Andropogon gerardii* (big bluestem)*, A. scoparius* (little bluestem)*, Sorghastrum nutans* (Indian grass)*, Sporobolus heterolepis* (prairie dropseed). Other frequent and characteristic associates include *Potentilla fruticosa* (shubby cinquefoil)*, Larix laricina* (larch)*, Salix candida* (hoary willow)*, Carex buxbaumii* (Buxbaum's sedge)*, C. stricta* (strict sedge)*,* other sedges: *C. sterilis, C. sartwellii,* and *C. prairea, Solidago ohioensis* (Ohio goldenrod)*, Heirchoe odorata*

(sweet grass), *S. riddellii* (Riddell's goldenrod), *Muhlenbergia glomerata* (muhly grass), *Eupatorium perfoliatum* (boneset), *E. maculatum* (joe-pye-weed), *and Thelypteris palustris* (marsh fern) (Penskar and Higman 1999).

In the Upper Peninsula along the lower Escanaba River in Delta County, *Muhlenbergia richardsonis* grows in the middle alvar zone along the river, described as a layer of thin, moist soil over limestone bedrock (MNFI 2002). In the lowest most moist alvar zone *Calamagrostis canadensis* and *Spartina pectinata* dominate the limestone outcrops at the river's edge. The upper and driest alvar zone is dominated by *Andropogon scoparius* and *Poa compressa*. Also found in this zone were *Antennaria sp., Astragalus neglectus, Galium boreale, Castilleja coccinea, Festuca rubra*, and *Iris lacustris* (Chapman 1986).

The Mackinac County site is in a northern sedge-dominated fen with marly pools and spring-fed streams. It is within a canidate RNA and is surrounded by sparse *Thuja occidentalis, Larix laricina*, and *Picea glauca* woods (MNFI 2002).

Minnesota

Wet prairie dominants in western Minnesota include *Andropogon gerardii, Calamagrostis inexpansa, Spartina pectinata,* and *Muhlenbergia richardsonis*. Common sedges include *Carex lanuginosa, C. praegracilis, C. sartwellii,* and *C. tetanica* (Wheeler *et al.* 1991).

Along the upper Minnesota River Valley *Muhlenbergia richardsonis, Calamagrostis inexpansa, Leersia oryzoides* are abundant in the wet prairie adjacent to a shallow drainageway (Wheeler *et al.* 1991).

Robert Dana, a prairie ecologist MN DNR (pers. comm. 2002), noted that *Muhlenbergia richardsonis* is very common in Kittson County. In western Minnesota, *M. richardsonis* becomes dominant in areas where soil salinity is elevated. Dana (pers. comm. 2002) notes that DNR staff have not attempted to measure soil salinity directly. They are basing their conclusion on species association, plus the presence of salt crusts in dry bare areas. *M. richardsonis* does not do well in the most saline conditions, however. Soil salts in North Dakota contain sodium chloride; whereas, in Minnesota carbonates and sulfates of calcium and magnesium are found (R. Dana pers. comm. 2002).

In Clay County, in a prairie fen community, low grassy hummocks are dominated by *Muhlenbergia richardsonis*; common associates are *Triglochin palustris, Lobelia kalmii, and Parnassia palustris* var. *neogaea* (Wheeler *et al.* 1991).

In Wilkin County there is a small calcareous fen perched on a west-facing slope of a low beach ridge of Glacial Lake Agassiz. Conspicuous grasses on the hummocks are *Muhlenbergia richardsonis, M. glomerata*, and less frequently *Andropogon gerardii* (Wheeler *et al.* 1991).

Robert Dana (pers. comm. 2002) felt that it would be reasonable for *Muhlenbergia richardsonis* to occur in the southeastern portion of the state in calcareous seepage fens; however, it has not been documented from that region. In other areas of Minnesota, *M. richardsonis* is very common in seepage fens where calcium carbonate is the major salt. This grass is often most abundant in low vegetation around marly pools.

North Dakota

M. richardsonis is important in both "low prairie" and "mid-prairie" stands. In low prairie situations *M. richardsonsis* is "omnipresent where it forms a fine, dense understory mat in almost all stands". It also extends into mid prairie stands, though not forming as dense a mat (Dix & Smeins 1967). Robert Dana (pers. comm. 2001) notes that the environmental relationships described in this paper apply equally well to the western Minnesota prairie.

Wisconsin

In 1989, *Muhlenbergia richardsonis* was found in Wisconsin for the first time in Green Lake County within the Berlin Fen. Berlin Fen is preserved as a Wisconsin Department of Natural Resources Scientific Area (Eddy and Harriman 1992). *M. richardsonis* is quite abundant in this calcareous community at the edges of small, damp pockets within the fen (WI EO 2002). It is associated with *Potentilla fruticosa, Sarracenia purpurea, Scleria verticillata, Tofieldia glutinosa,* and *Triglochin palustris* (Eddy and Harriman 1992). In 1992 another site was located in Walworth County (WI EO 2002).

Fire Ecology

Fire does not harm *M. richardsonis* to any great extent because the rhizome buds are insulated by soil; normally it is just top-killed (Benedict, 1984 *cf* USDA Forest Service, 2001). Mat muhly is "resistant" to fire-caused mortality; there is a greater than 65% chance that at least 50% of the plants in a population will survive a fire (Volland and Dell, 1981 *cf* USDA Forest Service, 2001). However, mat muhly may be more vulnerable in late spring and early summer than at other times of the year (Lent, 1984 *cf* USDA Forest Service, 2001).

Fire maybe an important component of this species' ecology. Anderson and Bailey (1980) found that after annual spring burns on grassland in Alberta, *M. richardsonis* responded with increased seedhead production. A prescribed spring burn on a undisturbed northwestern Minnesota prairie stimulated flowering in mat muhly (Pemble *et. al*. 1981 *cf* USDA Forest Service, 2001).

Mat muhly occurs in upland plant communities with a variety of fire regimes. The range of fire intervals reported for some of the dominate communities where mat muhly occurs are listed next.

Community dominant	Range of Fire Intervals (years)
Utah juniper (*Juniperus osteosperma*)	10-30
Ponderosa pine (*Pinus ponderosa* var. *scopulorum*)	30-41
Quaking aspen (*Populus tremuloides*)	7-10
Englemann spruce (*Picea englemannii*)	> 150

Post-fire regeneration strategy:
Rhizomatous herb, rhizome in soil
Ground residual colonizer (initial community component)

Mat muhly is a warm-season species, so the period of green-up in late spring and early summer is the period of highest susceptibility to fire injury (Lent, 1984 *cf* USDA Forest Service, 2001). In

Alberta, it was found to take 5 to 10 years for mat muhly to recover to pre-fire coverage after fire (Anderson and Bailey 1980, and Volland and Dell 1981 *cf* USDA Forest Service, 2001). Within a quaking aspen grassland parkland in east-central Alberta, annual early spring burning increased the percentage of seedheads present (not statistically significant) and seedhead density for mat muhly (Anderson and Bailey 1980 *cf* USDA Forest Service, 2001). Percent cover was 0.9 on unburned plots and 1.3 on burned plots. The difference was significant at $p<0.01$ (Anderson and Bailey, 1980 *cf* USDA Forest Service, 2001.

Effects of fire on mat muhly are varied. On a montane Sierra Nevada meadow, changes in mat muhly cover did not differ significantly between burned and unburned plots ($p=0.44$). The mean change in mat muhly percent cover from 1987 to 1988 (postfire) was as follows (std.err. in parenthesis) (Boyd, *et. al*., 1993 *cf* USDA Forest Service, 2001):

Burned plots (n=8)	Unburned plots (n=11)
0.28 (0.56)	1.00 (0.71)

On nearby plots, also within the Sierra Nevada, mean percent cover of mat muhly was significantly greater for burned than unburned plots ($p=.05$). The difference might be due to site differences or the heat of the fire. Mean estimated percent cover was as follows:

Burned plots (n=8)	Unburned plots (n=11)
3.80 (2.0)	0.25 (0.25)

In a fire-effects study in New Mexico forage production was reduced significantly the first year on the burned area, but recovered by the end of the second year. There was higher blue grama composition on burned areas, but *Muhlenbergia richardsonis* showed little change. Whereas *Muhlenbergia filiculmis* (slimstem muhly), *M. torreyi* (ring muhly), *Sporobolus cryptandrus* (sand dropseed), were all decreased as a result of fire (Dwyer & Pieper 1965).

Grazing / Forage

Young mat muhly is readily eaten by livestock. Plants become less palatable as they mature. Mat muhly cures well in the northern Great Plains and is grazed by all classes of livestock, especially in the winter (Dittberner and Olson, 1983; and USDA Forest Service, 1937 *cf* USDA Forest Service, 2001). Pieper reported that in a New Mexico pinyon-juniper grassland, mat muhly only comprised 8% of cattle diets over three years, although in one year from January to March, mat muhly comprised 24% of the cattle's diet (USDA Forest Service, 2001).

Mat muhly provides fair forage for cattle and horses. Because of its wiry leaves, mat muhly is grazed sparingly when palatable plants are available, but eaten more readily as palatable species become scarce. Mat muhly cures well on the stem and is eaten readily on winter pasture. Protein and phosphorus levels are lower than other associated grass species during the spring. Mat muhly is classified as an "increaser" with grazing pressure. Mat muhly provides little to no forage value to hoofed mammals, rodents, songbirds, upland gamebirds, and waterfowl (North Dakota State University, 1998).

Mat muhly plants usually grow in scattered patches, so they are seldom sufficiently abundant to be of major importance to livestock (Coupland 1992 *cf* USDA Forest Service, 2001). On a fertilized blue grama (*Bouteloua gracilis*) upland range site cattle occasionally used mat muhly forage more than either blue grama or sand dropseed (*Sporobolus cryptandrus*). However, mat muhly comprised

less than 5% of the plant ground cover and was not a major portion of the cattle's diet (Hitchcock, 1951).

Associated insect species:

Rare leafhopper (*Flexamia huroni*)
Muhlenbergia richardsonis is the sole food plant of *Flexamia huroni*, a recently discovered species of leafhopper. The regional rarity of mat muhly, its association with a globally imperiled plant community (prairie fen) and the absence of *F. huroni* from several fens known to contain this grass, make *Flexamia huroni* a strong candidate for listing as endangered in Michigan (Bess and Hamilton, 1999).

Flexamia huroni has been collected only from *M. richardsonis*, a threatened plant species in two Midwestern states (MI, WI). This grass is extremely rare in eastern North America, where it is typically associated with prairie fens or similar alkaline wetland types (Penskar pers.comm. 2001, and Voss 1981). It is known from 13 extant colonies in Michigan (Penskar pers. comm. *cf* Bess and Hamilton, 1999). This is the first *Flexamia* species to be associated with prairie fens. Four additional fens containing mat muhly (three in Michigan and one in Wisconsin) have also been sampled for this leafhopper, with no success. The Brandt Road site is highly unusual in that mat muhly forms extensive colonies ("mats"), co-dominating large portions of the fen along with big bluestem (*Andropogon gerardi*). No other Michigan prairie fen has mat muhly at this density. In all other fens sampled for this leafhopper, mat muhly was much more patchily distributed, usually as small clumps on sedge tussocks or old ant hills (Bess and Hamilton, 1999).

Ant hills association
In Montana, active *Formica* spp. (ants) mounds often developed a distinctive cover of the strongly rhizomatous grasses *M. richardsonis* and *M. glomerata* as they become older and larger in size. The strongest correlations with volume of *Formica* nests were with cover of bare soil (r=0.26) and canopy cover of *Muhlenbergia* spp (r= 0.54); all other variable were only weakly correlated ($-0.14 < r < 0.20$) (Lesica and Kannowski, 1998).

Other common graminoids on the surface of *Formica* and *Myrmica* nests (ants) were *Juncus balticus, Carex aquatilis, C. buxbaumii and Calamagrostis inexpansa.* Enhanced nutrient levels present (P, Na and K) in active mounds decline gradually but remain higher than adjacent ground for long periods (Czerwinski *et al*., 1971 *cf* Lesica and Kannowski, 1998). Once the ant nests become abandoned, they provide habitat for a different assemblage of plant species more typical of drier and/or warmer conditions (Lesica and Kannowski, 1998).

Association with ant hills has also been reported in Michigan for Kalamazoo County (Hanes 1947).

LIFE HISTORY

M. richardsonis is a perennial warm season grass beginning growth in early May and flowering from mid to late July until September (North Dakota State University 1998, Penskar and Higman 1999). Mat muhly starts to grow late in the spring except in the southwest, where growth starts earlier. Mat muhly regenerates vegetatively from rhizomes and also by seed (USDA Forest Service 2001).

M. richardsonis is most easily proprogated by seed. Its seed set abundance is medium and it has a high seedling vigor. It grows best in fine to medium soils as its drought tolerance is low. Its vegetative spread rate once established is rapid (USDA-NRCS 2001). See Appendix 2 – Growth and Reproduction for more details.

POTENTIAL THREATS

In the Upper Peninsula of Michigan, many element occurrences occur along a riverside alvar. Principle threats to this environment include the introduction of invasive non-native plant species and possible trampling of vegetation by anglers (Comer *et al.* 1997).

In the Lower Peninsula of Michigan and for the Wisconsin locations the preferred habitat is prairie fen. Protecting hydrology is the most important factor in the maintenance of the vegetative structure in prairie fens. Groundwater flow into the prairie fen can be altered by agricultural and residential drains. This often results in a lowered groundwater table. Maintenance of the present level of the groundwater table is critical since it is the calcareous seepage that maintains this community type. Land use planning is necessary to protect the aquifer recharge area and retain the area's unique hydrology. When these communities are disturbed they often slowly change to shrub-carr (MNFI 1997). If severely disturbed, invasion by shrubs such as *Rhamnus frangula* (Wastenaw County EO) becomes more likely (MNFI 2002). "Nutrient addition from leaking septic tanks and drain fields is suspected of contributing to the dominance of invasives such as *Typha angustifolia* (narrow-leaved cat-tail), *Phragmites australis* (reed), and *Lythrum salicaria* (purple loosestrife) in portions of some prairie fens" (Panno *et al.* 1989 in MNFI 1997).

POPULATION VIABILITY AND PROTECTION

Michigan:
The Mackinac County locality lies within a candidate Research Natural Area on the Hiawatha National Forest, and a Washtenaw County population is in a county nature park. Other colonies are partly or wholly on private land, several being maintained under informal protection agreement, and some populations are protected within preserves of The Nature Conservancy and other private organizations (Penskar and Higman 1999).

Prescribed burning is frequently used in southern Michigan fen habitats to control shrubs, which without fire would encroach upon threatened plant species such as mat muhly (Penskar and Higman, 1999). One Washtenaw County site, a small fen, has been degraded by encroaching *Rhamnus frangula* and is probably not a viable population (MNFI 2002).

Wisconsin:
Wisconsin has only two known sites (WI EO 2002). At the Green Lake County site, a Wisconsin Department of Natural Resources Scientific Area, mat muhly was noted as being quite abundant in a calcareous fen (Eddy and Harriman 1992).

Minnesota:
Minnesota has 64 specimens at Bell Herbarium from 28 counties; 35 of these occurrences are found on public or privately protected land (TNC = 13 EOs) (Univ. of Minnesota 2001).

Canada:
Schwarz and Redman (1988) feel that northern C4 plants deserve special consideration for protective measures. Some sites with C4 grasses in northwestern Canada are already well protected. Much of the Salt Plains is preserved within Wood Buffalo Provincial Park. Liard River Hot springs is a British Columbia Provincial Park. Other sites should be targeted for some form of protection (Schwarz and Redmann, 1988).

Restoration Use:

Mat muhly is valuable as a soil binder (USDA Forest Service, 1937 *cf* USDA Forest Service, 2001). Mat muhly often invades eroded sites where other plants cannot establish themselves (North Dakota State University, 1998). Because of its densely matted growth form it can furnish considerable erosion protection to the soil (Pohl, 1968). Mat muhly also withstands heavy grazing because of its sod-forming habit (USDA Forest Service, 1937 *cf* USDA Forest Service, 2001).

In a report by Cunningham, 1997, *M. richardsonis* is listed by the USDA Natural Resource Conservation Service as an approved native grass for planting on mesic prairies (University of Minnesota, 2001). *M. richardsonis* is a native grass that can be grown in a greenhouse setting for use in restoration work. Bareroot native grass seedlings have a very high survival rate if planted in early spring, usually 80-90% survive after one year (The Reveg Edge, 2001). In the Great Plains prairie states, mat muhly is being grown by nurseries and seed is being sold for restoration work (Prairie Habitats, 2001).

M. richardsonis is most easily prorogated by seed. Its seed set abundance is medium and does not require cold stratification. It has a high seedling vigor, but its drought tolerance is low. It grows best in fine to medium soils with a preferred pH range of 7.5 to 9.5. Its planting density per acre is 11,000 to 18,000. Its vegetative spread rate once established is rapid (USDA-NRCS 2001). See Appendix 2 – Growth and Reproduction for more details.

Research / Monitoring / Conservation Strategies:

Monitoring to determine the response to prescribed fire and other management regimes is a principal research need at present. *Muhlenbergia richardsonis* supports a newly described leafhopper (*Flexamia huronii*) in a southern Michigan fen (Hamilton and Bess 1999); further inventories are thus necessary to determine the range and status of the leafhopper and its relationship and natural history with regard to *Muhlenbergia richardsonis* (Penskar and Higman 1999).

Additional inventories are needed in Michigan to better understand the distribution of Mat muhly as here it is known primarily from fens whereas further west it is a prairie element. Monitoring of the Mackinac site within the candidate RNA is important since in Michigan *M. richardsonis* is fairly uncommon.

SUMMARY

Muhlenbergia richardsonis is reasonably common mat forming grass in the western United States and adjacent Canada primarily in Montane meadows, Pinyon-juniper and Chaparrel-mountain shrub, and in the Plains grasslands. In the Eastern United States and Canada it is known primarily

from wet, gravelly soil. In Michigan in the Lower Peninsula it is found on prairie fens; while in the Upper Peninsula it grows along a river alvar and in a marly fen at another site. It is the uniqueness of its habitat along with being at its southern distribution in the East that leads to its rarity in the mid-west. *M. richardsonis* is somewhat more common in Minnesota, especially western Minnesota where the prairie grassland community begins and continues westward. In Michigan it is state listed as Threatened; while Wisconsin with only two known sites lists it as Endangered.

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