Eriophorum chamissonis C.A. Mey. (Chamisso's cottongrass): A Technical Conservation Assessment

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Karin Decker, Denise R. Culver, and David G. Anderson
Colorado Natural Heritage Program
Colorado State University
Fort Collins, CO

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Authors' Biographies

Karin Decker is an ecologist with the Colorado Natural Heritage Program (CNHP). She works with CNHP's Ecology and Botany teams, providing ecological, statistical, GIS, and computing expertise for a variety of projects. She has worked with CNHP since 2000. Prior to this, she was an ecologist with the Colorado Natural Areas Program in Denver for four years. She is a Colorado native who has been working in the field of ecology since 1990, including four summers at the Rocky Mountain Biological Laboratory in Gothic, Colorado. Before returning to school to become an ecologist she graduated from the University of Northern Colorado with a B.A. in Music (1982). She received an M.S. in Ecology from the University of Nebraska (1997), where her thesis research investigated sex ratios and sex allocation in a dioecious annual plant.

Denise R. Culver is a wetland ecologist with the Colorado Natural Heritage Program (CNHP). Ms. Culver's work at CNHP includes inventory and assessment for wetlands throughout Colorado since 1995. Ms. Culver has been working in the ecology/botany field since 1987. She has 15 years experience within the Natural Heritage Network, working for the Wyoming Natural Diversity Database and the Montana Natural Heritage Program. Additionally, she worked in several National Parks and Monuments as a resource management ranger. She received a B.S. in Botany from the University of Wyoming, Laramie in 1989 and a M.S. in Biological Sciences from Montana State University, Bozeman in 1994. Her thesis title was *Floristic Analysis of the Centennial Region, MT*.

David G. Anderson is a botanist with the Colorado Natural Heritage Program (CNHP). Mr. Anderson's work at CNHP includes inventory and mapping of rare plants throughout Colorado, mapping weeds, maintaining and updating CNHP's database, and writing reports on the rare plants of Colorado. He has worked with CNHP since 1999. Much of Mr. Anderson's prior experience comes from five years of fieldwork studying the flora and ecosystem processes of the Alaskan and Canadian Arctic. Mr. Anderson also served in the Peace Corps as a science teacher in the Solomon Islands from 1996 to 1998. Mr. Anderson received his B.A. in Environmental, Populational, and Organismic Biology from the University of Colorado, Boulder (1991) and his M.S. in Botany from the University of Washington, Seattle (1996).

Summary of Key Components for Conservation of *Eriophorum chamissonis*

Status

Eriophorum chamissonis (Chamisso's cottongrass) is a circumpolar species with disjunct relictual occurrences in USDA Forest Service Region 2. Occurrences are known from alpine and subalpine wetlands and fens of the central and southwestern mountains of Colorado and northern Wyoming's Bighorn Mountains and Absaroka Range. All 12 documented occurrences in Region 2 are on National Forest System lands. Two occurrences are on the San Juan National Forest, five are on the White River National Forest, three are on the Bighorn National Forest, and two are on the Shoshone National Forest. Region 2 of the USDA Forest Service considers *E. chamissonis* to be a sensitive species. NatureServe considers it to be common, widespread, and abundant in its global range, but the Colorado Natural Heritage Program and the Wyoming Natural Diversity Database both consider the species to be rare because of its very limited distribution in those states. It is not listed as threatened or endangered under the provisions of the Federal Endangered Species Act (1973, U.S.C. 1531-1536, 1538-1540).

Primary Threats

Probable threats to *Eriophorum chamissonis* in Region 2 include, in order of decreasing priority, hydrologic alterations, grazing, motorized vehicle use, peat mining, fire, and global climate change. The small, disjunct nature of populations of *E. chamissonis* in Region 2 and the lack of knowledge of the species' biology contribute to the possibility that one or more of these factors may threaten the long-term persistence of the species without anyone being aware of it.

Primary Conservation Elements, Management Implications and Considerations

A lack of repeat observations of *Eriophorum chamissonis* occurrences, uncertainty regarding its possible synonymy with *E. altaicum* var. *neogaeum*, and the fact that additional occurrences are likely to be found, make it difficult to determine population trends for Region 2. The perception of the insecure status of the species in Region 2 arises from the low number of occurrences, the disjunct nature of these occurrences, and the irreplaceable nature of its preferred peatland habitat.

Protection of the wetland habitats in which *Eriophorum chamissonis* occurs is the key element for its conservation. Any management activities that maintain the hydrologic regime in these habitats will contribute to the persistence of this species. This includes the regulation and monitoring of hydrological modifications, domestic grazing, and motorized vehicle use. Our current understanding of the distribution and abundance of *E. chamissonis* suggests that it should remain a species of concern, and that the species would benefit from an expansion of our knowledge of its biology and habitat.

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INTRODUCTION

This assessment is one of many being produced to support the Species Conservation Project for the Rocky Mountain Region (Region 2), USDA Forest Service (USFS). *Eriophorum chamissonis* (Chamisso's cottongrass) is the focus of an assessment because it is a sensitive species in Region 2 (USDA Forest Service 2005). Within the National Forest System, a sensitive species is a plant or animal whose population viability is identified as a concern by a Regional Forester because of significant current or predicted downward trends in abundance and/or in habitat capability that would reduce its distribution (FSM 2670.5(19)). A sensitive species may require special management, so knowledge of its biology and ecology is critical. This assessment addresses the biology of *E. chamissonis* throughout its range in Region 2. This introduction defines the goal of the assessment, outlines its scope, and describes the process used in its production.

Goal of Assessment

Species conservation assessments produced as part of the Species Conservation Project are designed to provide forest managers, research biologists, and the public with a thorough discussion of the biology, ecology, conservation status, and management of certain species based on available scientific knowledge. The assessment goals limit the scope of the work to critical summaries of scientific knowledge, discussion of broad implications of that knowledge, and outlines of information needs. The assessment does not seek to develop specific management recommendations. Rather, it provides the ecological backgrounds upon which management must be based and focuses on the consequences of changes in the environment that result from management (i.e., management implications). Furthermore, it cites management recommendations proposed elsewhere and examines the success of those recommendations that have been implemented.

Scope of Assessment

This assessment examines the biology, ecology, conservation status, and management of *Eriophorum chamissonis* with specific reference to the geographic and ecological characteristics of the USFS Rocky Mountain Region. Although the most current taxonomic treatment of the genus (Ball and Wujek 2002) includes *E. altaicum* var. *neogaeum* as a synonym for *E. chamissonis*, this assessment does not include material currently assigned to that name. Because the USFS follows the treatment of USDA Natural Resources Conservation Service (2005) and Kartesz (1994), in which *E. chamissonis* and *E. altaicum* var. *neogaeum* are distinct taxa, this assessment addresses only material currently identified as *E. chamissonis*. For information on material currently designated as *E. altaicum* var. *neogaeum*, the reader is referred to the assessment by Ladyman (2004).

Although much of the literature relevant to this species and its congeners originates from field investigations outside of Region 2, this document places that literature in the ecological and social context of the central Rocky Mountains. Similarly, this assessment is concerned with reproductive behavior, population dynamics, and other characteristics of *Eriophorum chamissonis* in the context of the current environment rather than under historical conditions. The evolutionary environment of the species is considered in conducting the synthesis, but it is placed in a current context.

In producing the assessment, we reviewed refereed literature, non-refereed publications, research reports, and data accumulated by resource management agencies. All known publications, reports, and element occurrence records for *Eriophorum chamissonis* in Region 2 are referenced in this assessment, and many of the available experts on this species were consulted during its synthesis. Because basic research has not been conducted on many facets of the biology of *E. chamissonis*, literature on its congeners was used to make inferences. Specimens were viewed at COLO (University of Colorado Herbarium), KDH (Kathryn Kalmbach Herbarium, Denver Botanic Gardens), and RM (Rocky Mountain Herbarium). Specimen and occurrence data were also obtained from the Wyoming Natural Diversity Database and the Colorado Natural Heritage Program. This assessment emphasizes refereed literature because this is the accepted standard in science. However, non-refereed publications and reports are often the only source of information on occurrences in Region 2. When used, these were regarded with greater skepticism than refereed literature. Unpublished data (e.g., herbarium specimen labels and Natural Heritage Program records) were important in estimating the geographic distribution of *E. chamissonis* in Region 2.

Treatment of Uncertainty in Assessment

Science represents a rigorous, systematic approach to obtaining knowledge. Competing ideas regarding how the world works are measured against observations. However, because our descriptions of the world are always incomplete and our observations

are limited, science focuses on approaches for dealing with uncertainty. A commonly accepted approach to science is based on a progression of critical experiments to develop strong inference (Platt 1964). However, it is difficult to conduct experiments that produce clean results in the ecological sciences. Often, observations, inference, critical thinking, and models must be relied on to guide our understanding of ecological relations. Confronting uncertainty, then, is not prescriptive. In this assessment, the strength of evidence for particular ideas is noted, and alternative explanations are described when appropriate.

Treatment of this Document as a Web Publication

To facilitate the use of species assessments in the Species Conservation Project, they are being published on the Region 2 World Wide Web site. Placing the documents on the Web makes them available to agency biologists and the public more rapidly than publishing them as reports. More important, Web publication facilitates the revision of assessments, which will be accomplished based on guidelines established by Region 2.

Peer Review of this Document

Assessments developed for the Species Conservation Project have been peer reviewed prior to their release on the Web. This assessment was reviewed through a process administered by the Center for Plant Conservation, employing at least two recognized experts in this or related taxa. Peer review was designed to improve the quality of communication and to increase the rigor of the assessment.

MANAGEMENT STATUS AND NATURAL HISTORY

Management Status

Eriophorum chamissonis is considered a sensitive species in Region 2 of the USDA Forest Service (USDA Forest Service 2005). All known occurrences of *E. chamissonis* in Region 2 are on National Forest System lands (**Figure 1**; **Table 1**). These include seven occurrences in Colorado (five occurrences on the White River National Forest and two on the San Juan National Forest), and five occurrences in Wyoming (three on the Bighorn National Forest and two on the Shoshone National Forest). Occurrences are also known from federal lands outside of Region 2 in Montana's Gallatin and Flathead national forests and from National Park Service lands in Yellowstone and Glacier national parks. There are likely to be additional documented locations from federal lands throughout the global range of *E. chamissonis*, but a thorough search of all North American herbaria that might hold specimens of this species was beyond the scope of this assessment.

The current NatureServe global rank for *Eriophorum chamissonis* is G5. The global rank is based on the status of a taxon throughout its range. A G5 ranking is defined as "Secure – Common; widespread and abundant" (NatureServe 2005). State Natural Heritage Program ranks for this species are S1 in Colorado (Colorado Natural Heritage Program 2005) and S1S2 in Wyoming (Wyoming Natural Diversity Database 2004). The state (S) rank is based on the status of a taxon in an individual state. In Colorado, the S1 rank signifies that the species is "critically imperiled in the state because of extreme rarity (often five or fewer occurrences) or because of some factor(s) such as very steep declines making it especially vulnerable to extirpation from the state." The Wyoming rank of S1S2 indicates that the rank of the species falls somewhere between S1, as described above, and S2, "imperiled in the state because of rarity (6 to 20 occurrences), or because of other factors demonstrably making it very vulnerable to extirpation from the state" (NatureServe 2005).

Existing Regulatory Mechanisms, Management Plans, and Conservation Strategies

Eriophorum chamissonis is not a candidate for Threatened or Endangered status under the federal Endangered Species Act, and there are no state laws or federal regulations concerned specifically with its conservation. Because it is on the Region 2 sensitive species list, USFS personnel are required to "develop and implement management practices to ensure that species do not become threatened or endangered because of Forest service activities" (USDA Forest Service Manual, Region 2 supplement, 2670.22). Although such practices may include developing an individual species conservation strategy, as of this writing, a conservation strategy has not been written for *E. chamissonis* at a national or regional level by the USFS or any other federal agency.

Seven of the 12 documented USFS occurrences in Region 2 are on lands with special designations. The Warren Lakes occurrence on the White River National Forest in Colorado is managed as Special Interest Area (SIA). An SIA designation is intended to protect or

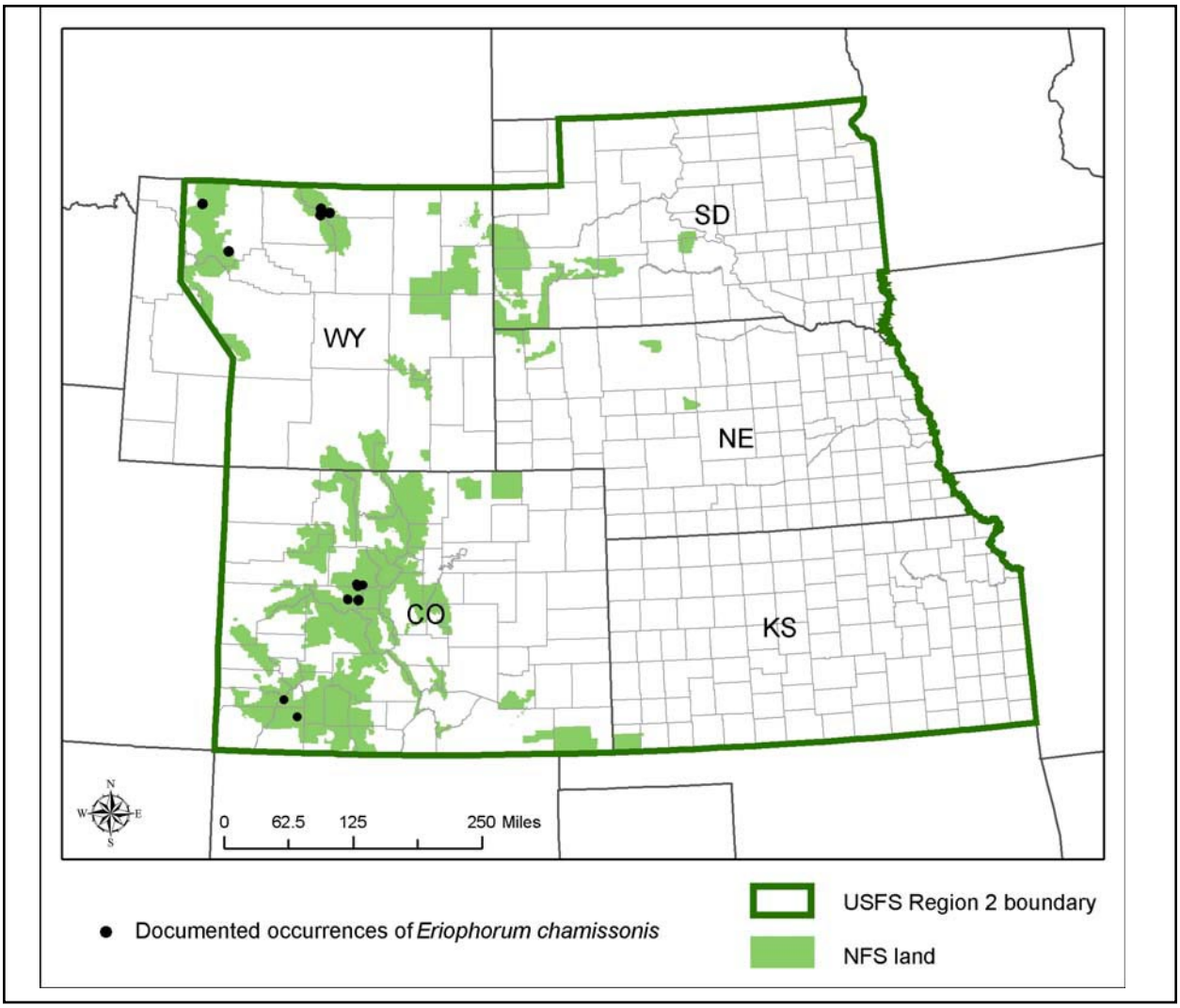

Figure 1. Documented occurrences of *Eriophorum chamissonis* in USDA Forest Service Region 2.

enhance an area with significant botanical, geological, historic, paleontological, scenic, or zoological characteristics. An SIA can be designated to protect and manage threatened, endangered, and sensitive species habitats and other elements of biological diversity. These areas are managed to maintain their special interest values. One Wyoming occurrence is in the Preacher Rock Bog Special Interest Area (SIA) in the Bighorn National Forest; *Eriophorum chamissonis* was one of the targeted species for the SIA designation (Neighbours and Culver 1990, Welp et al. 2000).

Five Colorado occurrences are in designated wilderness areas (three in the Holy Cross Wilderness Area on the White River National Forest, one in Weminuche Wilderness on the San Juan National Forest, and one in the Hunter-Frying Pan Wilderness on the White River National Forest). These areas are protected by the Wilderness Preservation Act of 1964 (16 U.S.C. 1131-1136). The use of mechanized or motorized equipment is prohibited in Wilderness Areas. However, a broad range of other activities is permitted, including hiking, horseback riding, camping, hunting, fishing, and grazing. Although a wilderness area designation does not explicitly protect *Eriophorum chamissonis*, occurrences in wilderness areas are likely to be somewhat more protected than occurrences on lands where more use is permitted. The remaining five Region 2 occurrences are on USFS lands in Colorado and Wyoming managed for multiple uses.

Known occurrences on federal lands outside Region 2 administrative boundaries include two on the Gallatin National Forest and one on the Flathead National Forest, ten in Yellowstone National Park, and one in Glacier National Park. National parks are managed by the Department of Interior to preserve the natural and cultural resources of the National Park

Table 1. Summary table of occurrences of *Eriophorum chamissonis* in USDA Forest Service Region 2. Occurrences are arranged by location (state and county) and arbitrarily numbered. Habitat type names are given as in the original source, using either scientific or common names.

	State County	Land Ownership	Date Last Observed	Location	Elevation (ft.)	Habitat	Population Size	Source ID
1	CO Eagle	USDA Forest Service White River National Forest Holy Cross Ranger District Holy Cross Wilderness Area	1999	Missouri Creek	10,760	Occurs in a wet meadow with sparse *Salix planifolia*. *Eriophorum* appears to occur most often at the edges of wetter pockets of *Eleocharis palustris*.	approx. 100	Colorado Natural Heritage Program Element Occurrence 01 Herbarium label: Cooper, D. #1503
3	CO Eagle	USDA Forest Service White River National Forest Holy Cross Ranger District Holy Cross Wilderness Area	2000	Tellurium Lakes	10,500	Wet lake shoreline. Occurs with *Carex* spp.	100	Colorado Natural Heritage Program Element Occurrence 03 Herbarium label: Snowden, T. s.n.
3	CO Eagle	USDA Forest Service White River National Forest Holy Cross Ranger District Holy Cross Wilderness Area	2001	Along trail #1917 at Henderson Peak	10,400	Fen surrounded by spruce-fir. Assoc. species *Sphagnum* ssp.	unknown	Colorado Natural Heritage Program Element Occurrence 06 Herbarium label: Holt, E.& B. Booth #7935
4	CO Pitkin	USDA Forest Service White River National Forest Aspen Ranger District Hunter-Frying Pan Wilderness	1934	Head of south fork of Frying Pan River	10,500	Mountain meadow, swamp.	rare, very scattered	Herbarium label: Rey, P. #R-20
5	CO Pitkin	USDA Forest Service White River National Forest Aspen Ranger District Warren Lakes Special Interest Area	2000	Warren Lakes	10,750	Glacial valley with organic/peat soils in a subalpine fen. Occurs with *Carex* spp.	estimated 60 to 90	Colorado Natural Heritage Program Element Occurrence 04 Herbarium label: Snowden, T. s.n.
6	CO San Juan	USDA Forest Service San Juan National Forest Columbine Range District	1994	1 mile southeast of Grizzly Peak	11,560	In peat fen in a moss carpet.	locally common	Colorado Natural Heritage Program Element Occurrence 05 Herbarium label: Komarek, S. #429.
7	CO La Plata	USDA Forest Service San Juan National Forest Columbine Ranger District Weminuche Wilderness	1995	Endlich Mesa	11,820	Peat bog. Occurs with *Pedicularis groenlandica*, *Caltha leptosepala*, and *Deschampsia cespitosa*.	50 to 1,000	Colorado Natural Heritage Program Element Occurrence 02 Herbarium label: Komarek, S. #493.

Table 1 (concluded).

	State County	Land Ownership	Date Last Observed	Location	Elevation (ft.)	Habitat	Population Size	Source ID
8	WY Big Horn	USDA Forest Service Bighorn National Forest Paintrock Ranger District	2003	2.5 miles southeast of Antelope Butte Ski Area	9,270	*Carex* bog with high soil moisture on a 1 to 2 percent south facing slope. Occurs with *Salix planifolia*, *Carex aquatilis*, and *C. utriculata*.	many	Wyoming Natural Diveristy Database Element Occurrence 13 Herbarium label: Morris, D. #2003-004
9	WY Sheridan	USDA Forest Service Bighorn National Forest Tongue Ranger District Preacher Rock Bog Special Interest Area	1999	Preacher Rock Bog	8,200	Flooded wetland of *Carex rostrata*, *C. saxatilis*, and *Eriophorum chamissonis* on gently sloping, humus-rich soil at edge of *Picea/Salix planifolia* hummock thickets and *Carex* rostrata marsh.	moderately sized	Wyoming Natural Diversity Database Element Occurrence 09 Herbarium labels: Evert, E.F. #4466 Dorn, R. #5098 Fertig, W, & B. Bornong #18824
10	WY Sheridan	USDA Forest Service Bighorn National Forest Tongue Ranger District	2003	4 miles northeast of Antelope Butte Ski Area	8,680	Bog within lodgepole pine forest in full light on soil with high moisture. Occurs with *Salix planifolia*, *Carex aquatilis*, *C. utriculata*, *Senecio triangularis*, *Agoseris lackschewitzii*, and *Trollius laxus*.	ca. 50	Wyoming Natural Diversity Database Element Occurrence 12 Herbarium label: Galloway, T. #2003-002
11	WY Park	USDA Forest Service Shoshone National Forest Clarks Fork Ranger District	1985	Upper Sunlight Creek Valley	7,800	Edge of forest and marsh.	unknown	Wyoming Natural Diversity Database Element Occurrence 10 Herbarium label: Hartman, R. & B.E. Nelson #21237
12	WY Park	USDA Forest Service Shoshone National Forest Greybull Ranger District	1956	Timber Creek	9,500	Subalpine bog on level organic soil.	scarce, rare	Wyoming Natural Diversity Database Element Occurrence 11 Herbarium label: Gierisch, R. K. #1864

System for the enjoyment, education, and inspiration of this and future generations. Grazing, off road vehicle travel, and logging are only permitted for special reasons (e.g., removal of hazard trees after fire) on National Park Service lands.

Eriophorum chamissonis almost always occurs in wetlands (estimated probability >99 percent), and it is considered an obligate wetland indicator species in U.S. Fish and Wildlife Service Regions 4 (North Plains), 8 (Intermountain), and 9 (Northwest). There are a variety of federal regulations and policies that, although they do not directly address the conservation of *E. chamissonis*, could provide a degree of protection for wetlands supporting this species. The primary federal law regulating wetland habitats is Section 404 of the Federal Water Pollution Control Act (Clean Water Act) of 1977 (33 U.S.C. ss/1251 et seq.). Activities in wetlands regulated under this Act are required to avoid wetland impacts where practicable, to minimize potential impacts to wetlands, and to compensate for any unavoidable impacts through restoration or mitigation. Environmental impact statements required for major federal actions affecting the environment under the National Environmental Policy Act (NEPA) of 1969 (42 U.S.C. 4321-4347) can also serve to focus attention on protection of wetland habitat. Federal codes and regulations specific to National Forest System lands include the Organic Administration Act of 1897 (16 U.S.C. 475), the Multiple Use – Sustained Yield Act of 1960 (16 U.S.C. 528), the National Forest Management Act of 1976 (16 U.S.C. 1600-1602, 1604, 1606, 1608-1614), the Federal Land Policy and Management Act of 1976 (43 U.S.C. 1701-1782, FSM 2729), the Forest Service Manual, and individual Forest Management Plans. These codes and regulations all provide some degree of focus on the preservation of water resources, including wetlands. Finally, a policy of "no-net-loss" of wetlands has been a national goal since first announced as an administration policy under President George H.W. Bush in 1989.

Adequacy of current laws and regulations

The above-mentioned laws and regulations provide tools for the conservation of *Eriophorum chamissonis* in wetland habitats, especially on USFS and other federal lands. However, additional protection is needed for fens in Region 2. Department of Interior and Department of Agriculture regulations consider peat a renewable resource (USDI Bureau of Mines 1994) and a leasable mineral (FSM 2822.1). For occurrences that might be found on privately owned lands, current laws and regulations may be inadequate to prevent damage or destruction of occurrences.

Adequacy of current enforcement of laws and regulations

There are no known cases in which an occurrence of *Eriophorum chamissonis* in Region 2 was extirpated due to human activities or by the failure to enforce any existing regulations. This does not necessarily indicate that current regulations or their enforcement are adequate for protection of *E. chamissonis* or its habitat. The National Research Council's Committee on Mitigating Wetland Losses (2001) concluded that mitigation criteria required for compliance with the provisions of Section 404 of the Clean Water Act have often not been attained, in part because permit expectations were unclear and compliance was never monitored. The Committee also found that although progress has been made since the 1980s, the goal of "no net loss of wetlands" is not being met (National Research Council 2001). The Committee's report indicates that enforcement of at least some current laws and regulations is inadequate to protect the unique habitat of *E. chamissonis*.

In Region 2, *Eriophorum chamissonis* is confined to a few isolated instances of unique and relatively rare habitat. Extirpation of these occurrences will not necessarily endanger the persistence of the species. However, a steady but gradual loss of occurrences over time could contribute to a contraction of the known range. Loss of the disjunct occurrences in Region 2 could reduce the genetic diversity of the species as a whole, as well as depress its resilience in the face of genetic, demographic, and environmental stochasticity. Careful attention to the preservation of the habitat of *E. chamissonis* in Region 2, using all available regulatory tools, is likely to be the most effective means of conserving the species.

Biology and Ecology

Classification and description

Eriophorum chamissonis is a member of the Cyperaceae or sedge family, a moderate-sized family of approximately 100 genera and 5,000 species, including 27 genera and 843 species in North America (Ball et al. 2002). The complete taxonomic classification of *E. chamissonis* is available online from the PLANTS database (USDA Natural Resources Conservation Service 2005). The genus *Eriophorum* is distinguished

from other genera in Cyperaceae by the presence of numerous long and silky perianth bristles that appear as conspicuous cotton-like tufts on the flowering plant. These tufts give the genus its name from the Greek: *erion* (wool) and *phoreo* (to bring or carry) hence, "wool bearing" (Griffith 2002). The "woolly hairs" of cottongrass develop at the base of the ovary and are actually modified flower petals and sepals. There are approximately 25 species of *Eriophorum* in the northern hemisphere; Ball and Wujek (2002) list 11 species as occurring in North America, mostly in cool temperate, alpine, and arctic regions. In some species, including *E. chamissonis*, the North American populations are considered by some authors to be conspecific with Eurasian populations, but Ball and Wujek (2002) suggest that these relationships should be investigated more thoroughly because of differences in achene micromorphology and isozyme data from the two regions.

History of knowledge

Eriophorum chamissonis was named in honor of Adelbert von Chamisso (1781-1838), a French naturalist aboard the Russian ship "Rurick" that visited Alaska and California in 1816 (Chambers 2003). *Eriophorum chamissonis* was originally described in 1825 by C. A. Meyer during a presentation to the St. Petersburg Academy in a paper entitled "Cyperaceae Novae descriptionibus et iconibus illustratae" (Fernald 1905), but the description was not formally published until 1831 (Meyer 1831). In the interim, Ledebour included *E. chamissonis* in his 1829 Flora Altaica (Ledebour 1929), ascribing it to Meyer, but citing specimens from the Altai region in southeastern Siberia that proved to be unlike the Alaskan and Kamchatkan plants that Meyer described. Fernald (1905) identified the Altai material as *E. callitrix*, also a subject of much taxonomic confusion. The location of the original *E. chamissonis* material is unclear. An apparent neotype specimen of *E. chamissonis*, collected by A. McIlhenny near Point Barrow, Alaska in 1898, is located at the New York Botanical Gardens (ID #51111). This mixed-species herbarium sheet was apparently typified by D.E. Wujek in 1991, resulting in a disparity in dates between the original description and the type collection.

Current synonyms for *Eriophorum chamissonis* include: *E. chamissonis* var. *aquatile* (Norman) Fernald, *E. rufescens* Andersson, *E. russeolum* Fries subsp. *rufescens* (Andersson) Hylander, *E. russeolum* var. *albidum* F. Nylander, *E. russeolum* var. *leucothrix* (Blomgren) Hultén, and *E. russeolum* var. *majus* Sommier (Robinson 1908, Porsild 1964, Hultén 1968, Ball and Wujek 2002). Ball and Wujek (2002) also treat *E. altaicum* var. *neogaeum* as a synonym for *E. chamissonis*. However, USDA Natural Resources Conservation Service (2005) and Kartesz (1994) separate *E. altaicum* var. *neogaeum* and *E. chamissonis*. *Eriophorum altaicum* var. *neogaeum* (also known as *E. scheuchzeri*) has a similar distribution to *E. chamissonis*; it is present in British Columbia, Montana, Utah, Wyoming, and Colorado (Welsh 1974). The main morphological difference between *E. chamissonis* and *E. altaicum* var. *neogaeum* is anther size. *Eriophorum chamissonis* anthers are 1 to 3 mm while those of *E. altaicum* var. *neogaeum* are shorter, 0.5 to 1.5 mm (Welsh 1974, Hartman personal communication 2003, Holt personal communication 2003).

The above-mentioned taxa comprising the *Eriophorum chamissonis* complex are separated mainly on the basis of stem size, bristle color (Raymond 1954, Polunin 1959, Hultén 1968, Welsh 1974), and anther length (Polunin 1959, Welsh 1974). Because much of the variation appears to be continuous and there are many intermediate forms, this complex requires additional research to clarify the taxonomic status of the variants (Ball and Wujek 2002). Until the possible separation of the complex, especially *E. chamissonis* and *E. altaicum* var. *neogaeum*, is resolved, the conservation status of both species can only be approximated.

Description

As described by Hitchcock and Cronquist (1972), Dorn (1992), and Ball and Wujek (2002), *Eriophorum chamissonis* is a perennial, colonial graminoid with creeping rhizomes and non-tufted culms, 20 to 70 cm tall. Spikes are solitary, erect, without blade-bearing involucral bracts (**Figure 2**). Roots are pallid-brown, rhizomatous or stoloniferous, and scales are present. The basal and lower leaves have a well-developed sheath and short, narrow triangular to channeled blades up to 2 mm wide. The sheaths are grayish brown or brown (sometimes reddish), with margins fused to the apex. Ligules are 0.5 to 1.0 mm long, transversely oblong with obtuse and entire apices. Uppermost leaves are bladeless and borne near the middle of the culm. Fertile scales have hyaline margins at least 1 mm wide. Flowers have anthers more than 1 mm long, triangular achenes, oblong to obovoid, 2.0 to 2.7 mm, as wide as long with an abruptly pointed style, and numerous cinnamon or reddish perianth bristles that elongate in fruit to form a "cotton-ball" head (**Figure 3**). *Eriophorum chamissonis* is diploid ($2n = 58$).

Figure 2. *Eriophorum chamissonis* specimen (Cooper #1503). Photograph by David G. Anderson.

Published descriptions and other sources

Complete technical descriptions and illustrations are available in Fernald (1905), Britton and Brown (1913), Raymond (1954), Hitchcock and Cronquist (1972), and Ball and Wujek (2002). Online sources for descriptions and photographs of plants and habitat are numerous and include Larson (1993), Aiken et al. (1999), and Wisconsin State Herbarium (2004).

Distribution and abundance

Eriophorum chamissonis is a circumpolar species. It occurs in most of the northern tier of U.S.

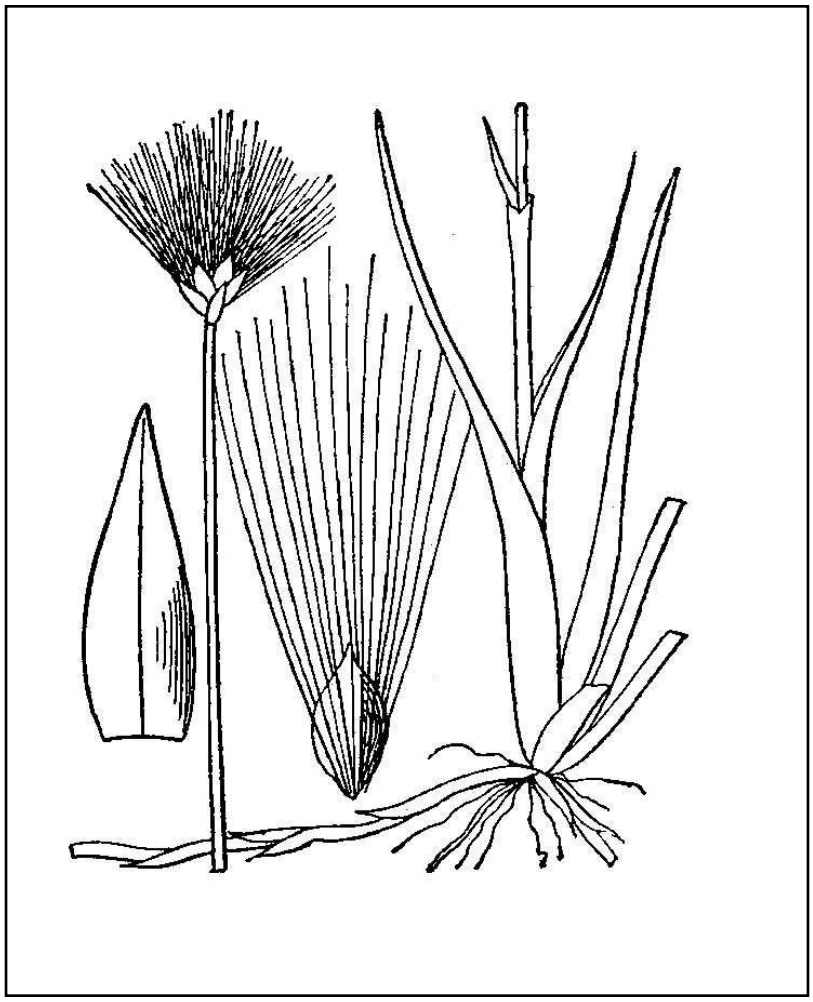

Figure 3. Illustration of *Eriophorum chamissonis* from Britton and Brown (1913). USDA Natural Resources Conservation Service PLANTS Database / Britton, N.L., and A. Brown. 1913. Illustrated flora of the northern states and Canada. Vol. 1: 323. This image is not copyrighted and may be freely used for any purpose.

states west of the Great Lakes (i.e., Alaska, Colorado, Idaho, Minnesota, Montana, North Dakota, Oregon, Washington, Wisconsin, Wyoming) as well as in all of the Canadian provinces (**Figure 4**) and northern Eurasia (Hultén 1968, Kartesz 1999, Ball and Wujek 2002). The current taxonomic controversy means that some specimens that could define the extent of the species' distribution may not be currently labeled as *E. chamissonis*. As far as is known, the current distribution of this species is more or less equivalent to the recent post-glacial distribution. Although the global range of *E. chamissonis* is circumpolar, at the southern extent of its range in Region 2 it occurs in small, disjunct populations.

In Region 2, *Eriophorum chamissonis* occupies the Temperate Steppe Division of the Dry Domain in the Ecoregion Classification of Bailey (1995). Within the Temperate Steppe Division, *E. chamissonis* is found in the Southern Rocky Mountain Steppe-Open Woodland-Coniferous Forest-Alpine Meadow Province (Bailey 1995). In Region 2, this division corresponds to the Utah-Wyoming Rocky Mountain and the Southern Rocky Mountain Ecoregions as defined by The Nature Conservancy (2001). *Eriophorum chamissonis* is conspicuously absent from the lower and drier Wyoming Basins Ecoregion that lies between the two. In Region 2, *E. chamissonis* is found in the central and southwestern mountains of Colorado and in northern Wyoming's Bighorn Mountains and Absaroka Range. These disjunct occurrences are likely Pleistocene relicts from a time when arctic vegetation was found at more southerly latitudes in North America (Pielou 1991). Documented occurrences of *E. chamissonis* in Region 2 are shown in **Figure 1** and described in **Table 1**. All known occurrences in Region 2 are on National Forest

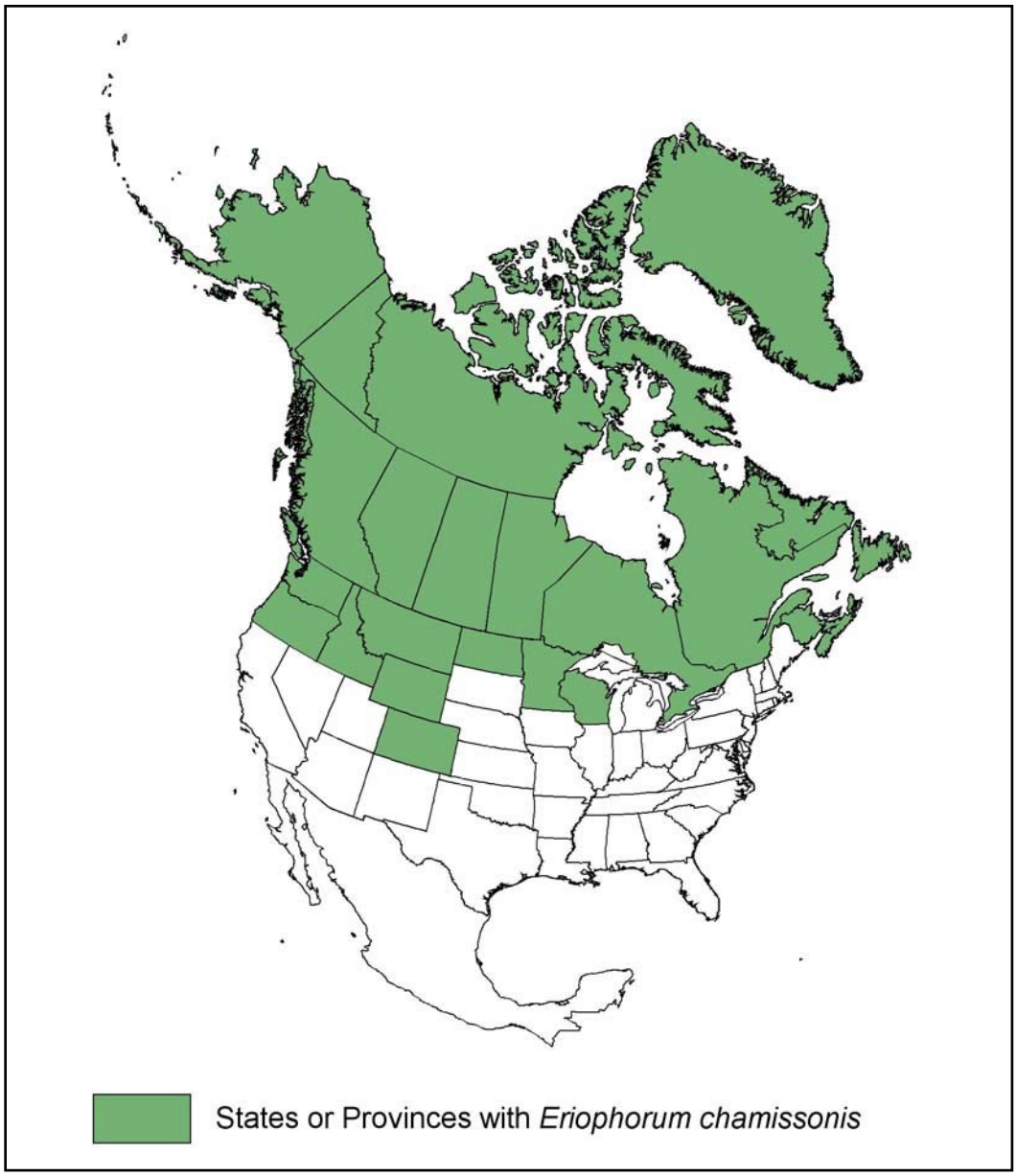

Figure 4. Generalized North American distribution of *Eriophorum chamissonis*.

System lands. There may be additional documented material from Region 2 at herbaria not searched for this assessment, including specimens that are not currently labeled as *E. chamissonis*, but that may eventually be annotated as this species. There are also likely to be additional locations for which no documentation currently exists. Although new material could help to refine estimates of the abundance of *E. chamissonis* in Region 2, it is unlikely to change the disjunct character of occurrences in this region. Similarly, a combination of *E. chamissonis* and *E. altaicum* var. *neogaeum* would not substantially change the overall pattern of distribution in Region 2, but it would increase the number of known locations.

In Colorado, *Eriophorum chamissonis* is known from seven locations in four counties (**Table 1**). There are two known centers of distribution in Colorado, one in the San Juan Mountains in southwestern Colorado, and one in the Sawatch Range in central Colorado. The two occurrences on the San Juan National Forest include one in the Weminuche Wilderness Area. The five occurrences on the White River National Forest include three in the Holy Cross Wilderness, one historical record in the Hunter-Frying Pan Wilderness, and one at Warren Lakes.

In Wyoming, *Eriophorum chamissonis* is known from fifteen occurrences, five of which are

on USFS Region 2 lands. On the Bighorn National Forest in north-central Wyoming, *E. chamissonis* is known from Preacher Rock Bog and from fens in the vicinity of the Antelope Butte Ski Area. There are two known occurrences on the Shoshone National Forest in northwestern Wyoming. The remaining Wyoming occurrences are in Yellowstone National Park, also in northwest Wyoming, where there are at least 10 documented occurrences. Three of these occurrences have not been relocated since the original collections in the late 1800s to mid-1900s.

Abundance information for occurrences of *Eriophorum chamissonis* in Region 2 lacks detail. The clonal nature of *E. chamissonis* makes it nearly impossible to obtain accurate counts of the number of genetic individuals in a population. Reported numbers refer to the number of stems observed; the number of genetic individuals is probably much smaller. As a consequence, it is difficult to estimate the total number of individuals occurring in Region 2. Colorado occurrence abundance estimates range from "rare" to "locally common." Where numbers are reported, the occurrences in the White River National Forest are generally around 100 stems. The two occurrences on the San Juan National Forest may be somewhat larger, as they are reported as consisting of 1,000 stems in one case and "locally common" in the other. Region 2 occurrences in Wyoming also are reported as ranging from "scarce" to "moderately sized" to "many individuals (stems)." The only count reported was approximately 50 stems. In Yellowstone National Park, just outside the administrative boundaries of Region 2, occurrences are similarly sized, ranging from occasional individuals to groups of several hundred stems (Whipple personal communication 2003). Herbarium labels for specimens from Canada often report *E. chamissonis* as "common", as would be expected for areas close to the center of its range.

Population trend

Because most documented occurrences have not been counted more than once, information is insufficient to allow an assessment of range-wide population trends. Occurrences in Region 2 are generally small and disjunct and so are probably more vulnerable to environmental stochasticity and anthropogenic disturbance than occurrences in the center of the range. Although population monitoring data are lacking, there is evidence to suggest that some occurrences have disappeared. Three occurrences from Yellowstone National Park that were last seen in 1885, 1899, and 1956 have never been relocated in spite of recent survey efforts (Whipple personal communication 2003). It is unclear if these disappearances represent an overall downward population trend.

Habitat

Globally, *Eriophorum chamissonis* is found in cool temperate, alpine, and arctic regions, in wetlands with peat soils that are supported by groundwater discharge or snowmelt (Ball and Wujek 2002). In Region 2, *E. chamissonis* is typically found in subalpine wet meadows and fens (**Figure 5**) with saturated peat soils, where graminoids and forbs dominate the vegetation (Dorn 1992, Ball and Wujek 2002). Habitats are often described as "bogs" or "marshes" in the original source material; however, all peatlands in Region 2 are properly classified as fens (Cooper 1986, Cooper and Andrus 1994). *Eriophorum chamissonis* occurrences range from 7,800 to 9,500 ft. (2,375 to 2,895 m) elevation in Wyoming and from 10,400 to 12,000 ft. (3,170 to 3,660 m) in Colorado (**Table 1**).

Eriophorum chamissonis in Region 2 is associated with vegetation and saturated soils characteristic of montane fens. Specimen labels and element occurrence records show *E. chamissonis* growing with the species shown in **Table 2**. Little information is available with which to characterize microhabitat preferences of *E. chamissonis*. It is likely to be specialized within the fen habitat since many fen species appear to exhibit microhabitat specialization along micro-relief, hydrologic, or chemical gradients (Sanderson and March 1996).

In Region 2, *Eriophorum chamissonis* is associated with the Rocky Mountain Alpine-Montane Wet Meadow and Rocky Mountain Subalpine-Montane Fen ecological systems as defined by NatureServe (2003). These two systems are defined as "small patch" types that usually have distinct boundaries, require specific environmental conditions, and are strongly linked to and dependent upon the landscape around them (Anderson et al. 1999).

The Rocky Mountain Alpine-Montane Wet Meadow ecological system includes high-elevation, herbaceous-dominated plant communities on wet sites with very low-velocity surface and subsurface flows. These ecosystems occur in montane or subalpine valleys throughout the Rocky Mountains as large meadows, as narrow strips bordering ponds, lakes, and streams, and along toeslope seeps. They range in elevation from montane to alpine (3,280 to 11,810 ft. [1,000 to 3,600 m]) and are typically found on flats or

Figure 5. Example of subalpine wet meadow habitat in Colorado. This figure shows the closely related *Eriophorum altaicum* var. *neogaeum*, but the habitat is similar to that of *E. chamissonis*. Photograph by Denise Culver.

Table 2. Species associated with *Eriophorum chamissonis* in USDA Forest Service Region 2.

Shrubs-subshrubs	**Graminoids**
Betula glandulosa	*Carex aquatilis*
Dasiphora floribunda	*Carex canescens*
Kalmia microphylla	*Carex gynocrates*
Gaultheria humifusa	*Carex illota*
Salix planifolia	*Carex saxatilis*
	Carex utriculata (=*Carex rostrata*)
Forbs	*Deschampsia cespitosa*
Agoseris lackschewitzii	*Juncus brevicaudatus*
Senecio pauciflorus	*Juncus regelii*
Senecio triangularis	*Luzula parviflora*
Trollius laxus	
Non-vascular	
Sphagnum spp.	

slopes with gradients up to 10 percent. In alpine regions, wet meadows typically form on snowbeds or in small depressions lying below late-melting snow patches. This system may have mineral or organic soils but shows typical hydric soil characteristics.

The Rocky Mountain Subalpine-Montane Fen system is defined by groundwater discharge, soil chemistry, and at least 40 cm of peat accumulation. Fens form at low points in the landscape or on slopes where groundwater discharge maintains a constant water table at or near the surface. Constant high water levels and general cool temperatures lead to an accumulation of undecomposed organic material. Fen microtopography consists of hummocks, hollows, and other patterns on the soil surface. Some fens support floating peat mats that "quake" when walked upon, due to the presence of plants with air in their roots and stems (Austin

2003). Rocky Mountain fens usually occur as a mosaic of several plant associations dominated by *Carex aquatilis*, *Betula glandulosa*, *Kobresia myosuroides*, *K. simpliciuscula*, and *Trichophorum pumilus*. Due to the slow accumulation of peat, fens take centuries to develop, and fen habitat is essentially irreplaceable.

Reproductive biology and autecology

Life history and strategy

In the Competitive/Stress-Tolerant/Ruderal (CSR) model of Grime (2001), *Eriophorum* species have been categorized as both stress-tolerators (*E. vaginatum*) and competitors (*E. scheuchzeri*), depending on their response to nutrient availability. Their rhizomatous nature tends to argue for the competitive character, but their reliance on disturbance (open sites) for seedling establishment means that they do not precisely fit Grime's criteria (McGraw and Chapin 1989). Grime (2001) characterizes the stress-tolerant competitor as a rhizomatous or tussock-forming perennial that has a lower maximum potential relative growth rate and longer leaf life-span than a strict competitor, and a shoot morphology that is intermediate between the stress-tolerator and competitor. Too little is known about these characters in *E. chamissonis* to be confident of its classification, but less aggressive growth habits compared with congeners such as *E. vaginatum* may best fit the concept of stress-tolerant competitor. As a long-lived perennial species that probably devotes several years to vegetative growth before reproducing, and that lives in a stable environment at or near carrying capacity (Ball personal communication 2003), *E. chamissonis* can be regarded as a *k*-selected species in the classification scheme of MacArthur and Wilson (1967).

Reproduction

Eriophorum chamissonis is a perennial graminoid that reproduces both sexually by seed and vegetatively by long, creeping rhizomes (Ball and Wujek 2002). Like most other species in the Cyperaceae, *E. chamissonis* is monoecious, having separate male and female flowers on the same plant. Worldwide, this sexual system is found in perhaps five percent of species (Yampolsky and Yampolsky 1922). The monoecious condition allows self-pollination, and some *Eriophorum* species apparently produce large amounts of seed (McGraw et al. 1991) that could result from selfing. However, *Eriophorum* species that have been studied reproduce primarily by vegetative growth, perhaps because of a lack of suitable open sites for germination. Although the reproductive biology of *E. chamissonis* has not been investigated, it is likely that this species shares the characteristic found in other members of the genus of reproducing primarily through rhizomatous growth.

Pollinators and pollination ecology

Eriophorum species are wind pollinated, or anemophilous (Cronquist 1988, Cronk and Fennessy 2001), as are almost all grasses, sedges, and rushes. This trait is common among species growing in habitats where pollinators may be scarce. It is also strongly associated with monoecy (Proctor et al. 1996). Wind pollination requires the production of large amounts of pollen, and this is the most likely means of gene flow among disjunct occurrences of *E. chamissonis*. Although most pollen is deposited close to its source (Levin and Kerster 1974), under weather conditions producing strong convection, pollen may be carried long distances from the source (Procter et al. 1996). If long distance pollen dispersal events do occur in *E. chamissonis*, they are likely to be extremely rare.

Phenology

Flowering and fruiting occur from May to August in *Eriophorum chamissonis* (Welp and Fertig 2000, Ball and Wujek 2002). After flowering, plants bear showy white, fluffy, cottony seed plumes that persist for weeks. Flowering stems are mature and conspicuous by July.

Fertility and propagule viability

If *Eriophorum chamissonis* is similar to other species in the genus, then plants are several years old before they are capable of producing seed (Howard 1993, Tolvanen and Henry 2000). Seeds of many *Eriophorum* species demonstrate high initial germinablity at moderate and high temperatures (Grime et al. 1981, Gartner et al. 1986). This trait is often linked to species that germinate in summer or early autumn and are less likely to form large, persistent seed banks (Schutz 2000). The fertility and propagule viability of *E. chamissonis* are unknown.

In peatlands, open sites for seedling establishment may be rare, produced by localized disturbance such as trampling by domestic or wild ungulates. Although a positive effect of such disturbance on the germination of many herbaceous fen species has been demonstrated (e.g., Isselstein et al. 2002), Stammel and Kiehl (2004) found that tolerance of the negative effects of trampling (e.g., soil compaction, changes in the availability of light and water) was not the same for all species, and

concluded that gap creation by trampling may not be a suitable conservation tool for rare species.

Dispersal mechanisms

The seeds of *Eriophorum* species are dispersed by wind and water (Ball personal communication 2003). The long perianth bristles of *Eriophorum* achenes are presumed to aid in wind dispersal (Burrows 1975).

Cryptic phases

There is evidence of a persistent seed bank in at least some *Eriophorum* species (Grime et al. 1988). *Eriophorum vaginatum* often dominates northern seedbanks, where seeds buried in peat remain viable for up to 200 years in cold arctic conditions (McGraw et al. 1991). Although *E. chamissonis* may share this characteristic in northern parts of its range, it is unlikely to hold true for occurrences in Region 2.

Phenotypic plasticity

Phenotypic plasticity has not been reported for *Eriophorum chamissonis*. In general, flowering plants are noted for their great phenotypic plasticity (Savile 1972). Other *Eriophorum* species show phenotypic plasticity in response to changes in nutrient and light levels (McGraw and Chapin 1989), and *E. chamissonis* is likely to share this trait. Experiments with *E. vaginatum* suggest that phenotypic responses to environmental stimuli can persist in clonal offspring (Schwaegerle et al. 2002). However, McGraw and Chapin (1989) found that important characters such as root to shoot ratio were constant across genotypes regardless of environmental effects. Detailed investigation of the biology of *E. chamissonis* would be required to determine the extent of phenotypic plasticity and the persistence of environmental effects in this species.

Mycorrhizal relationships

The arctic tundra, where most *Eriophorum* species have their center of distribution, is a strongly nutrient-limited system, and most vascular plant species there are mycorrhizal (Urcelay et al. 2003). However, the Cyperaceae are generally non-mycorrhizal (Gardes and Dahlberg 1996), and this includes at least some *Eriophorum* species such as *E. vaginatum* (Chapin et al. 1993). Although the mycorrhizal status of *E. chamissonis* has not been investigated, it is likely to share the non-mycorrhizal condition of its family.

Hybridization

Hybridization in *Eriophorum chamissonis* has not been studied. Although the varieties comprising the *E. chamissonis* complex display essentially continuous variation across their distribution, there is no evidence that these variations are due to hybridization. A number of other *Eriophorum* species occur in similar habitats in Region 2, including *E. callitrix*, *E. scheuchzeri*, and *E. viridicarinatum* in Wyoming and *E. altaicum* var. *neogaeum*, *E. angustifolium*, and *E. gracile* in both Wyoming and Colorado. Occurrences of *E. chamissonis* may sometimes be within a mile or two of occurrence of other *Eriophorum* species, with potential for gene flow between them. The tendency of *Eriophorum* species to propagate almost exclusively by vegetative reproduction suggests that hybridization would be a rare event, if it occurs at all.

Demography

Given the distance between occurrences, there is probably very little gene flow among most occurrences of *Eriophorum chamissonis* in Region 2. Areas of unsuitable habitat for this species act as sinks when seeds land there. Also, this species' reliance on vegetative reproduction may mean that effective breeding populations are much smaller than indicated by counts of flowering stems.

Most *Eriophorum* species achieve most of their reproductive success through vegetative growth (i.e., "tillering"). Notwithstanding the possibility of the persistence of environmental effects in later generations of tillers (Schwaegerle et al. 2000) or the chance of somatic mutation, offspring of *Eriophorum* species are essentially genetically identical to the parent plant. Due to the clonal nature of this genus, demographic studies have tended to focus on the life cycle of individual ramets rather than on genetic differences between individuals. Tolvanen et al. (2001) developed a generalized lifecycle graph for sedge tillers in their study of the effects of grazing on *E. angustifolium* ssp. *triste*, *Carex aquatilis* ssp. *stans* and *C. membranacea*. **Figure 6** shows this generalized tiller lifecycle diagram adapted for *E. chamissonis*, with the addition of sexual reproduction. Transition probabilities are unknown for *E. chamissonis*, but the lifespan of individual tillers was 8 to 10 years for ungrazed plants in *E. angustifolium* ssp. *triste*, and combined survival of tillers (either in same stage or progressing to the next stage) was high. Grazing had no significant effect on the overall

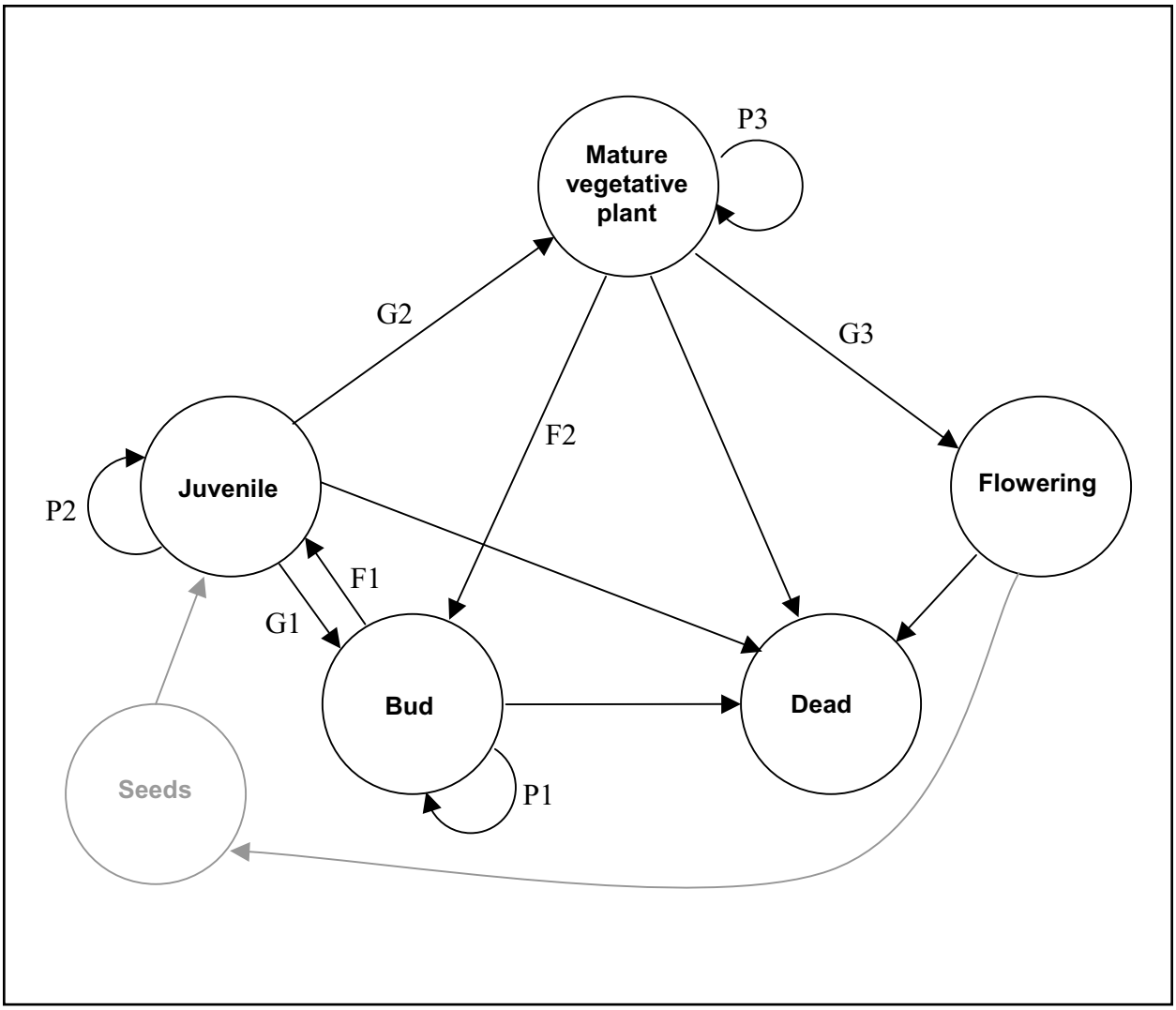

Figure 6. Generalized life cycle diagram for *Eriophorum chamissonis* (after Tolvanen et al. 2001).

population growth rates for the two Carex species (*E. angustifolium* ssp. *triste* was not studied under grazing), but tillers in grazed habitat moved quickly to the next stage and died earlier (Tolvanen et al. 2001). Such changes in population stage-class structure may have implications for population stability under other stresses as well.

No Population Viability Analysis (PVA) has been performed for *Eriophorum chamissonis*. Identifying a minimum viable population could assist in the formation of quantitative management objectives (Brackley 1989). However, an analysis would be difficult with the little that is known about the life history of *E. chamissonis*. Information on tiller growth rates and lifespan, seed production and longevity, and variables controlling these parameters would help to reveal potential bottlenecks in this species' life history.

Community ecology

The community ecology and interspecific relationships of *Eriophorum chamissonis* have not been formally studied, but some inferences can be made from its association with subalpine wetland and fen communities. Wetland habitats where *E. chamissonis* grows are often densely vegetated, and species may have highly specialized niches along a micro-topographic or hydrologic gradient.

Herbivores

While herbivory of *Eriophorum chamissonis* has not been documented, other members of this genus are known to be subject to herbivory. Tolvanen et al. (2001) reported grazing on *E. angustifolium* ssp. *triste* by muskox, arctic hare, collared lemmings, and greater

snow geese. Howard (1993) reported that *E. vaginatum* was grazed by sheep, cattle, lemmings, ground squirrels, caribou, and geese (Howard 1993). These *Eriophorum* species have no apparent mechanisms to resist herbivory (e.g., secondary compounds, thorns), and it is likely that *E. chamissonis* is similarly palatable to the vertebrate herbivores in its environment. In Region 2, *E. chamissonis* is exposed to grazing both by domestic and wild vertebrate herbivores, including cattle, sheep, horses, moose, elk, deer, rodents, and waterfowl (Austin 2003). The occurrence of invertebrate herbivory or seed predation in *Eriophorum* species has not been investigated.

Competitors

The work of McGraw and Chapin (1989) on the competitive ability of two related species, *Eriophorum vaginatum* and *E. scheuchzeri*, indicates that *Eriophorum* species can be adapted to specific micro-site conditions of either low or high nutrient availability, with a corresponding competitive advantage in the habitat to which they are adapted. Although the specific adaptations and competitors of *E. chamissonis* have not been investigated, the wetland and fen habitats where it occurs are usually densely vegetated, with competition for light, water, and nutrients. The tendency for *Eriophorum* species to rely on disturbance for seedling establishment means that *E. chamissonis* is likely to be in competition with other wetland plants for this resource as well.

Other interactions

There have been no reports of parasites or diseases of *Eriophorum chamissonis*. Community interactions that affect pollination and dispersal are presumably minimal since these functions are accomplished by abiotic means.

CONSERVATION

Threats

The identification of threats to *Eriophorum chamissonis* is complicated by taxonomic uncertainties and the nearly complete lack of information regarding its biology and ecology. Because we know little about the response of this species to disturbance, it is difficult to assess the immediacy of potential threats. In order of decreasing priority, potential threats to the persistence of *E. chamissonis* in Region 2 include hydrologic alterations, grazing, motorized vehicle use, peat mining, fire, and global climate change. A lack of systematic tracking of population trends and conditions, and the lack of knowledge about its life cycle, occurrence extent, and demographics also contribute to the possibility that one or more of these factors will threaten the long term persistence of the species without anyone knowing about it or taking steps to prevent it.

Altered hydrology

Because *Eriophorum chamissonis* is limited to wetland habitats, hydrologic alteration is the foremost threat to the species. This threat interacts to some degree with all of the other threats. Any alterations to a site or watershed that affect water quality or quantity will almost certainly have a negative impact on *E. chamissonis*. Hydrologic alteration can result from natural or human impacts, including trenching, ditching, logging, mining, fire, and grazing (Bursik and Moseley 1992). Changes in hydrologic regime can influence nutrient cycles, soil and water chemistry, sedimentation, species composition, and habitat quality in wetland systems (Mitsch and Gosselink 1993). Other threats, such as grazing, motorized vehicle use, peat mining, fire, and global climate change, can influence the hydrology of *E. chamissonis* habitat in addition to directly affecting occurrences and individual plants.

Currently, the only occurrence in Region 2 known to have been subjected to significant hydrologic modification is at Warren Lakes. These lakes were created by dams built over a period beginning in the late 1880s. The dams were removed after the USFS acquired the land in 1997, and attempts have been made to restore the wetland to its pre-dam condition. There is no information that would confirm that any other Region 2 occurrences have been affected by altered hydrology. Occurrences in wilderness areas are less threatened by hydrologic modification than occurrences outside such areas. However, wilderness areas contain facilities that are maintained to support grazing, including stock tanks and there are few watersheds that have no hydrologic modifications. The general scope and severity of hydrologic modifications throughout Region 2 means that all occurrences are likely to be affected by them to some extent.

Grazing

Grazing is potentially a threat to individual plants, to occurrences, and to habitat quality. Cattle and sheep grazing have significantly impacted many subalpine and montane wetlands throughout the Rocky Mountains (Windell et al. 1986, Wahren et al. 1999). Major impacts of grazing include removal and

reduction of vegetation, soil compaction, increased erosion, and decreased water storage capacity. These impacts have been shown to affect hydrology, water chemistry, and other variables (Menke 1977, Johnston and Brown 1979). Although some observers (Beard personal communication 2004, Houston personal communication 2004, Ives personal communication 2004) suggest that cattle generally avoid peatlands because of the soft substrate, livestock may impact fen margins in dry years. The presence of domestic livestock in fens can negatively affect plant species sensitive to trampling (Pearson and Leoschke 1992, as cited in Austin 2003), alter fen hydrology, and damage the edges of fens (Mullen et al. 1992, as cited in Austin 2003). Grazing animals can create paths in peaty soils, eventually channelizing water that would otherwise move through the peatlands in a sheet (Windell et al. 1986, Chadde et al. 1998, Bursik 1993). If the grazing regime produces channelization, these habitats may dry out and cattle use will increase (Bursik 1993).

Improper grazing can trigger a shift in community composition due to the removal of native species or the introduction of non-native species. Cattle prefer grasses, sedges (including *Eriophorum* spp.), and willows. Research on *E. vaginatum* has shown that plants are able to tolerate light grazing but are eventually killed by continued heavy defoliation (Howard 1993). If grazing is too intense, then it would negatively affect the percent cover and plant diversity of the wetland (Ellison 1954). Grazing has been shown to alter the population age-class structure in other rhizomatous species (Tolvanen and Henry 2000), and this could also have unexpected consequences for demographic stability in *E. chamissonis*.

Four of the five Region 2 occurrences in Wyoming are in active grazing allotments. The exception is the occurrence at Preacher Rock Bog Special Interest Area in the Bighorn National Forest. Occurrences on the Bighorn and Shoshone national forests are grazed by cattle from mid to late summer through mid September (Beard personal communication 2004, Houston personal communication 2004, Morris personal communication 2004), when *Eriophorum chamissonis* is generally in fruit. The only Colorado occurrence on an active grazing allotment is the Endlich Mesa occurrence on the San Juan National Forest, which is in the East Silver Mesa grazing allotment. This allotment permits 700 cow/calf pairs, moved weekly, from July 1 thru October 4 (Tucker personal communication 2004). There are no studies evaluating the impacts of livestock grazing in these areas. All Region 2 occurrences are likely to be grazed by native herbivores such as elk, deer, and small vertebrate herbivores.

Motorized vehicle use

Threats to *Eriophorum chamissonis* from motorized vehicle use arise from the construction and use of designated roads and trails as well as the illegal use of off-road vehicles that create trails in wetlands themselves. Roads and trails impact wetlands by affecting key physical processes such as water runoff and sediment yield. Even at a distance from a wetland, roads can concentrate water flows, increase flow rates, increase erosion, and reduce percolation and aquifer recharge rates (Forman and Alexander 1998). The major impact from off-road vehicle tracks is the creation of trails and paths that impact water levels, as well as destroy the habitat of subalpine wetlands. Tracks intercept surface and groundwater flow, draining portions of the wetland (Forman et al. 2003). Wetlands are particularly vulnerable to a certain class of off-road vehicle user, who appear to be unable to resist the challenging conditions provided by saturated soils (e.g., the "Caribou Flats Mudfest", see Brooks 2000).

In Region 2, six *Eriophorum chamissonis* occurrences are on lands with special designations (five in wilderness areas, one in a special interest area). These occurrences are protected from the effects of motorized vehicle use, except unauthorized trespass. The other six occurrences are in areas where motorized vehicle use is permitted but restricted to designated routes. Travel regulations for these areas allow vehicles to go off designated routes for distances of up to 300 feet for the purpose of camping, game retrieval, firewood collecting, and picnicking, as long as no resources are damaged, and travel is not parallel to the designated route (Bighorn National Forest 2004). Four Region 2 occurrences of *E. chamissonis* are within a quarter mile of a road. Although no direct impacts to *E. chamissonis* occurrences have been observed (Boyst personal communication 2004, Ives personal communication 2004, Morris personal communication 2004, Redders personal communication 2004), enforcement of travel regulations is difficult, and the potential for violations remains.

Peat mining

Because *Eriophorum chamissonis* occurs in fens, it is potentially threatened by peat mining. Peat mining destroys habitat for *E. chamissonis* by removing the substrate, reducing vegetation cover, altering species

composition by reducing species richness, eliminating microtopography, and altering edaphic and hydrologic properties. Furthermore, restoration of fens and shallow wetlands that support *E. chamissonis* is generally regarded to be difficult or impossible due to their reliance on groundwater and snowmelt (Windell et al. 1986) and the slow rates of peat accumulation (20 to 28 cm per 1,000 years; Cooper 1986). Once damaged, recovery is slow, and any hydrologic alterations may result in permanent degradation (Johnson 2000).

Colorado is the only state in Region 2 where commercial peat mining is permitted and ongoing (USDI Bureau of Mines 1994, Austin personal communication 2004). The only occurrence of *Eriophorum chamissonis* known to have been affected by peat mining is the Warren Lakes occurrence, where mining took place from the 1930s through the early 1960s. No other documented occurrence of *E. chamissonis* on USFS lands in Region 2 is known to be affected by peat mining. This threat is more likely to impact occurrences on private lands.

Fire

Fire frequency and severity are likely to be different for occurrences of *Eriophorum chamissonis* in Region 2 than for occurrences in tundra communities in the heart of its range. The tundra species *E. vaginatum* survives and perhaps even benefits from repeated, low intensity fire, while more intense fire destroys both above- and belowground portions of the plant (Howard 1993). Wein and Bliss (1973) found that aboveground plant parts of *E. angustifolium* are susceptible to fire even when the peat substrate is wet. *Eriophorum* species for which fire effects have been reported are typically tussock-forming. *Eriophorum chamissonis*, which does not form dense tussocks, may be somewhat more susceptible to fire.

Plants that survive a low-intensity fire may be more vulnerable to grazing. Klein (1982) found that regrowth of *Eriophorum vaginatum* after a mid-summer fire was preferentially grazed by migrating caribou. Thus, the primary threat from fire to *E. chamissonis* is twofold: 1) the potential for increased herbivory on post-fire vegetation that could critically depress population vigor, and 2) the chance that an isolated occurrence could be destroyed by fire without the potential for recolonization. No documented occurrences in Region 2 are known to have been affected by fire, and the degree of threat is low.

Global climate change

Although global climate change is potentially the most serious threat to *Eriophorum chamissonis* in Region 2, it appears last on the list of priority threats because of the uncertainty surrounding its regional effects and severity. Global climate change is likely to have wide-ranging effects in the near future for all habitats, especially high elevation wetlands. Projections based on current atmospheric CO_2 trends suggest that average temperatures will increase while precipitation will decrease in the western United States (Manabe and Wetherald 1986). These changes will significantly affect hydrology, nutrient cycling, vapor pressure gradients, and a suite of other environmental variables. In particular, a decrease in precipitation (snow pack) would lead to lower water tables and reduced wetland habitat. Finally, the effects of climate change could also result in shifts in vegetation dominance that would eventually eliminate *E. chamissonis* from its habitat. In a global climate change study, Chapin and Shaver (1996) manipulated light, temperature, nutrients, and length of growing season to simulate global environmental change for common upland tundra plants, including *E. vaginatum*. The results of this experiment suggest that warming eventually will promote the growth of birch at the expense of sedges, forbs, and other plants that caribou and other wildlife favor as food sources in the Alaskan arctic. During a 15-year study (1981 to 1995) that included the warmest decade on record, *Eriophorum* species decreased by 30 percent while birch biomass increased, even in control plots (Chapin and Shaver 1996, Hobbie and Chapin 1996). Because of the disjunct nature of *E. chamissonis* occurrences in the southern extreme of its range, and the fact that these occurrences will be unable to retreat to more suitable conditions nearby, this threat is pertinent to all occurrences in Region 2.

Influence of management activities or natural disturbances on habitat quality

There have been no studies on the effects of management activities or natural disturbances on *Eriophorum chamissonis*. Some inferences can be drawn from our knowledge of its preferred habitat of subalpine wetlands and fens. *Eriophorum chamissonis* depends on a functional hydrologic regime to maintain suitable habitat. Any management activity or natural disturbance that disrupts the hydrologic dynamics of its habitat is likely to have a negative effect on habitat quality for *E. chamissonis*.

Influence of management activities or natural disturbances on individuals

In general, management activities or natural disturbances that affect habitats are likely to have similar effects on individuals or subpopulations. In particular, hydrological modification associated with road building, livestock grazing, motorized vehicle use, or mining is likely to have a direct impact on individuals and occurrences of *Eriophorum chamissonis*. Plants may be killed or damaged as a result of these activities, and occurrence remnants may be unable to recolonize disturbed areas. Surface disturbance may also affect the survival and reproductive success of individuals by altering local patterns of erosion and drainage, and by eliminating safe sites for germination. Although there are no reports of occurrences lost or damaged by management activities in Region 2, three historic occurrences in Yellowstone National Park were likely extirpated by road maintenance or expansion.

Interaction of the species with exotic species

No exotic species have been documented from any of the Region 2 *Eriophorum chamissonis* occurrences. Non-native species are generally not a problem in fens of the Southern Rockies (Rondeau et al. 2000). There are few non-native species adapted to the saturated soils and limited growing season of *E. chamissonis* habitat.

Threats from over-utilization

There are no known commercial uses for *Eriophorum chamissonis*, other than as an incidental component of peat or forage for domestic grazers. *Eriophorum angustifolium* has been used in northern Europe, Scotland, and England for making wicks, stuffing pillows/mattresses, dressing wounds, and for tinder and clothing (Schofield 1989), but it is extremely unlikely that any similar use poses a threat to *E. chamissonis* in Region 2. *Eriophorum chamissonis* is occasionally collected in botanical surveys, but it has never been the subject of formal scientific investigation. There is no evidence to suggest that past levels of collecting have endangered any occurrences, and limited collecting should be approved whenever it will enhance our current knowledge of its abundance and distribution.

Conservation Status of Eriophorum chamissonis in Region 2

The lack of repeat observations of *Eriophorum chamissonis* occurrences, uncertainty regarding its synonymy with *E. altaicum* var. *neogaeum*, and the likely existence of additional occurrences make it impossible to substantiate a population decline in Region 2. There is likewise no evidence that occurrences are expanding. The current perception of the insecure status of the species in Region 2 arises from the low number of occurrences and the disjunct nature of these occurrences.

Occurrences of *Eriophorum chamissonis* in Region 2 are generally small (fewer than 1,000 stems), and it is unclear how many genetic individuals are represented by reported counts. Small populations are often vulnerable to genetic, demographic, and environmental stochasticity. In some occurrences, numbers may not to be sufficient to mitigate genetic or demographic stochasticity. The perennial, clonal habit of *E. chamissonis* may buffer to some extent from the effects of environmental stochasticity; however, the degree to which it can survive bad years depends on how long the underground rhizome can survive unfavorable conditions or plants can remain dormant as seeds. The total population size in Region 2 is also very small (perhaps fewer than 2,000 stems), and occurrences are isolated from each other, making the recolonization of extirpated sites unlikely without human intervention. Stochastic processes and normal environmental variation could easily result in extirpation of any of the Region 2 occurrences, regardless of current levels of protection.

Eriophorum chamissonis is closely tied to a small-patch type of habitat that is found only in a narrow range of environmental conditions, where it is often isolated from similar habitat on the landscape. Moreover, occurrences in Region 2 are at the southern edge of the species' distribution, and the environmental conditions are different than those experienced by occurrences further north in the center of the range. Documented occurrences are in intact natural landscapes largely unaltered by anthropogenic effects.

Management of Eriophorum chamissonis in Region 2

Implications and potential conservation elements

Current knowledge of the distribution and abundance of *Eriophorum chamissonis* in Region 2 suggests that the species' persistence is precarious due to its specialization on a rare habitat and a small number of disjunct occurrences. Additional information is needed to clarify the species' status. We know very

little about patterns of abundance throughout the main part of the range, which makes it difficult to determine the importance of Region 2 occurrences.

In general, isolated populations of plants provide an important resource for research in biogeography, metapopulation dynamics, population genetics, and other topics. Disjunct occurrences of *Eriophorum chamissonis* are of interest to conservationists even when the survival of the species does not depend directly on these occurrences. *Eriophorum chamissonis* is part of a unique, relictual, post-glacial community that provides information about the Quaternary natural history of North America. Disjunct occurrences may also be important as genetic reserves since outlying occurrences sometimes contain genetic variation in response to more difficult environmental conditions at the edge of the species' range.

Occurrences of *Eriophorum chamissonis* in Region 2 are most vulnerable to changes in the environment that affect their wetland and fen habitats. Any management activities that maintain an appropriate hydrologic regime for these habitats will contribute to its persistence. This includes the regulation and monitoring of hydrological modifications, domestic grazing, and motorized vehicle use. Hydrological modifications are pervasive throughout the range of *E. chamissonis*, but potential habitat for the species is protected to a large degree by designated wilderness areas in much of Region 2. Natural environmental changes may also affect the wetland and fen habitat favored by *E. chamissonis*. Changes in regional precipitation patterns and natural disturbances elsewhere in the watershed may lead to an altered hydrology that is detrimental to *E. chamissonis*. In these instances, management policy could focus on mitigating these effects when possible. Desired environmental conditions for *E. chamissonis* include an intact, natural hydrological regime with few or no alterations resulting from increased or decreased drainage, clearing, livestock grazing, anthropogenic nutrient inputs, or mining (especially peat mining).

Tools and practices

Species and habitat inventory

The ideal inventory for *Eriophorum chamissonis* would thoroughly search all potential habitat, locate and map all occurrences, accurately census each occurrence, and repeat this effort at regular intervals. Because such efforts are usually prohibitively expensive and time consuming, inventory work normally concentrates on obtaining reasonable estimates of occurrence density and extent. The methods used should be based on a standard protocol suitable for the scale and purpose of the inventory. The objective of most vascular plant inventories is to produce a species list rather than to document the distribution of a single species. Consequently, methods of species inventory for plants are poorly standardized in some aspects although they usually adhere to the same fundamental methodology. The National Park Service Guidelines for Biological Inventories (National Park Service 1999) is an excellent protocol for both species and habitat monitoring; it is available online at http://science.nature.nps.gov/im/inventory/biology/.

Searching potential habitat for additional occurrences is a high priority for *Eriophorum chamissonis*. Areas with the highest likelihood of new occurrences are those with hydric and edaphic qualities similar to those of known occurrences. The Colorado Natural Heritage Program routinely uses aerial photography, topographic maps, soil maps, and geology maps to refine search areas when conducting inventories of large areas. This approach has been highly effective in Colorado and elsewhere. It is most effective for species about which there is knowledge of its substrate and habitat specificity from which distribution patterns and potential search areas can be deduced. The wetland habitat of *Eriophorum* species is highly conspicuous and can be identified readily on aerial photographs (Sanderson and March 1996, Proctor personal communication 2004). Initial surveys should concentrate on areas with peat soils near known occurrences. Search areas should be linked to digital georeferenced data, especially aerial photographs (both visual spectrum and infrared images), detailed soil maps, and vegetation maps, when available. Locations of known occurrences overlaid on aerial imagery would provide a quick method of identifying the extent of similar habitat in the areas where *E. chamissonis* has been documented. This information should be cross-checked and augmented with the expert knowledge of local USFS personnel who are familiar with the area.

Ideally, surveys should be conducted by trained professionals who are familiar with *Eriophorum chamissonis*. Survey personnel should also be familiar with methods of soil and habitat characterization. Preparatory work should take into account the remoteness and difficult access of many locations. Some areas within the known range of *E. chamissonis* have not been searched because they are located in wilderness areas and are difficult to access. Inventories should take place during the flowering and fruiting season, preferably from July to September when *E. chamissonis*

is in fruit and easiest to identify. Surveyors should use Global Positioning System (GPS) instruments for quick and accurate collection of location data and delineating the extent of the occurrence. Collecting detailed data on the number of genetic individuals in each occurrence is nearly impossible; it would be most practical to use stem counts as a surrogate for population size estimates. Even rough population estimates based on numbers of flowering stalks and spatial extent would be useful in determining population trends. USFS personnel who visit potential habitat in the course of other work should be alerted to check for the presence of *E. chamissonis*, and to record their observations (positive or negative) carefully. Collection of voucher specimens may be appropriate. Determining the need for further inventory, the extent of occurrences and critical habitat characteristics should be shared among state and federal agencies, natural heritage programs, local and regional experts, and interested members of the public.

Population monitoring

Monitoring population trends and the effects of management would provide the most immediately useful information for land managers. Monitoring sites under a variety of land use scenarios will help managers to identify appropriate management practices for *Eriophorum chamissonis* and to understand this species' population dynamics and structure. To be effective, the implementation of a monitoring program must be accompanied by a commitment by the managing agency to adjust management practices based on the results. Additional monitoring that collects demographic data on growth patterns, recruitment, seed production, plant longevity, and population variability can also provide useful information for both management and the scientific community, but this may be of lower priority.

Quantitative data from periodic monitoring of established plots or transects would be useful in generating information on population dynamics. However, quantitative studies are time consuming and expensive. If agency resources are limited, a minimal level of effort could provide an ongoing qualitative awareness of general population trends. Presence/absence monitoring could give early warning of declining populations. These data could be collected annually at established stations and would be most useful if combined with some form of habitat monitoring. Ideally, stations would coincide with locations already visited by agency personnel in the course of other duties, and for which information on the effects of current management practices is most needed. In Region 2, Wyoming's Preacher Rock Bog SIA and Colorado's Warren Lakes SIA sites are of particular interest since both are relatively easy to access and have had management changes or restoration efforts implemented.

The design of a population monitoring program for *Eriophorum chamissonis* should take into account the long-lived, perennial, clonal character of the species, recognizing that monitoring will not be able to establish an exact number of individuals present, and that accumulation of demographic data will be a long-term process. Other considerations include small population sizes, few isolated locations, and sensitive habitat. The effects of disturbance and management practices on occurrences of *E. chamissonis* are of particular interest. With minimal effort, estimates of stem numbers could be made at each station (see Elzinga et al. 1998), and photographs could record habitat condition.

Habitat monitoring

Habitat and population monitoring should be conducted concurrently at sites supporting *Eriophorum chamissonis*. Monitoring soil moisture, water table depth, and water chemistry would be useful for this species since it relies on a narrow range of hydrologic conditions. Documenting the scope and severity of any disturbance could alert managers to new impacts such as damage from motorized vehicle use or grazing, and it would allow management changes to be implemented in time to prevent serious damage to occurrences. Change in environmental variables might not cause observable demographic repercussions for several years, so resampling key variables may help to identify underlying causes of population trends. Correlation of this information with population trends would greatly augment our present understanding of the habitat requirements and management needs of *E. chamissonis*. Furthermore, because the wetland and fen habitat of *E. chamissonis* often supports a suite of regionally rare species and communities, habitat monitoring would be the most efficient way to detect impacts and population trends for a number of important resources.

Beneficial management actions

The primary consideration for any management action in or around *Eriophorum chamissonis* habitat is to maintain an intact hydrology, both within the occurrence and in the surrounding watershed. In general, management actions that maintain the hydrology of fens and subalpine meadows and that promote natural levels of connectivity between them will benefit occurrences of *E. chamissonis*. Restricting

domestic livestock access in wetlands known to contain *E. chamissonis* will also benefit the species. Motor vehicle use should be prohibited in the immediate habitat, and its effects in the surrounding watershed should be monitored for hydrologic impacts. Effects of other management activities that may affect hydrology and sedimentation in wetland habitat, including fire suppression or reclamation, logging, mining, and road construction, should also be considered both in the immediate habitat as well as the surrounding watershed. Including surveys for *E. chamissonis* as a part of the management planning process would help to minimize threats to this species. The establishment of protected areas managed for the conservation of *E. chamissonis* would be a useful strategy for this species. Some type of protective designation (research natural area or special interest area) for occurrences on the Bighorn and Shoshone national forests could help to ensure the protection of this species on USFS lands in Wyoming.

Seed banking

No seeds or genetic material of *Eriophorum chamissonis* are currently in storage at the National Center for Genetic Resource Preservation (Miller personal communication 2003). It is not among the National Collection of Endangered Plants maintained by the Center for Plant Conservation (2002). Collection of seeds for long-term storage will be useful if restoration work is necessary. Propagation of tiller cuttings or plugs is also a possible means of producing material for revegetation of damaged areas.

Information Needs

Distribution

It is important to locate additional occurrences of *Eriophorum chamissonis*, if they exist, in order to clarify the extent to which the USFS is responsible for persistence of the species in Region 2. Some occurrences have only been identified recently, and it is likely that more are yet to be located. It is also of interest to compare the distribution patterns of the species in the high latitudes of Canada and Alaska with those of the disjunct occurrences of Region 2. These and other investigations would be facilitated by a resolution of the relationship of *E. chamissonis* with *E. altaicum* var. *neogaeum*.

Life cycle, habitat, and population trend

Characteristics of the fen and wetland habitats where *Eriophorum chamissonis* is found are reasonably well documented. However, the specific position of *E. chamissonis* within these ecological systems is not well understood. Research on this topic should focus on clarifying the exact hydrologic, chemical, and micro-topographic tolerances of the species, and how to recognize these in the field. The relative importance of reproduction through vegetative growth compared to sexual reproduction in this species will have important implications for the population dynamics and persistence of the species in disjunct occurrences. Additional information on growth and recruitment patterns as well as on importance of disturbance in creating establishment sites, would also contribute to our understanding of population trends in *E. chamissonis*.

Response to change

The effects of natural environmental variation or anthropogenic disturbance on the growth, reproductive rates, dispersal mechanisms, and establishment success of *Eriophorum chamissonis* have not been investigated. The same is true for its relationship with herbivores, pollinators, and other species. As a consequence, the effects of both fine- and broad-scale habitat change in response to management or disturbance will be difficult to evaluate. Detailed information on the habitat requirements of *E. chamissonis* will enable better understanding of the potential effects of disturbance and management actions in these habitats.

Metapopulation dynamics

The importance of metapopulation structure and dynamics for the long-term persistence of *Eriophorum chamissonis* at local or regional scales is unknown. It is not clear that metapopulation dynamics are in fact operating in the disjunct occurrences of Region 2, and there is no information that would enable an analysis of the species' persistence at either the local or regional scale. Given the level of effort that would be required to collect even elementary data on migration, colonization, and extinction rates, as well as environmental factors contributing to inter-population connectivity, this information is a lower priority than other topics.

Demography

At present, only the broadest generalizations can be made regarding the demography of *Eriophorum chamissonis*. Studies of other *Eriophorum* species provide a good generalized model with which to approach the demography of rhizomatous species, but it is not clear how *E. chamissonis*' growth rates and resource allocation patterns compare to the studied

species. The detailed investigation required to construct a lifecycle projection matrix would involve a level of destructive sampling that is probably unacceptable for occurrences in Region 2. In the absence of more complex studies, it may still be useful to collect growth and longevity data on tillers of marked plants in their natural habitat.

Population trend monitoring methods

The use of common population monitoring methods is complicated by the clonal, rhizomatous growth habit of *Eriophorum chamissonis*. Standard methods that rely on counts of individual plants will be very difficult to use without modification. Possible alternatives are to use individual stems as a sampling unit, or to use some sort of density per unit area estimate.

Restoration methods

Restoration methods have not been explicitly developed for this species. Fen habitats are essentially unrestorable, but plugs of *Eriophorum chamissonis* containing root material may survive if transplanted to undamaged habitat. Because of the complexity of the associated relictual plant communities, it is unlikely that complete restorations will be feasible. Development of restoration methods for this species should concentrate on mitigation of damage *in situ*, and not on the creation of new habitat.

Research priorities for Region 2

Research priorities for *Eriophorum chamissonis* are, in order of priority:

- identification of potential suitable habitat and location of additional occurrences
- development and utilization of practical population monitoring methods in concert with habitat monitoring
- quantification of the effects of disturbance and land management practices on the survival and persistence of the species
- investigation of the growth and reproductive requirements of individual plants.

Additional research and data resources

There are likely to be many additional specimens of *Eriophorum chamissonis* in herbaria throughout North America, as well as an informal body of knowledge of its distribution among land managers and botanists. Collating this information could clarify the global distribution and abundance patterns of *E. chamissonis*, which would enable a clearer perspective of its status in Region 2. This information would be most useful if linked to investigation and explication of the disjunct post-glacial remnant communities in which it occurs.

Definitions

Achene – small, dry indehiscent, one-loculed, one seeded fruit consisting usually of a single carpel (Weber and Wittmann 2001).

Autecology – the study of the ecology of individual species (Jones et al. 1992).

Competitive/Stress-tolerant/Ruderal (CSR) model – a model developed by J.P. Grime in 1977 in which plants are characterized as Competitive, Stress-tolerant, or Ruderal, based on their allocation of resources. Competitive species allocate resources primarily to growth; stress-tolerant species allocate resources primarily to maintenance; ruderal species allocate resources primarily to reproduction. A suite of other adaptive patterns characterizes species under this model (Barbour et al. 1987).

Culm – the hollow or pithy stem of grasses, sedges, and rushes (Harris and Harris 1994).

Demography – the statistical study of populations with reference to size, density, and distribution (Jones et al. 1992).

Diploid – having two sets of homologous chromosomes (Weber and Wittmann 2001)

Element occurrence – an animal, plant, or plant community occurrence (Nature Serve 2004).

Edaphic – of the soil, or influenced by the soil (Allaby 1992).

Hyaline – thin, membranous and transparent or translucent (Harris and Harris 1994).

Ligule – membranous appendage arising from the inner surface of the leaf where it joins the leaf sheath in many grasses and some sedges (Harris and Harris 1994).

Monoecious – having the stamens and carpels in different flowers on the same plant (Weber and Wittmann 2001).

Phenotypic plasticity – the capacity of organisms with the same genotype (genetic properties of an organism) to vary in developmental pattern in phenotype (visible properties of an organism) according to varying environmental conditions (Allaby 1992).

Scale – in sedges, the bract subtending the sedge flower.

Stochastic – randomly variable, governed by chance.

Xeric – dry environment (Allaby 1992).

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