Eriophorum altaicum Meinshausen var. *neogaeum* Raymond (whitebristle cottongrass): A Technical Conservation Assessment

Prepared for the USDA Forest Service,
Rocky Mountain Region,
Species Conservation Project

October 29, 2004

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Peer Review Administered by
Society for Conservation Biology

Ladyman, J.A.R. (2004, October 29). *Eriophorum altaicum* Meinshausen var. *neogaeum* Raymond (whitebristle cottongrass): a technical conservation assessment. [Online]. USDA Forest Service, Rocky Mountain Region. Available: http://www.fs.fed.us/r2/projects/scp/assessments/eriophorumaltaicumvarneogaeum.pdf [date of access].

ACKNOWLEDGEMENTS

The time spent and help given by all the people and institutions mentioned in the reference section are gratefully acknowledged. I would also like to thank the Colorado Natural Heritage Program, in particular Susan Spackman and David Anderson, and the Colorado Natural Areas Program, in particular Ron West, for their generosity in making their files and records available. I also appreciate access to the files and assistance given to me by Andrew Kratz, USDA Forest Service Region 2, and Chuck Davis, U.S. Fish and Wildlife Service, both in Denver, Colorado. The conversations with, and information sent from, Nan Lederer and Tim Hogan, Herbarium at the University of Colorado, Tom Cardamone, Aspen Center for Environmental Studies, Bonnie Heidel, Wyoming Natural Diversity Database, Teresa Prendusi USDA Forest Service Region 4, Barry Johnston USDA Forest Service-Gunnison National Forest, Thomas A. Zanoni, New York Botanical Garden, Rusty Russell, United States National Herbarium, and Ronald Hartman and Joy Handley, Rocky Mountain Herbarium at the University of Wyoming are also very much appreciated. I value the thoughtful reviews of this manuscript by Richard Scott, Beth Burkhart, and an unknown reviewer and thank them for their time in considering the assessment.

AUTHOR'S BIOGRAPHY

Juanita A. R. Ladyman received her B.Sc. degree (with First-class honors) in Biochemistry from London University, England. Her first professional position was as plant pathology laboratory technician and, later, as greenhouse research supervisor with the Arid Lands Research Center on Sadiyat Island in the United Arab Emirates. She obtained her Ph.D. degree in Botany and Plant Pathology from Michigan State University where she was also a research assistant with the D.O.E. Plant Research Laboratory. She worked as a plant physiological ecologist and plant scientist for Shell Development Company conducting research on the physiology, ecology, and reproductive biology of economically important plant species and their wild relatives. She then worked for a plant biotechnology company in their Genetic Transformation and Plant Tissue Culture Division. For the last 13 years she has worked in the area of conservation, particularly on rare, endemic, and sensitive plant species in the southwest United States. For three years of that time, she was the botanist with the New Mexico Natural Heritage Program. She has conducted research and monitoring programs on both non-vascular and vascular species. She currently is a partner in *JnJ Associates LLC*, an environmental consulting company in Colorado.

SUMMARY OF KEY COMPONENTS FOR CONSERVATION OF *ERIOPHORUM ALTAICUM* VAR. *NEOGAEUM*

Status

The NatureServe Global rank for *Eriophorum altaicum* Meinsh. var. *neogaeum* Raymond (whitebristle cottongrass) is apparently secure (with some uncertainty) for the species *E. altaicum* and between vulnerable and apparently secure for the variety *neogaeum* (G4?T3T4). In Region 2 of the USDA Forest Service, it is designated vulnerable (S3) by the Colorado Natural Heritage Program. Recently, *E. altaicum* var. *neogaeum* has been placed in synonymy with *E. chamissonis*. However, there are herbarium specimens in Colorado identified as *E. altaicum* var. *neogaeum* that do not possess all of the characteristics of *E. chamissonis*; they therefore cannot be consigned to this taxon. Until this situation is resolved, this assessment strictly refers to these specimens as *E. altaicum* var. *neogaeum*. *Eriophorum altaicum* var. *neogaeum* is not recognized by the Wyoming Natural Diversity Database (WYNDD). *Eriophorum chamissonis*, which is recognized by WYNDD, is ranked as imperiled (S2) in Wyoming.

Primary Threats

Activities and events that change the hydrology of its habitat are primary threats to *Eriophorum altaicum* var. *neogaeum*. Recreational use of habitat, such as foot traffic, off-road recreational vehicles, and activities related to skiing, may pose a threat to some occurrences throughout its range. As the human population grows in areas within easy access to *E. altaicum* var. *neogaeum* habitat and as recreational use increases, the impacts may become substantially more significant. Mineral and peat mining activities are not perceived as threats to any of the currently known occurrences although individual occurrences may have been impacted in the past. Introduced mountain goats and domestic sheep are likely to have adversely impacted habitat in some parts of its range. Invasive weeds are not currently believed to be a concern at any of the known occurrence sites but may pose a threat in the future. Wet nitrogen deposition (acid rain) and air pollution are likely to change the composition of many communities in alpine tundra, especially in some regions where *E. altaicum* var. *neogaeum* occurs in Colorado. The specific effect on *E. altaicum* var. *neogaeum* is unknown. Global warming is a potential threat to all species currently restricted to sub-alpine and alpine-tundra zones.

Primary Conservation Elements, Management Implications and Considerations

Eriophorum species appear to occur relatively infrequently in the Rocky Mountain states of the continental United States. *Eriophorum altaicum* var. *neogaeum* appears to be a naturally uncommon species growing at elevations above 3,000 m in relatively uncommon bog and fen communities that are vulnerable to modification. Information on the peat composition of the fens and bogs not currently supporting *Eriophorum* species may elucidate their past abundance and distribution.

Eriophorum altaicum var. *neogaeum* is only recognized as a unique taxon in Colorado. *Eriophorum altaicum* var. *neogaeum* has been placed in synonymy with *E. chamissonis* in most scientific treatments of the genus and in other parts of the United States, Canada, and the world. However, some specimens taken from occurrences of *E. altaicum* var. *neogaeum* in Colorado do not match all the characteristics of *E. chamissonis*. These need to be re-evaluated. One possibility is that they may represent an eco-type of another solitary-headed *Eriophorum* species, perhaps *E. scheuchzeri*. However, until this situation has been resolved a conservative approach is to treat them as a unique species, namely *E. altaicum* var. *neogaeum*. *Eriophorum chamissonis* is a more widespread species, being circumpolar with small disjunct populations occurring in isolated mountain ranges south of the population centers in the boreal forest zone of the arctic and Canada. For reference purposes, *E. chamissonis* is designated globally secure (G5). However, this taxon is designated critically imperiled (S1) in Colorado (Region 2), North Dakota, and Oregon and imperiled (S2) in Wyoming (Region 2) and Wisconsin. It has also been reported, but is unranked, from Alaska, Idaho, Minnesota, Montana, and Washington. In Canada, it is designated between imperiled and vulnerable (S2S3) in New Brunswick and Newfoundland Island, vulnerable (S3) in Alberta and Prince Edward Island, between vulnerable and apparently secure (S3S4) in Nova Scotia, between vulnerable and abundant (S3S5) in Labrador, and abundant and secure (S5) in British Columbia, Saskatchewan, and Manitoba. It is reported but unranked in Nunavut, Quebec, Yukon Territory, and Northwest Territories.

The information currently available suggests that several *Eriophorum altaicum* var. *neogaeum* occurrences are relatively secure in Colorado because they occur in areas that are afforded protection either by land use designation, for example USDA Forest Service wilderness area, or by their remote, relatively inaccessible location. A research natural area that includes an occurrence of *E. altaicum* var. *neogaeum* has been proposed on the White River National Forest.

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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) of the USDA Forest Service (USFS). *Eriophorum altaicum* var. *neogaeum* (whitebristle cottongrass) is the focus of an assessment because it is designated a sensitive species in Region 2 of the USFS (USDA Forest Service 2003). Within the National Forest System, a sensitive species is a plant or animal species 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, and therefore knowledge of its biology and ecology is critical.

This assessment addresses the biology of *Eriophorum altaicum* var. *neogaeum* throughout its range in Region 2, which appears to be restricted to the Rocky Mountains of Colorado. The lack of information leads to some constraints on the specificity of information for particular locales. This introduction defines the goal of the assessment, outlines its scope, and describes the process used in its production.

Goal

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 scientific knowledge accumulated prior to initiating the assessment. 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 background 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, this assessment cites management recommendations proposed elsewhere and examines the success of any implementation of those recommendations.

Scope

This *Eriophorum altaicum* var. *neogaeum* assessment examines the biology, ecology, conservation status, and management of the species with specific reference to the geographic and ecological characteristics of the USFS Rocky Mountain Region. Although the majority of the literature relevant to this species originates from field investigations on related species outside the region, this document places that literature in the ecological and social context of the central Rockies. Similarly, this assessment is concerned with the reproductive behavior, population dynamics, and other characteristics of *E. altaicum* var. *neogaeum* in the context of the current environment rather than under historical conditions. The evolutionary environment of the species is considered in conducting this synthesis, but placed in a current context.

In producing this assessment, refereed literature, non-refereed publications, research reports, and data accumulated by resource management agencies were reviewed. Not all publications on *Eriophorum altaicum* var. *neogaeum* may have been referenced in the assessment, but an effort was made to consider all relevant documents. The assessment emphasizes the refereed literature because this is the accepted standard in science. Some non-refereed literature was used in the assessment because information was unavailable elsewhere. In some cases, non-refereed publications and reports may be regarded with greater skepticism. However, many reports or non-refereed publications on rare plants are reliable, and non-refereed publications on rare plants are often 'works-in-progress' or isolated observations on phenology or reproductive biology. For example, insufficient funding or manpower may have prevented work in subsequent years after the start of a project. One year of data is generally considered inadequate for publication in a refereed journal, but the initial report and data still provide a valuable contribution to the knowledge base of a rare plant species. Unpublished data (for example, state natural heritage program and herbarium records) were important in estimating the geographic distribution and population sizes of this species. These data required special attention because of the diversity of persons and methods used in collection. Records that were associated with locations at which herbarium specimens had been collected at some point in time were weighted higher than observations only. Furthermore, completing the assessment promptly required that only current label information on herbarium specimens be analyzed, and no attempt was made to evaluate the accuracy of specimen identification.

Because there is so little information on *Eriophorum altaicum* var. *neogaeum*, observations on other species of *Eriophorum* are considered and related to *E. altaicum* var. *neogaeum* in the Rocky Mountains

within Region 2. However, for management planning purposes it is unwise to rely on observations of other species because the physiology, morphology, and ecology of *Eriophorum* species may be substantially different from one another (Grime et al. 1988).

Treatment of Uncertainty

Science represents a rigorous, systematic approach to obtaining knowledge. Competing ideas regarding how the world works are measured against observations. However, because our descriptions for 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, good thinking, and models must be relied on to guide our understanding of ecological relations. These scientific tools are to be used in concert with the most complete species status data to produce a robust analysis. The data and analyses presented in this assessment on *Eriophorum altaicum* var. *neogaeum* in the Rocky Mountain Region address all information and records produced as documentation of its distribution and biology. The strength of evidence for particular interpretations or ideas is noted, and alternative explanations are described when appropriate.

One element of uncertainty for this species lies in questions about the uniqueness of its genetic identity. As a synonym for *Eriophorum chamissonis*, *E. altaicum* var. *neogaeum* is a member of a worldwide complex that many taxonomists regard as a pool of continuous variation (Ball and Wujek 2002). In this case, *E. altaicum* var. *neogaeum* does not represent a unique taxon. According to the most recent treatment of the genus *Eriophorum*, Ball and Wujek (2002) made *E. altaicum* var. *neogaeum* synonymous with *E. chamissonis*. This must be clearly distinguished from *E. altaicum*, which is synonymized with *E. scheuchzeri* (Ball and Wujek 2002). In Wyoming, three *Eriophorum* species with solitary spikelets have been reported, *E. chamissonis*, *E. scheuchzeri*, and *E. callitrix* (Dorn 2001). In the most recent Colorado Floras (Weber and Wittmann 2001a and 2001b) *E. altaicum* var. *neogaeum* is described as the only *Eriophorum* species with a solitary spikelet occurring in Colorado. Several specimens in the University of Colorado herbarium have since been annotated as *E. chamissonis*. It is clear that the synonymy *per se* is not the source of uncertainty but that there is the potential for misidentification and mistakes when specimens at herbaria are automatically renamed without careful examination. Currently, there now arises the situation where there are *E. altaicum* var. *neogaeum* specimens taken from occurrences within Region 2 that do not have characteristics of *E. chamissonis* and therefore can not automatically be referred to as such. Although briefly commenting upon *E. chamissonis* in Region 2, this assessment focuses on those specimens formally identified as *E. altaicum* var. *neogaeum*, all of which are deposited at herbaria in Colorado.

Publication of Assessment on the World Wide Web

To facilitate 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, it facilitates their revision, which will be accomplished based on guidelines established by Region 2.

Peer Review

Assessments developed for the Species Conservation Project have been peer reviewed prior to release on the web. This assessment was reviewed through a process administered by the Society of Conservation Biology, employing at least two recognized experts on 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 altaicum var. *neogaeum* is a rare member of the Cyperaceae, or sedge, family. The NatureServe global[1] heritage status rank (18 September 2000) for this species is apparently secure with some uncertainty for the species *E. altaicum* and between vulnerable and apparently secure for the

[1]For definitions of ranking system see Ranks in the Definitions section at the end of this document.

variety *neogaeum* (G4?T3T4), with a rounded global heritage status rank of vulnerable for the variety (T3; NatureServe 2002). It is designated vulnerable (S3) by the Colorado Natural Heritage Program. The taxon is not recognized by the Wyoming Natural Diversity Database; the taxonomic entity recognized in Wyoming that includes *E. altaicum* var. *neogaeum* is *E. chamissonis*, which is ranked as imperiled (S2) in Wyoming. *Eriophorum altaicum* var. *neogaeum* is designated sensitive by the USFS in Region 2 (USDA Forest Service 2003). A sensitive species indicates that it "is a plant species identified by the Regional Forester for which population viability is a concern as evidenced by a significant current or predicted downward trend in population number or density and/or a significant current of predicted downward trend in habitat capability that would reduce a species' existing distribution" (USDA Forest Service 2003).

Eriophorum altaicum var. *neogaeum* has recently been placed into synonymy with *E. chamissonis* (Ball and Wujek 2002; see further discussion on the strict treatment of *E. altaicum* var. *neogaeum* as it applies in Colorado in the Introduction). *Eriophorum chamissonis* is designated critically imperiled (S1) in Colorado (Region 2), North Dakota, and Oregon and imperiled (S2) in Wyoming (Region 2) and Wisconsin (Colorado Natural Heritage Program 2004, Wyoming Natural Diversity Database 2004, NatureServe 2004). It is not ranked in other states where it occurs in the United States. In Canada, *E. chamissonis* is also not ranked in all provinces and territories where it occurs. Where it is ranked, it is designated between imperiled and vulnerable (S2S3) in New Brunswick and Newfoundland Island, vulnerable (S3) in Alberta and Prince Edward Island, between vulnerable and apparently secure (S3S4) in Nova Scotia, between vulnerable and abundant (S3S5) in Labrador, and abundant and secure (S5) in British Columbia, Saskatchewan, and Manitoba (NatureServe 2004).

Existing Regulatory Mechanisms, Management Plans, and Conservation Strategies

Approximately 29 occurrences of *Eriophorum altaicum* var. *neogaeum* are known to occur on land managed by the USFS Region 2 and the Bureau of Land Management (BLM), and on private land in Colorado. Approximately 25 of those are known from National Forest System lands on the White River (two occurrences), Pike (two occurrences), Gunnison (one occurrence), San Juan (18 occurrences), Rio Grande (one occurrence), and Uncompahgre (one occurrence) national forests. It is described in sensitive plant species guides developed for the Rio Grande National Forest by Erhard (1994) and for the Pike-San Isabel National Forest and Comanche and Cimarron Grasslands by Ryke et al. (1993) and Kettler et al. (1993) to assist field crews in recognizing sensitive species. *Eriophorum altaicum* var. *neogaeum* is mentioned in a document outlining general sensitive species management strategy for the Grand Mesa, Uncompahgre, San Juan, Rio Grande, Pike and San Isabel national forests and Comanche-Cimarron National Grasslands (USDA Forest Service 1999).

Relatively few formal surveys have been conducted for this species. Most reports and observations are incidental to other projects. Some location information is sufficiently vague as to preclude precise locations, and occurrences may be on patented mining claims. The species is found in the Silverton and Cinnamon Pass area on land managed by the BLM. However, it is not included in their sensitive plant species list (Colorado Bureau of Land Management State Director's Sensitive Species List 2000) and therefore does not receive any particular attention (Hayes personal communication 2002).

Several populations are in wilderness areas designated by the USFS, specifically the Weminuche Wilderness (San Juan National Forest), the Holy Cross Wilderness (White River National Forest), the Sangre de Cristo Wilderness (Rio Grande National Forest) and the Hunter Fryingpan Wilderness (White River National Forest). An occurrence may also be within the Maroon Bells-Snowmass Wilderness (White River National Forest). Occurrences are afforded some protection from anthropogenic activities in wilderness areas. Congress passed the 1964 Wilderness Act to protect pristine public lands by designating them as wilderness. Wilderness is defined in the law as "an area of undeveloped federal land retaining its primeval character and influence, without permanent improvements or human habitation, which is protected and managed so as to preserve its natural conditions..." (Environmental Media Services 2001). In general the Wilderness Act prohibits commercial activities, motorized access, roads, bicycles, campground developments and structures, although Congress has granted numerous exemptions (Environmental Media Services 2001). In addition, the National Forest that is responsible for the management of a particular Wilderness Area sometimes limits the size of groups that can visit the area at one time.

On the White River National Forest, several sites are managed under a specific management prescription that is aimed to protect wetlands and their associated

plant communities (Johnston personal communication 2002). The population in a proposed research natural area (RNA) within the Hunter Fryingpan Wilderness of the White River National Forest has been mapped, and habitat in the area is undergoing restoration (Lyon 1995, Cardamone personal communication 2002, Holland-Sears personal communication 2002). Parts of the proposed RNA had been impacted by attempts to mine peat in the earlier part of the last century. Considerable drying of the peat areas had occurred due to excavation. In 2001, the ditches were filled with the peat that had been dug but left in piles at the site in an attempt to restore the water-saturated peat area to its full extent (Cardamone personal communication 2002, Holland-Sears personal communication 2002). In addition, *Eriophorum altaicum* var. *neogaeum* seedlings from locally collected seed were transplanted at the site (Cardamone personal communication 2002). These sites will be surveyed periodically in the future (Cardamone personal communication 2002). Currently, it is too soon after restoration and plantings to conclude how successful the undertaking has been. It is noteworthy that many peat-mined areas show little natural recolonization by fen species even after 40 years (Cooper and MacDonald 2000).

Biology and Ecology

Classification and description

Systematics and synonymy

Eriophorum is a genus in the Cyperaceae family, also commonly known as the sedge family. *Eriophorum altaicum* is known from Asia and North America while variety *neogaeum* is restricted to the New World (Raymond 1957). Weber and Wittmann (2001a and 2001b) and the PLANTS Database (USDA Natural Resources Conservation Service 2002) recognize it as a unique species. *Eriophorum altaicum* var. *neogaeum* is also accepted by the Integrated Taxonomic Information System (2004). According to Raymond (1954) each species of *Eriophorum* has an intricate story attached to its name, and there are often strongly divergent views on its taxonomic position. *Eriophorum altaicum* var. *neogaeum* is no exception.

Eriophorum altaicum is reported to be particularly similar to *E. scheuchzeri* (Shishkin 1935). The differences between *E. altaicum* and *E. scheuchzeri* appear to be subtle. According to Meinshausen (1900) both *E. scheuchzeri* and *E. altaicum* have short anthers (0.5 to 1.0 mm), white bristles, long stolons, and fewer than seven basal glumes. According to the various species descriptions, two specific characteristics appear to separate *E. scheuchzeri* from *E. altaicum*. The juvenile, immature, spikelet of *E. scheuchzeri* is spherical, or globose, while that of *E. altaicum* is elongate, only becoming globose with age; the bristles of *E. scheuchzeri* are soft or pliant while those of E altaicum are vertical or rigid (**Table 1**). Recognizing some constant morphological differences within *E. scheuchzeri*, variety *tenuifolium* was described. *Eriophorum scheuchzeri* var. *tenuifolium* is taller and more slender than variety *scheuchzeri* (Hultén 1968). Hultén (1968) suggested placing *E. altaicum* in synonymy with *E. scheuchzeri* var. *tenuifolium*. Ball and Wujek (2002) reported that, based on the North American specimens that they examined, *E. scheuchzeri* var. *tenuifolium* could not be differentiated from the full species.

In the most recent treatment in the Flora of North America (Ball and Wujek 2002), *Eriophorum altaicum* is placed in synonymy with *E. scheuchzeri* whereas *E. altaicum* var. *neogaeum* is in synonymy with *E. chamissonis* (see **Table 2** for tabulated synonyms). *Eriophorum chamissonis* is also placed in synonymy with *E. russeolum* and *E. rufescens* (Ball and Wujek 2002). Raymond (1954) described several differences, especially in the head and achene characters, between *E. chamissonis* and varieties of *E. russeolum*, but Ball and Wujek (2002) determined that *E. chamissonis* is a complex that contains taxa based mainly on stem size and bristle color and reported that much of the variation appears to be continuous with abundant intermediates. They conclude that experimental studies are needed to determine the biological basis of the variation. Such studies may help to clarify if unique genotypes comprise the disjunct populations of the Rocky Mountains. The British Columbia Conservation Data Centre treats *E. altaicum* var. *neogaeum* as a synonym of *E. chamissonis* in agreement with their standard taxonomic references (Douglas et al. 1998, Douglas et al. 1999, Donovan personal communication 2002). Hitchcock and Cronquist (2001) also placed *E. chamissonis*, *E. russeolum*, and *E. altaicum* var. *neogaeum* in synonymy.

Descriptions that distinguish *Eriophorum altaicum* var. *neogaeum* from *E. chamissonis*, *E. altaicum*, and *E. scheuchzeri* are summarized in **Table 1**. Some individuals of *E. chamissonis* or *E. russeolum* were initially identified as *E. altaicum* var. *neogaeum* in Colorado. Several specimens initially identified as *E. altaicum* var. *neogaeum* have since been annotated *E. chamissonis* at the University of Colorado Herbarium by Hartman (2001, COLO Accessions 426082, 456215,

Table 1. Description comparisons of *Eriophorum altaicum* var. *neogaeum*, *E. chamissonis*, *E. scheuchzeri*, and *E. altaicum*. All have solitary spikelets.

Authority*	Species	Stem (culm) height; morphology	Anther length (mm)	Scales	Bristles and achenes
Meinsh. in R. 1957	*E. altaicum* var. *neogaeum*	Culms >25 cm tall; slender, upright; from long stolons.	0.5 to 1	Moderately thick, lanceolate, tapering to a narrow point, dark ash grey, outwardly spreading, colorless and transparent and finely/minutely with red dots upwards.	Bristles: white, very upright, elongate head becoming globose with age. Achenes: sub-ovate cuneate 1.2 to 1.5 mm long pale brown.
Meinsh. in R. 1957	*E. altaicum*	Culms 10 to 25 cm tall; moderately thick, smooth, terete, sub-trigonal above; from long stolons.	0.5 to 1 1.5 to 3	Moderately thick, lanceolate, tapering to a narrow point, dark ash grey, outwardly spreading, colorless and transparent and finely/minutely with red dots upwards.	Bristles: white, very upright, globose head. Achenes: sub-ovate cuneate 1.2 to 1.5 mm long pale brown.
B & W 2002	*E. chamissonis*	Culms (20) 30 to 70 (80) cm tall; stout, somewhat trigonous; long creeping rhizomes.	(0.6) 1.5 to 3	Proximal scales obovate or trigonous-obovate, apex blunt, blackish to purplish brown, margins white or paler and wide as the dark portion; distal scales obovate to ovate-lanceolate, margins hyaline.	Bristles: red-brown to white, 10 or more, head globose in fruit. Achenes: oblong-obovoid, 2 to 2.7 mm as wide as long, apex apiculate (0.3 to 0.5 mm).
B & W 2002	*E. scheuchzeri*	Culms 5 to 35 (70) cm; usually not more than 1mm diameter basally; long creeping rhizomes.	0.5 to 1.5	Proximal scales ovate, gray to blackish green; distal scales narrower, more attenuate, margins hyaline.	Bristles: bright white, sometimes red tinged 10 or more, head broadly obovoid to subglobose in fruit. Achenes: narrowly oblong, 0.4 to 2.5, apex with subulate beak.
H & C 2001.	*E. chamissonis*. Syn: *E. russeolum*, *E. altaicum* var. *neogaeum*, *Scirpus chamissonis*	Culms 30 to 70 cm tall; arising singly from creeping rhizomes.	1 to 2.5	Broad and blunt, pale distally and along margins.	Bristles: often reddish. Achenes: no information.
H & C 2001.	*E. scheuchzeri* Syn.= *E. leucocephalum*, *Scirpus leucocephalus*	Culms seldom >30 cm tall; arising singly from creeping rhizomes.	0.5 to 1	Narrow, tapering, blackish green, not pale margined.	Bristles: white. Achenes: no information.
C. et al. 1977	*E. scheuchzeri* Syn.= *E. leucocephalum*, *Scirpus leucocephalus*	Culms 10 to 40 cm tall; from creeping rhizomes.	0.5 to 1 (dry)	Narrow, tapering to slender tip; distal half or two-thirds wholly blackish green, sometimes pale-margined distally.	Bristles: no information Achenes: brown or blackish. ~2mm long.
Shishkin 1935	*E. scheuchzeri* Syn.= *E. leucocephalum*	Culms 8 to 30 cm tall; stoutish, erect, terete; with long stolons.	No data	Dark grey to blackish, often with narrow whitish margins; intermediate scales narrowly lanceolate, gradually long-acuminate, outermost scales broadly ovate, subobtuse, or short acuminate.	Bristles: pure white, broadly ovoid to subglobose head becoming depressed-globose with age. Achenes: oblong, sub-terete, ~2 mm long and 0.5 mm broad.

*Authority (for complete citation see Reference Section):

H&C 2001: Hitchcock and Cronquist 2001

C et al. 1977: Cronquist et al. 1977.

Meinsh. in R. 1954: Meinshausen in Raymond 1957.

B&W 2002: Ball and Wujek 2002.

Table 2. Synonyms of the three *Eriophorum* species with solitary spikelets that occur in USDA Forest Service Region 2, according to the most recent edition of the Flora of North America (Ball and Wujek 2002).

Name in Flora of North America (Ball and Wujek 2002)	Synonym* relative to E. altaicum	Other synonyms*
Eriophorum chamissonis	*E. altaicum* var. *neogaeum*	*E. chamissonis* var. *aquatilis*
		E. rufescens
		E. russeolum ssp. *rufescens*
		E. russeolum ssp. *albidum*
		E. russeolum ssp. *leucothrix*
		E. russeolum var. *majus*
Eriophorum scheuchzeri	*E. altaicum*	*E. capitatum*
	E. scheuchzeri var. *tenuifolium*	
Eriophorum callitrix	none	none

*Authorship:
E. chamissonis C.A. Meyer
E. altaicum Meinshausen
E. chamissonis var. *aquatile* (Norman) Fernald
E. rufescens Andersson
E. russeolum Fries ssp. *rufescens* (Andersson) Hylander
E. russeolum ssp. *albidum* F. Hylander
E. russeolum ssp. *leucothrix* (Blomgren) Hultén
E. russeolum var. *majus* Sommier
E. capitatum Host
E. scheuchzeri var. *tenuifolium* Ohwi

457189, and 475192; see **Table 3**). One possibility is that *E. altaicum* var. *neogaeum* specimens in Colorado herbaria that do not have the characteristics of *E. chamissonis* are *E. scheuchzeri* (**Table 1**). However, this cannot be assumed without further study. Therefore, at the present time, there appears to be two taxonomies (Weber and Wittmann 2001a and 2001b, Ball and Wujek 2002). One has *E. altaicum* var. *neogaeum* endemic to Colorado (Weber and Wittmann 2001a and 2001b) while the other has it part of the *E. chamissonis* complex (Ball and Wujek 2002). In light of this situation, the *E. altaicum* var. *neogaeum* specimens, especially those with short (<1 mm) anther length, should be re-examined to determine if they are actually *E. scheuchzeri* or whether they do indeed represent a unique taxon.

History of species

Species in the genus *Eriophorum* have been beset by multiple names, and the designation and revocation of synonyms appears to be the rule rather than the exception (Shishkin 1935, Raymond 1954, Kartesz 1994). One of the principal causes of confusion is the similarity between many species and the range over which they occur. Raymond (1954) notes that most circumpolar species have been described in Asia, Europe, and North America under different names. In addition, many herbarium specimens have been repeatedly misidentified. This is probably because they resembled species that were described on another continent, but specimens with which they could be compared were not readily available.

Eriophorum altaicum was originally described by Meinshausen from Dzhung, Alatau, a region bordering Xinjiang Province in China and Kazakhstan south of the Altai Mountain range that lies between Xinjiang Province and Mongolia (Shishkin 1935, National Geographic Society 1999). To Russian botanists its name apparently, but erroneously, suggested it came from the Altai region of west-central Russia (Shishkin 1935). Raymond described a New World variety, *neogaeum*, in 1957. Accordingly, Raymond annotated specimens of both *E. altaicum* and *E. altaicum* var. *neogaeum* in United States National Museum, Smithsonian Institution (copies of specimen sheets provided courtesy of Dr. Russell, the United States National Herbarium). The variety *neogaeum* was described from the type specimen in Alaska and additional specimens from Alaska and Utah (Raymond 1957). These specimens show the juvenile, immature, spikelet of *E. altaicum* is elongate, becoming globose with maturity (photocopies of herbarium specimens observed by author).

Table 3. Occurrences of *Eriophorum altaicum* var. *neogaeum* in Colorado. For comparative purposes, occurrences where specimens have been since identified as *E. chamissonis* have been included.

Arbitrary occurrence number	Date of observations	County	Management	Location	Source
1	August 10, 1990	Park	Private land and/or Pike National Forest	Horseshoe Cirque, above Fourmile Creek southwest of Fairplay. Southern side of cirque basin.	Colorado Natural Heritage Program element occurrence records. *W.A. Weber 18082* COLO
2	July 20, 2000	Park	Private land and/or Pike National Forest	Leavick tarn area, Mount Sheridan.	Colorado Natural Heritage Program element occurrence records
3	August 26, 1995	Pitkin	White River National Forest; Hunter Fryingpan Wilderness and Warren Peak proposed Research Natural Area	Warren Peak (restoration project plots B, 8 and 2). Within approximately 1 mile of *E. chamissonis* at Thimble Rock (occurrence extends over parts of two sections).	Colorado Natural Heritage Program element occurrence records
*E. chamissonis**	August 9, 2000	Pitkin	White River National Forest	Thimble Rock; within approximately 1 mile of restoration project plots B, 8 and 2 (see preceding occurrence) in Warren Peak proposed Research Natural Area	Colorado Natural Heritage Program element occurrence records. *T. Snowden s.n.* COLO
4	August, 1960	Gunnison	Gunnison National Forest (possibly in Maroon Bells-Snowmass Wilderness)	Northeast Mount Belleview; "Rustler Gulch, above in alpine basin" (11 August) and "above upper Rustlers Gulch, Gothic" (18 August).	Colorado Natural Heritage Program element occurrence records. *J. Barrell 240-60* CS Same collection number for August 11 and August 18, 1960 CS. *J. Barrell 240-60* August 18, 1960 COLO
*E. chamissonis**	August 14,1995	La Plata	San Juan National Forest, Weminuche Wilderness	Endlich Mesa Basin; Endlich Mesa, 17 miles northeast of Durango.	Colorado Natural Heritage Program element occurrence records. *S. Komarek 493* COLO
5	September 10, 1995	San Juan	San Juan National Forest	San Juan National Forest. Road 550 to Purgatory Lt. To Hermosa Creek Rd (FS548). At junction of Cascade Creek Rd. and Relay Creek Rd., turn on Cascade Creek Rd.	*C. Holmes 931* COLO
*E. chamissonis**	July 27, 1994	San Juan	San Juan National Forest	One mile south east of Grizzly Peak.	*S. Komarek 429* COLO
6	August 16, 1995	Mineral	San Juan National Forest, Weminuche Wilderness	Piedra River, Puerto Blanco area.	Colorado Natural Heritage Program element occurrence records
7	August 16, 1995	Mineral (border with Hinsdale)	San Juan National Forest, Weminuche Wilderness	Piedra River.	Colorado Natural Heritage Program element occurrence records
8	August 11, 1995	Hinsdale	San Juan National Forest, Weminuche Wilderness	Boggy area with many small lakes in Cave Basin area at Emerald Lake 21 miles north of Bayfield. Access from Dollar Lake trailhead.	Colorado Natural Heritage Program element occurrence records. *P. Skartvedt 1* COLO

Table 3 (cont.).

Arbitrary occurrence number	Date of observations	County	Management	Location	Source
9	August 26, 1994; August 23, 1994	La Plata	San Juan National Forest, Weminuche Wilderness	August 26: 1 mile south of overlook point near West Virginia Gulch; August 23: Needle Creek at Emerald Lake (occurrence extends over parts of four sections).	Colorado Natural Heritage Program element occurrence records
10	August 15, 1995	La Plata	San Juan National Forest, Weminuche Wilderness	*S. Komarek 499* (COLO): Lower end of Silver Mesa, 18 miles northeast of Durango, southwest of Lake Marie. *S. Komarek 495* (COLO): Lake Marie, Florida River drainage headwaters, 18 miles northeast of Durango (occurrence extends over parts of 3 sections).	Colorado Natural Heritage Program element occurrence records. *S. Komarek 499* COLO; *S. Komarek 495* COLO
11	August 14, 1995	La Plata	San Juan National Forest, Weminuche Wilderness	Columbine Pass.	Colorado Natural Heritage Program element occurrence records
12	August, 1962	San Juan	San Juan National Forest, Weminuche Wilderness	Ruby Basin. Animas River drainage approximately 18 miles southeast of Silverton. Outlet to Ruby Lake.	Colorado Natural Heritage Program element occurrence records. *J. Michener F786* 1962. COLO
13	August 26, 1961	San Juan	San Juan National Forest. Weminuche Wilderness	Ten Mile Basin, Animas River drainage approximately 18 miles southeast of Silverton. On shelf high on the south side of valley.	Colorado Natural Heritage Program element occurrence records. *J. Michener 58* 1961 COLO
14	August 2, 1996	La Plata	San Juan National Forest, Weminuche Wilderness	San Juan Range, Needle Mountains, upper Sunlight Basin near Sunlight Lake.	Colorado Natural Heritage Program element occurrence records. *T. Hogan 3080a with T. Andrews* COLO
15	July-August 1972 (2 observations); August 22, 1995; August 11, 1997	San Juan	San Juan National Forest on boundary of the Weminuche Wilderness	Kite Lake (occurrence location includes two sections). July-August 1972: above Kite Lake, San Juan Mountains. Head of Bear Creek across divide from Eldorado Lake, south corner of county. August 4, 1972: 0.5 miles east of Continental Divide above Kite Lake. 1995: Kite Lake basin, 8.5 miles southeast of Silverton, above Kite Lake.	Colorado Natural Heritage Program element occurrence records. *C.W. Loder s.n.* July-August 1972 COLO, INSTAAR San Juan Ecology Project. *SJEP 459* August 4, 1972 COLO, *S. Komarek 502* August 22, 1995 COLO
16	August 3, 1994	San Juan	San Juan National Forest Weminuche Wilderness	Highland Mary Lake, 6 miles southeast of Silverton. Southwest inlet of largest lake and next lake above.	*S. Komarek 431* (COLO)
17	Undated	San Juan	San Juan National Forest; occurrence extends over the Weminuche Wilderness border	Crater Lake Trail (occurrence extends over parts of two sections).	Colorado Natural Heritage Program element occurrence records. *D.N.D. Jamieson s.n.* Fort Lewis College Herbarium

Table 3 (concluded).

Arbitrary occurrence number	Date of observations	County	Management	Location	Source
18	August 20, 1991	San Juan	Bureau of Land Management and/or private land	Spencer Basin.	Colorado Natural Heritage Program element occurrence records. *D.N.D. Jamieson s.n.* Fort Lewis College Herbarium
19	August 21, 1955	San Juan	San Juan National Forest	Ice Lake Basin Trail; trail from South Mineral Campground to Ice Lake Basin, approximately 6 miles northwest of Silverton, pond in upper basin.	Colorado Natural Heritage Program element occurrence records. *W. Weber & J. Langenheim 9531* CS, COLO
20	August 22, 1993	San Juan	San Juan National Forest	Clear Lake.	Colorado Natural Heritage Program element occurrence records
21	August 30, 1995	San Juan	San Juan National Forest	Twin Sisters, Lime Creek.	Colorado Natural Heritage Program element occurrence records
22	July 8, 1934; August 22, 1993	San Juan	San Juan National Forest	Ice Lake Basin.	Colorado Natural Heritage Program element occurrence records; *Penland* two sheets of *1037* 1937 COLO; *K. Carsey KC* 1993 CSU
23	September 1, 1995	San Miguel	San Juan National Forest	Bilk Basin.	Colorado Natural Heritage Program element occurrence records
24	July 26, 1997	Hinsdale	Bureau of Land Management (and possibly private land)	Lake Fork.	Colorado Natural Heritage Program element occurrence records
25	July 22, 2000	Hinsdale	Bureau of Land Management and/or private land	On west side of Cinnamon Pass Road, 0.25 miles below pass, on east side of pass.	*J. Coles s.n.* COLO
26	August 1, 1986	San Juan	Bureau of Land Management and/or private land	Cinnamon Pass, along jeep road between Animas Forks and Lake City.	Colorado Natural Heritage Program element occurrence records. *P. Lehr s.n.* COLO
27	1993; July 8, 1999; August 15, 2001	San Miguel	Uncompahgre National Forest, Telluride Ski Area	Prospect Basin - Alta Lakes. 2001: 10 km south of Telluride.	Colorado Natural Heritage Program element occurrence records. *D. Cooper 2440* 2001 COLO
28	August 19, 1942; August 8, 1997	Saguache	Rio Grande National Forest, Sangre de Cristo Wilderness	Wild Cherry Lake.	Colorado Natural Heritage Program element occurrence records. *R. Gierisch 1416* 1942 CSU
*E. chamissonis**	August 12, 2000	Eagle	White River National Forest, Holy Cross Wilderness	Tellurium Lakes region.	Colorado Natural Heritage Program element occurrence records. *T. Snowden s.n.* COLO
*E. chamissonis**	July 23, 1999	Eagle	White River National Forest and/or private land	Holy Cross City. 1986: Sawatch Range; Missouri Creek drainage near headwaters of Homestake Creek Valley.	Colorado Natural Heritage Program element occurrence records. *D. Cooper 1503* 1986 COLO
29	August 9, 1998	Pitkin	White River National Forest - boundary of Holy Cross Wilderness	North Fork Fryingpan; Mormon Creek.	Colorado Natural Heritage Program element occurrence records

**Eriophorum chamissonis* C.A. Meyer determined by R.L. Hartman 2001.

The lectotype of *Eriophorum altaicum* selected by Raymond (1957) is in the New York Botanical Garden Herbarium although he did not annotate the specimen sheet. This lectotype specimen was first identified as *E. chamissonis* var. *humile* and then annotated, apparently by N.L. Britton in the early 1900s, as *E. callithrix* Cham. A second specimen on the sheet is identified as *E. chamissonis*, later annotated as *E. russeolum* (Zanoni personal communication 2002). The origin of both specimens is less than clear. The *E. russeolum* specimen is reported from Baical, a region with an enormous lake (Lake Baical) on the border of Russia and northern Mongolia. The specimen of *E. altaicum* is apparently from Sarchan in the Dzungar Alatau mountain range at the eastern edge of the Altai Mountains on the border between southwestern Mongolia and Xinjiang province in China. This *Eriophorum* collection was widely distributed in Europe as well as North America (for example Kew Gardens in England, and Paris, France), but apparently, just as the New York specimens, it was a mixture of several different species and in some cases had two species on the same sheet (Raymond 1957).

No record of an *Eriophorum* species with a solitary-spikelet is reported in the 1906 edition of the Flora of Colorado (Rydberg 1906). In 1954 Harrington reported three species of *Eriophorum* in Colorado: *E. gracilis*, *E. angustifolium*, and *E. chamissonis*. *Eriophorum chamissonis* was the only *Eriophorum* species with a solitary spikelet on each culm, and Harrington mentioned that only two specimens of this species existed at the time. *Eriophorum altaicum* var. *neogaeum* was apparently first collected in Colorado in 1934 by Penland (1037 COLO) from San Juan County. The original identification was *E. gracile* Koch, which is also rare but has multiple spikelets per stem and is clearly distinguishable from *E. altaicum* var. *neogaeum*.

Non-technical description

Eriophorum altaicum var. *neogaeum* is a perennial, grass-like plant. The stems, or culms, lack well developed leaf blades. The head, which resembles a cotton ball at maturity, is solitary on the stem apex. During the initial flowering time the hairs in the flowers are small and invisible from a distance but become a conspicuous silvery-white as the head matures. The fluffy bristles in the flower head account for the common names for *Eriophorum*, namely cottongrass, bog wool, and cotton sedge. The anthers are 0.5 to 1.0 mm, and the pale brown achenes are 1.2 to 1.5 mm in length.

The solitary spikelet on each stem differentiates *Eriophorum altaicum* var. *neogaeum* from the more common, sympatric species, *E. angustifolium*. *Eriophorum callithrix*, another solitary-headed species that occurs in Wyoming, is very similar to *E. altaicum* var. *neogaeum* but lacks stolons and rhizomes. Synonyms for all the *Eriophorum* species that occur within Region 2 have been listed in the Definitions section of this report.

References to technical descriptions, photographs, line drawings, and herbarium specimens

A technical description and photograph of the lectotype specimen of *Eriophorum altaicum* var. *neogaeum* are in Raymond (1957). Another technical description is published in Weber and Wittmann (2001a and 2001b). A line drawing, photograph, and brief description are in Spackman et al. (1997). A description and a line drawing are also in a guide published by the Colorado Native Plant Society (1989).

Raymond (1954) made a thorough review of *Eriophorum chamissonis*. Other technical descriptions of *E. chamissonis* include those in Ball and Wujek (2002), Dorn (2001), Hitchcock and Cronquist (2001), Dorn (1988), Dorn (1984), Hultèn (1968), Harrington (1964), Fernald (1950), and, as *E. russeolum*, in Polunin (1959), Porsild (1951), and Scoggan (1950). This is not in anyway a complete list of books that describe this taxon but merely a representative selection of some of the primary publications throughout its range.

Distribution and abundance

Eriophorum altaicum var. *neogaeum* occurs in the Rocky Mountains of Colorado (Weber and Wittmann 2001a and 2001b; see **Figure 1**). Discounting those occurrences where specimens have been annotated to indicate another species of *Eriophorum*, *E. chamissonis*, there are approximately 29 occurrence sites (**Table 3**). Approximately 25 occurrences are found on National Forest System lands: White River National Forest (2), Rio Grande National Forest (1), San Juan National Forest (18), Pike National Forest (2), Uncompahgre National Forest (1), and Gunnison National Forest (1). Five occurrences have not been observed within the last 30 years. In addition, several occurrences are without specimens or even photographs to confirm the observation. Although photographs do not permit taxonomic verification, they do permit

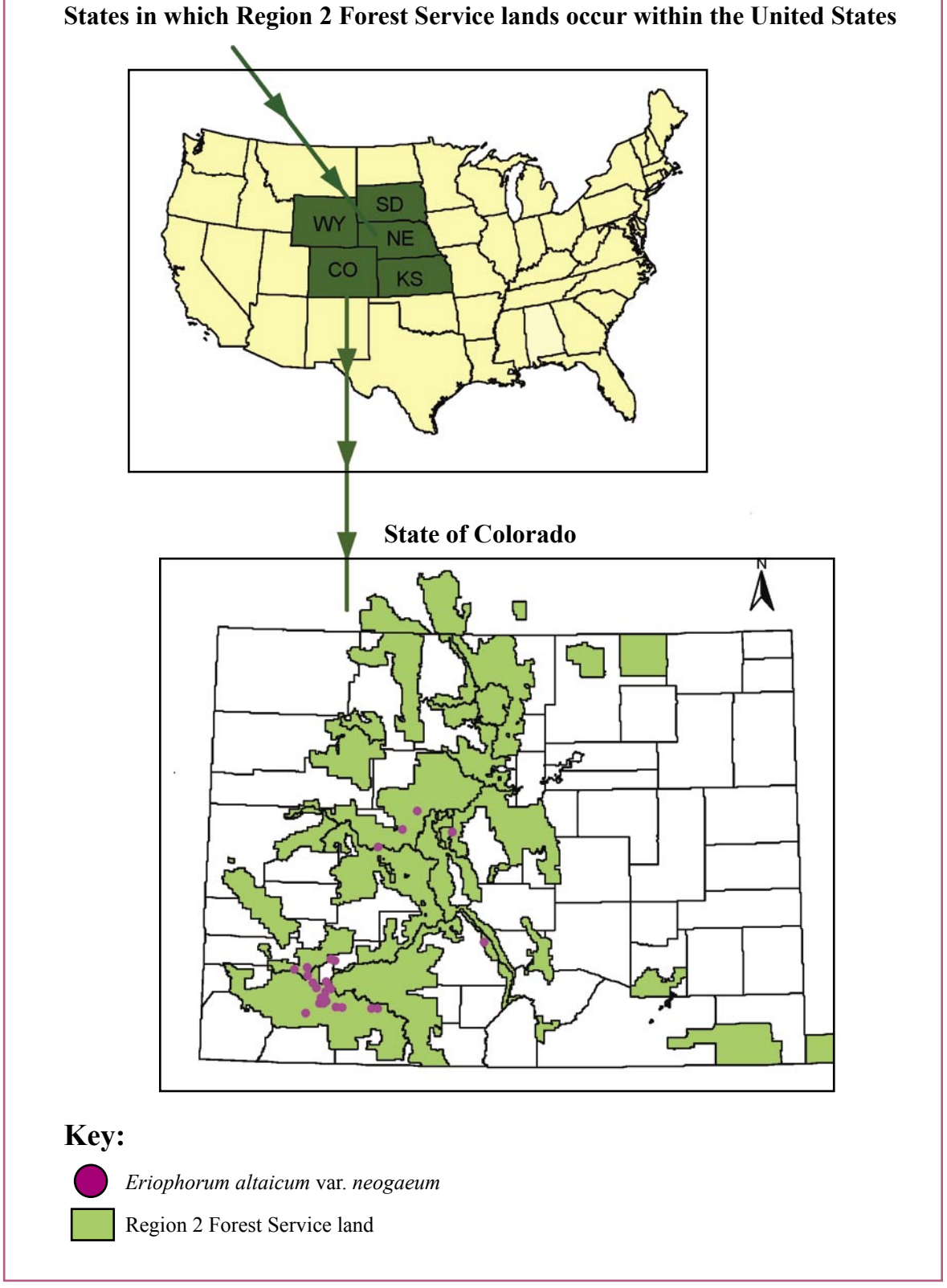

Figure 1. Range of *Eriophorum altaicum* var. *neogaeum* in USDA Forest Service Region 2.

gross confirmation that the specimen matches the identification. For example, *E. gracile* would be readily distinguished from *E. altaicum* var. *neogaeum* by anyone familiar with both species (see History of the species section). Therefore, because it has often been confused with other species of *Eriophorum*, occurrence data that is not accompanied by photographs or where no specimens were collected must be treated with some uncertainty. Occurrence data have been compiled from the Colorado Natural Heritage Program, specimens at the University of Colorado Herbarium (COLO), Colorado State University Herbarium (CS), the Kathryn Kalmbach Herbarium at Denver Botanic Gardens (KHD), the Gray Herbarium at Harvard University (GH), The New York Botanical Garden Herbarium (NY), and the United States Herbarium (US). It must be noted that many records do not have precise location information, and errors may have been made in determining the exact number of occurrences; in some cases a site may have been revisited and designated a new occurrence, or discrete populations in the same general vicinity may have been estimated to be the same site.

Eriophorum altaicum var. *neogaeum* is not inevitably found in suitable alpine habitats within its range (Skartvedt 1995, Mason personal communication 2002). Skartvedt (1995) suggested that the continental divide might demarcate the distribution of the species in southern Colorado. *Eriophorum altaicum* var. *neogaeum* occurs in small isolated patches of less than a square meter in size, or it can be relatively locally abundant. Occurrence size ranges from a patch with as few as 10 individual stems to an estimated 1,750 individuals covering approximately 0.1 acre. Occurrences often comprise subpopulations. An occurrence is most often reported to comprise approximately 100 individuals distributed in two or more patches over 1 to 2 acres (Colorado Natural Heritage Program element occurrence records 2002). The largest area reported was comprised of three subpopulations with a total of 650 to 700 individuals over 3 acres. Subpopulations are understood to interact genetically, for example through cross-pollination or seed dispersion.

Population trend

There are insufficient data in the literature, associated with herbarium specimens, or at the Colorado Natural Heritage Program to determine the long-term population trends for *Eriophorum altaicum* var. *neogaeum*. There is indication that plants persist in the same general area for many decades. Records indicate plants were first collected in 1934 in the Ice Lake Basin in the San Juan Mountains, and plants were found in the same general area again in 1993. There was no information with which to compare the size of the occurrences. Plants were also located near Kite Lake in San Juan County in 1972, 1993, 1995, and 1997. From the brief descriptions of these sites it is unlikely the exact area was relocated each time, but interestingly, the number of stems observed was estimated to be of the same order of magnitude: approximately 140 to 150 in 1972, 200 in 1993, 140 in 1995, and 93 in 1997. The density and extent of the occurrence at Cinnamon Pass have apparently remained fairly unchanged since the early 1980s (Mason personal communication 2002). Habitat for this species is relatively rare in the Rocky Mountains, but even within suitable habitat this species appears to naturally occur relatively infrequently.

It should be noted that, although sphagnum moss is most often the major constituent of peat, in many cases herbaceous cover significantly contributes to peat accumulation (Clymo 1983). This is particularly true in Colorado where much of the peat is derived from vascular plant roots and leaves (Cooper 1991). Worldwide, *Eriophorum* species are often primary contributors to fen and bog peat development (Gore 1983) and can be expected to be a major component in the localized areas where they occur in Colorado. Therefore, the persistence of *Eriophorum* species in any one suitable location can be expected to be on the order of thousands of years. Colorado peat deposits are estimated to be between 4,000 and 10,000 years old (Chimner et al. 2002, Hoelter 2002). In the Colorado Rocky Mountain climate, peat accumulates very slowly at rates of only 8 to 30 cm every 1,000 years (Cooper and MacDonald 2000, Hoelter 2002). There is little evidence to suggest that *E. altaicum* var. *neogaeum* is either more or less common at the present time than in the past. Information on the peat composition of fens and bogs not currently supporting *E. altaicum* var. *neogaeum* may indicate its historical, or even archeological, abundance in comparison with that currently observed.

Habitat

Eriophorum altaicum var. *neogaeum* grows in the sub-alpine and alpine tundra zones of the Rocky Mountains. It occupies habitats that often support communities of several disjunct species that are likely relics from, at least, the last glacial stage of the Pleistocene (Cooper 1991). The habitat is broadly defined as a Palustrine System (Cowardin et al. 1979). Within that system, the habitat falls in the Emergent Wetland Class, which is characterized by erect, rooted,

herbaceous hydrophytes, and less frequently in the Moss-Lichen Wetland Class. Cowardin et al. (1979) have developed class descriptions based on life form, water regime, substrate type, and water chemistry to avoid the confusion often associated with the more common and often less precisely defined marsh, swamp, and bog. However, in order to facilitate visualization of habitat by the reader, the more familiar terms are also used here to describe habitat. *Eriophorum altaicum* var. *neogaeum* is always associated with water-saturated soils. Individuals grow in bogs, fens, wetlands, and along very wet streamsides. The difference between a bog and a fen is based upon the source of water and nutrients (see Definitions section for distinctions between bog and fen). Essentially, fens are generally nutrient rich with a source of incoming water. They are usually on flat or gently sloping land and tend to be slightly concave. Bogs are nutrient-poor, acidic, and have become raised above the influence of the water table by progressive peat accumulation. The condition of a bog is referred to as ombrotrophic or "food from the sky". Bogs tend to be convex in shape. Fens may have low or high floristic diversity depending upon conditions while a bog always has low floristic diversity. A poor fen may easily be mistaken for a bog in some circumstances. Although many of the occurrences in Colorado are described as bogs, the descriptions of many of the sites suggest that they may be more correctly classified as fens. An example of the habitat is shown in **Figure 2**.

Details of habitat are primarily taken from herbarium specimen labels and Colorado Natural Heritage Program element occurrence records (**Table 4**). Within Colorado, *Eriophorum altaicum* var. *neogaeum* is reported at elevations between 3,097 and 4,023 m with the majority of occurrences located between 3,500 m and 3,749 m (**Figure 3**). It grows on level ground or on gentle slopes with up to a 20 percent incline. The slope shape is often described as slightly concave. Sites have been reported with aspects facing north, northwest, south, west, and less commonly east. They grow in open and, more rarely, partially shaded environments. *Eriophorum altaicum* var. *neogaeum* grows in soils that can be primarily clay in the uppermost horizon, sandy, or with high levels of gravel. However, they always have a high level of organic matter usually described as humus, peat, or fine organic sphagnum matter. Soils are hydric. Some of the technical descriptions include deep, skeletal soil derived from glacial till;

Figure 2. Habitat of *Eriophorum altaicum* var. *neogaeum* in Colorado. Photograph by the author.

Table 4. Summaries of the habitat conditions, abundance, and comments at occurrences of *Eriophorum altaicum* var. *neogaeum* in Colorado (see also **Table 3**). For comparative purposes, occurrences where specimens have since been identified as *E. chamissonis* have been included.

Arbitrary occurrence number	Habitat	Abundance and comments
1	Local in a fen surrounding a small tarn on the southern side of the cirque basin.	No information.
2	2000: Alpine wet meadow/tundra. On open flat land in the cirque basin in saturated loam (organic/derived limestone) soil. Tree and shrub cover 0 percent; moss/lichen cover 0 percent; bare ground 0 percent; forb cover 70 percent, graminoid cover 30 percent Associated plant species: *Bistorta* spp., *Caltha leptosepala*, *Primula parryi*, *Carex* spp., *Juncus* spp., *Geum* spp., *Rhodiola integrifolia*, *Clementsia rhodantha*.	2000: Isolated population that "seems to be doing well." Estimated 100 individuals in an area of 100 ft. x 100ft.
3	On level open ground in an upland sphagnum bog. Usually occurs near edge of bog. Saturated and partially inundated fine organic soils. Forb cover 25 percent, graminoid cover 75 percent, moss/lichen cover 5 to 25 percent, bare ground cover <15 to 25 percent open water. Elevation 11,200 ft. Associated plant species: *Eleocharis quinqueflora*, *Deschampsia caespitosa*, *Caltha leptosepala*, *Carex aquatilis*, *C. ebenea*. At plot 8: *Salix planifolia*, *Carex scopulorum*, *C. illota*, *C. praeceptorum*.	Estimate approximately 100 individuals in three subpopulations.
*E. chamissonis**	2000: Sub alpine fen in glacial valley. Flat, open ground with organic peat soil; elevation 10,600 to 10,840 ft. Tree, shrub, bare ground 0 percent; forb cover 10 percent, total graminoid cover 80 percent, moss/lichen cover 10 percent.	Estimate 20 to 30 individuals in each of three subpopulations. Each subpopulation covered approximately 0.1 hectare.
4	Wet alpine basin.	Reproductive status: fruit and flower. Original identification was *Eriophorum scheuchzeri* Hoppe. Annotation *E. altaicum* Meinsh. var. *neogaeum*, det. W.A. Weber, 1983.
*E. chamissonis**	In a peat fen; elevation: 11,820 ft.	Over 50 individuals counted.
5	Boggy area. "Talus to chute from Grizzly above lakes".	Reproductive status: fruit and flower.
*E. chamissonis**	In peat fen at 11,560 ft. In moss carpet; rhizomes present.	Locally common.
6	1995: In tundra on mid to upper slope of 0 to 5 percent incline with open west aspect in saturated soil on glacial outwash plain. Soil parent material is volcanic extrusive. Tree and shrub cover 0 percent, forb cover 100 percent, graminoid cover 10 percent, moss/lichen cover ? and bare ground cover 0 to 1 percent. Associated plant species: Elephant head pedicularis, alpine timothy, *Carex* spp., buttercup, bistort.	Estimated number of individuals: 200+ in 1 acre. 70 + percent (?) flowering.
7	Elevation: 11,240 to12,000 ft.	No information.
8	High alpine peat bog in large glaciated wetland complex (hundreds of small ponds and lakes). In saturated soil in partial shade at 11,800 ft. Associated species: moss, willow, *Pedicularis groenlandica*, *Rhodiola integrifolia*, *Psychrophila leptosepala*. Shrub cover 50 percent, forb cover 20 percent, moss/lichen cover 30 percent.	"4 population sites within approximately 1 mile of each other. Site 1 had two groups of 15 individuals in each group. Site 2 had approximately 35 plants scattered in a 200 ft. x100 ft. area. Site 3 had 40 individuals in small area. Site 4 had 15 individuals in small area."

Table 4 (cont.).

Arbitrary occurrence number	Habitat	Abundance and comments
9	1994: Snowmelt basin in alpine tundra, very wet. In marsh surrounded by spruce/fir forest. "Probably histosol or histic over mollic" soil and cryoboroll soils, small wet depresional areas in alpine tundra. Indirect water source. Indirect water source. Some patches associated with *Eriophorum angustifolium*. Scattered *Salix planifolia* growing less than 0.5 m. Associated species include *Carex* spp. with lots of moss, *Caltha leptosepala*, *Clementsia rhodantha*, *Juncus mertensianus*, *Deschampsia* spp. *Senecio* spp., *Pedicularis groenlandica*, *Calamogrostis* spp. *Swertia perennis*.	August 23: a moderate (100 to 150 individuals) and a very large sized (1,000+ individuals) patch very close to trail used by hikers and horseback riders; no weedy species. Two large patches not near trail with little impact from sheep or people. In all patches many (50 to 75 percent) stems blooming. Very large (1,000+ individuals) patch occupies "300 ft. x 100 ft". August 26: large stand, over 300 individuals and many in bloom. Historically area was mined - does not seem mined in basin. Sheep grazing in area. Next to a trail with horse traffic.
10	*S. Komark 499* (COLO). Small lakes/fens on mesa top. On hummocks, 500 individuals counted 11900 feet. *S. Komarek 495* (COLO) edge of peat fen, mostly granitic gravel with water passing through 50 to 100 individuals just beginning to bloom - 11,555 ft. elevation. Colorado Natural Heritage Program summary 1997: elevation 11,600 to 12,000 ft. Total cover: Tree: 0 percent; Forb: 5 to 40 percent; moss/lichen: 0 to <5 percent; Shrub: 0 percent; Graminoid: 5 to 60 percent; Bare ground: 0 to 90 percent. Associated plant species: *Pedicularis groenlandica*, *Psychrophila* (*Caltha*) *leptosepala* , *Deschampsia caespitosa*. Hummocks in peat bog and unvegetated gravel. Slope: 0 percent. Light exposure: open. Topographic position: bottom and crest. Parent material: granite. Geomorphic land form: alpine glacial valley and glaciated mountain slopes. Soil texture: gravelly and peaty.	Colorado Natural Heritage Program summary 1997: total of 3 suboccurrences. Total population numbers are between 650 to 700 individuals and covers 3 to 4 acres. 100 percent flowering, many emerging stems. It was a late snowmelt year. *S. Komark 499* (COLO). Small lakes/fens on mesa top. On hummocks, 500 individuals counted at 11,900 feet. *S. Komarek 495* (COLO) edge of peat fen, mostly granitic gravel with water passing through 50 to 100 individuals just beginning to bloom - 11,555 ft. elevation.
11	1995: Peat bog at 11,840 ft. elevation. On essentially flat part of glaciated mountain slopes in saturated peat soil in open light exposure. Granitic parent material. Total tree and shrub cover: 0 percent. Total forb cover: 40 percent. Total moss/lichen cover: 25 percent. Total graminoid cover: 40 percent, Total bare ground cover: 0 percent. Associated plant species: *Pedicularis groenlandica*, *Psychrophila* (*Caltha*) *leptosepala*, *Deschampsia caespitosa*, *Eriophorum angustifoliium*, *Primula parryi*, *Carex canescens*, *Carex aquatilis*. 1994: above timberline in late snowmelt basin at 11,820 ft. "26 cm of organic soil over mollic." Lots of *Caltha leptosepala* but *Carex aquatilis* is dominant.	1995: Estimated <50 individuals; population covers area <1acre. Flowers are barely emerging. 1994: Estimated 1,000+ individuals, many in bloom.
12	Outlet to lake. Mixed with *Juncus triglumis*, *Carex microglochin*. Associated taxa: *Juncus* spp., *Carex* spp.	No information.
13	Between hummocks of vegetation in a very wet boggy stream bank area at 12,000ft. on the shelf high on the south side of the valley.	No information.
14	In alpine wetland in open site at 12,400 ft. (3,780 m). Total graminioid cover 75 percent and total bare ground cover 25 percent. With *Carex saxatilis* (dominant) and *Pedicularis groenlandica*.	Estimate 25 individuals in less than one acre.

Table 4 (cont.).

Arbitrary occurrence number	Habitat	Abundance and comments
15	1972: at lake by a small stream at 12,100 ft. August 1972: alpine bog near 12,300 ft. 1995: Peat fens on upper basin above lake. 1997: Southeast aspect and slightly concave slope. Light exposure open. Inundated (moisture) soil. Elevation 12,600 ft. 1993: southeast aspect, slightly concave slope, inundated soils and open light exposure. Plant seems to prefer inundated sites with little competition from *Carex* spp. and marsh marigold. When these species cover exceeds about 30 percent you do not find this *Eriophorum* species. Soil mapped as cryumbrepts-rock outcrop. *Carex aquatilis*, *Psychrophila* (*Caltha*) *leptosepala, Clementsia rhodantha*, *Rhodiala integrifolia*, *Bistorta bistortoides*, *Pedicularis groenlandica*. Elevation 12,560 ft. July-August 1995: total tree and shrub cover: 0 percent. Total forb cover: 20 to 50 percent. Total moss/lichen cover: 0 to 5 percent. Total shrub cover: 0 percent. Total graminoid cover: 10 percent. Very little bare ground.	July-August 1972: by small stream, only 140 to 150 plants seen here - elevation 12,100 ft. August 1972: in alpine bog at 12,300 ft. 1993: SITE 1: 30+ aerial stems flowering; probably total 100+ stems. SITE 2: 40+ aerial stems flowering; probably total 200+ stems. Plants are reproducing both vegetatively and sexually. Estimate 30 percent population flowering. Both sites are about 0.1 acre. 1995: peat fens on upper basin above lake (water flowing through them). 200 plants counted. 1995: approximately 140 in 25 to 35 patches over an area of <0.5 acre. Many with bloom emerging. 1997: 93 aerial stems observed in about 1 acre, 100 percent flowering. A historic hard rock mine is in the vicinity. "Anthers 1 mm long" written above label on COLO specimen sheet.
16	Peat fen near lake shore where water moves through.	No information.
17	Extensive wetland.	No information.
18	"On bench; pond; 12,000 ft."	No information.
19	In sedge hummocks in pond in upper basin - elevation range 10,000 to 11,800 ft.	On COLO specimen sheet: "Attached packets A and B illustrate the difference between *Eriophorum altaicum* and *E. scheuchzeri*." W.A. Weber 1988.
20	Plants in a small depression next to a road. Small, wet, boggy area on tundra with standing water in puddles. Rocky. Site may be wetter than it would be naturally because of the adjacent road. Associated species: *Deschampsia caespitosa*, *Salix planifolia*, *Carex* spp.	1,750 individuals observed in an area about 20 x 20 m. Fruiting. Small area grazed by sheep. Site is adjacent to road, very wet, recently grazed by sheep. However, the sheep seemed to avoid the wettest area where the *Eriophorum altaicum* var. *neogeaum* was most common.
21	1996: west aspect, open light exposure in saturated soil, probably a perennial seep. Site is on a gentle streambank high on south flowing branch of creek at elevation: 11,000 to 11,200 ft. No shrubs or tree cover.	Approximately 10 stems over about 30 square feet.
22	1934: 12,100 to 12,300 ft. 1993: small area with wet soil streamside with *Salix planifolia* and also in a small bog (isolated from stream; 5m x 2m area). Associated species: *S. planifolia*, *Caltha* spp., *Carex* spp. *Deschampsia* spp., *Pedicularis groenlandica*. 20 percent slope with 120 deg. aspect at 12,300 ft.	There were more than 2 patches observed. One patch had 426+ plants and another patch had 350+ plants. Estimate approximately 1,200 individuals; 50 percent fruiting. Estimate 50 percent "potential habitat" occupied. Estimate amount of potential habitat= 0.5 acre. Sheep grazing in the vicinity.

Table 4 (concluded).

Arbitrary occurrence number	Habitat	Abundance and comments
23	Subalpine understory - total vegetation cover 95 percent; bare ground 1 percent, rock cover 1 percent, litter 98 percent. Aspect 25 degrees, slope 8 percent, organic saturated soil. Pools and rivulets occurred among bedrock outcrops and patches of Krummholz frost heaved "islands" supported trees and drier plant species The 7 Engelmann spruce in the plot were less than 4 in (10 cm) in diameter and 10 ft. (3m) tall. The soil was deep, skeletal and derived from glacial till; the uppermost horizon was a mottled, dark clay. Small pools occurred in terraces in the basin drainage. Associated taxa: *Salix planifolia*, *Caltha leptosepala*, *Arnica mollis Erigeron peregrinus*, *Picea engelmannii*, *Oxypolis fendleri*, *Senecio triangularis*, *Carex scopulorum*, *C. nova*, *Artemisia scopulorum*.	Very small population; plants form a patch 1 m in diameter emerging from a pool of water. 100 percent fruiting.
24	1997: in alpine glacial valley. *Carex* spp. wetland. Northeast aspect on 2 percent, concave-shaped slope. Open light exposure, wet-saturated soil of humic parent material. Elevation 11,590 ft. Total cover: Forb: 65 percent. Graminoid: 30 percent. Bare ground: 5 percent.	Estimate 50 individuals over an area of approximately 0.25 acre; flowering. A lot of people use the area but avoid the really wet areas.
25	In alpine basin on islands of saturated peat between small snowmelt streams. With *Psychrophila leptosepala*, *Primula parryi*, *Juncus drummondii*, *Deschampsia caespitosa*.	Plants grow right to edge of road and occupy patch about 20 m x 30 m in size. In fruit.
26	Saturated to inundated marshy area to south of road at 12,200 ft.	Original identification *Eriophorum russeolum*.
27	1999: wetland with *Carex utriculata*, *Pedicularis groenlandica*, *Juncus drummondii*, *Caltha leptosepala*, *Cardamine cordifolia*, *Eriophorum angustifolium*. According to an observer nearby wetlands have *Eriophorum angustifolium* only. Elevation 11,400 ft.	1999: approximately 200 plants in excellent condition wetland. Occurrence was first found during clearance survey for ski area expansion in 1993.The new ski lift was believed to be able to span the wetlands (Colorado Natural Heritage Program element occurrence records).
28	1997: in a formerly glaciated lake basin at treeline growing in frigid, hydric soils. Associated taxa: *Salix planifolia*, *Carex scopulorum*, *C. aquatilis*, *Artemisia scopulorum*, *Clementsia rhodantha*, *Pedicularis groenlandica*. 1942: sandy humus soil of bog.	1997: a rather small, but dense stand of the plant occurring in shallow snowmelt pools of an alpine fen. 1997: Approximately 260 plants in population. There are probably other small populations in the upper basin. 1942: Sparse.
*E. chamissonis**	Wet shor line of lake associated with other sedges, *Carex* spp. Open, flat (0 percent slopes), moist ground at 10,535 ft. Organic soil. Total tree and shrub cover 0 percent. Total forb: 20 percent. Total graminoid cover: 60 percent. Total moss/lichen cover: 20 percent. Total bare ground: 0 percent.	2000: in approximately 0.1 hectare, estimate 100 seed heads in at least 2 subpopulations: 75 plants in one patch, 25 in second patch. Cattle grazing in the vicinity. There are no fence lines separating the lake from grazed areas.
*E. chamissonis**	1999: plants occur in a wet meadow with sparse *Salix planifolia*. *Eriophorum chamissonis* appears to occur most often at the edges of wetter pockets of *Eleocharis palustris*. Other associates include: *Phleum alpinum*, *Caltha leptosepala*, *Carex aquatilis*, *Luzula suncapitata*, *Sphagnum* spp., *Limnorchis* spp., *Castilleja* spp., *Rhodiola integrifolia*, *Pedicularis groenlandica*. *Eriophorum angustifolia* is also present. 1986: drainage near the headwaters of a creek at elevation 3,050 m.	1999: approximately 100 plants seen. Water diversions are occurring in the area (1999).
29	1998: *Carex aquatilis*-*Carex utriculata* meadow. To the west is a spruce-fir dominated riparian area. A steep slope to the east is dominated by fir, avalanche chutes, and large gneiss (?) rock outcrops. Total Cover: Tree (Englemann spruce): 5 to 10 percent. Shrub (*Salix monticola*, *S. planifolia*, *Betula glandulosa*): 10 to 20 percent. Moss (Sphagnum): 20 to 30 percent. Graminoid (*Carex aquatilis*, *C. utriculata*, *Eleocharis quinquefolia*): 20 to 50 percent. Forb (*Pedicularis* spp., *Limnorchis* spp., star gentian, queens crown, *Pyrola* spp., *Caltha* spp., *Vaccinium* spp., lovage, *Erigeron* spp., *Senecio* spp.): 10 to 40 percent.	1998: 137 plants counted. There is a water diversion approximately 0.5 miles downstream of this occurrence. There are many exotic plant species at this diversion.

**Eriophorum chamissonis* C.A. Meyer determined by R.L. Hartman 2001.

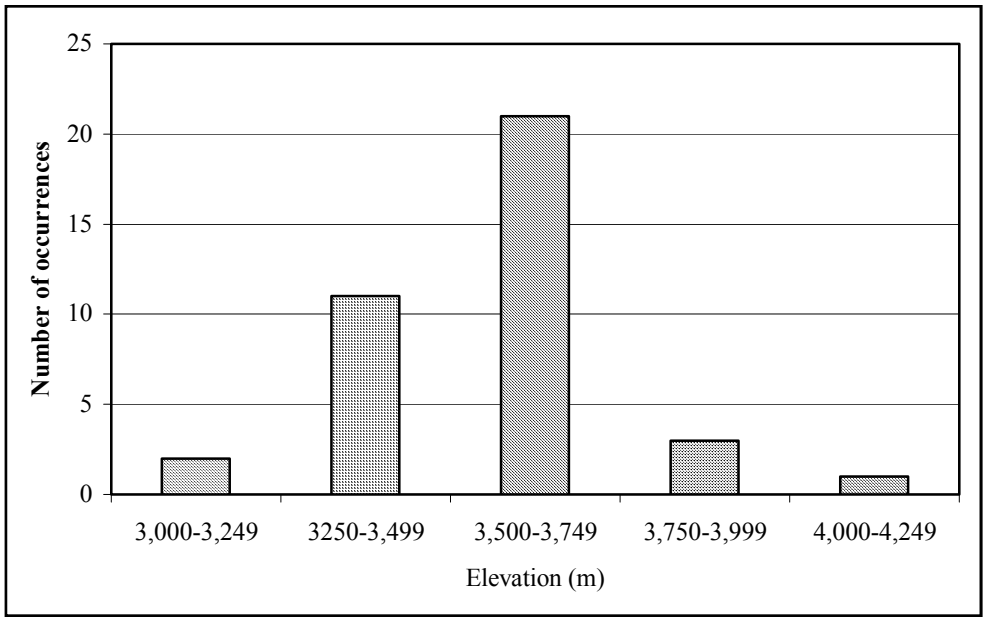

Figure 3. Frequency of elevations reported for the occurrences of *Eriophorum altaicum* var. *neogaeum* in Colorado. Where a range was given for an occurrence, the lowest and highest elevations reported were included in the analysis.

cryumbrepts; histosol; or histic over mollic soils. Where geological association was reported, granite is the most common parent material, but the plants are also found on soils derived from limestone, sedimentary rocks (Uncompahgre formation), and volcanic rocks (Tweto 1978, Colorado Natural Heritage Program element occurrence records 2002).

Ground cover, as percent of the total ground surface in the patches occupied by *Eriophorum altaicum* var. *neogaeum*, was reported for many of the occurrences (Colorado Natural Heritage Program element occurrence records 2002), and the maximum, minimum, and mode (most often reported value) are tabulated in **Table 5**. Tree cover was usually numerically reported as 0 percent although one report indicated a canopy cover of 5 to 10 percent and there were observations that some occurrences were associated with *Picea engelmanii* (Englemann spruce) cover.

From the habitat descriptions it is not certain that *Eriophorum altaicum* var. *neogaeum* is uniquely found in areas with open water (**Table 4**). *Eriophorum scheuchzeri* prefers bog sites adjacent to open water, and at least in Greenland, the proximity of open water is a typical characteristic of its habitat (Crawford 1983). Open water means free water, often "standing water." However, functional "open water" may be difficult

Table 5. Percent ground cover at the patches of *Eriophorum altaicum* var. *neogaeum* where numerical values were reported (Colorado Natural Heritage Program element occurrence records 2002).

Ground cover	Number of observations*	Mode (%)	Minimum (%)	Maximum (%)
Bare ground (or open water)	13	0	0	90
Forb cover	13	40	5	100
Graminoid cover	13	75	5	75
Moss/Lichen cover	10	0	0	40
Shrub cover	6	0	0	50
Tree cover	5	0	0	10

*Some observations did not mention all classes of cover. In this case omission was not regarded as a negative report and was not included in estimating the mode.

to determine for a non-specialist. Some of the least compact surface materials (peat, soil, etc.) become supersaturated in wet conditions so that the structure expands to admit intrusions of free water (Ingram 1983). This process, whereby the bulk density and hydraulic conductivity of the surface materials change, has been particularly associated with *Sphagnum-Eriophorum* microtopes that undergo seasonal variation in these properties (Ingram 1983).

Associated shrub and tree species include *Picea engelmanii*, *Salix planifolia* (diamondleaf willow), and *Vaccinium* (blueberry) species. Other plant species that have been reported to be associated are listed in **Table 6**. Although the moss and lichen cover may be high (**Table 5**), associated bryophyte species have not been reported. Three boreal fen mosses, *Sphagnum contortum*, *Scorpidium scorpioides*, and *Paludella squarrosa*, were reported for either rich or poor-to-intermediate fens in the southern Rocky Mountains. Each of the three species have rarely been encountered in the contiguous 48 states, and it would be interesting to know more about the associations and interactions between cryptogams and *Eriophorum* species in the Rocky Mountains.

Reproductive biology and autecology

Eriophorum altaicum var. *neogaeum* is a perennial species. It is exceptionally rhizomatous (Weber and Wittmann 2001a and 2001b), and vegetative propagation is likely critical to population sustainability. It also reproduces sexually. The flowers are hermaphroditic. Flowering occurs in late spring,

Table 6. Species reported to be associates of *Eriophorum altaicum* var. *neogaeum*. This is not an exhaustive list and represents only the observations that were made on herbarium sheets, in Colorado Natural Heritage Program element occurrence records, and in the literature.

Grass-like species	**Forb species**
Carex aquatilis	*Arnica mollis*
Carex canescens	*Artemisia scopulorum*
Carex chalciolepis	*Bistorta bistortoides*
Carex ebenea	*Bistorta* species
Carex illota	*Caltha leptosepala*
Carex microglochin	*Caltha* species (syn: *Psychrophila* species)
Carex nova	*Cardamine cordifolia*
Carex praeceptorum	*Clementsia rhodantha*
Carex saxatilis	*Erigeron peregrinus*
Carex scopulorum	*Erigeron* species
Carex utriculata	*Geum* species
Carex species	*Ligusticum* species
Eleocharis quinqueflora	*Limnorchis* species
Eriophorum angustifolium	*Luzula* species
Juncus drummondii	*Oxypolis fendleri*
Juncus mertensianus	*Pedicularis groenlandica*
Juncus triglumis	*Pedicularis* species
Juncus species	*Primula parryi*
	Pyrola species
Grasses	*Rhodiola integrifolia*
Calamagrostis canadensis	*Rubus arcticus* ssp. *acaulis*
Deschampsia caespitosa	*Saxifraga orgegana*
Deschampsia species	*Senecio triangularis*
	Senecio species
	Swertia perennis

and fruiting occurs from late July to August (Spackman et al. 1997). Flowering and seed fill may be influenced by environmental conditions. Another tussock-forming species, *E. vaginatum*, exhibits a wide variation in flowering and annual seed production depending upon environmental factors and disturbance (Wein and MacLean 1973). For example, fire apparently elicited *E. vaginatum* flowering and a higher seed yield was harvested from burned areas than from unburned areas (Wein and MacLean 1973). Similar to other *Eriophorum* species, *E. altaicum* var. *neogaeum* is most likely wind-pollinated, and the seeds are also likely dispersed primarily by wind. In general, wind-dispersed seeds move relatively short distances, and the main bulk of wind-borne seeds typically fall within 4 m of the seed parent (Salisbury 1961, Silvertown 1987).

Seeds of many *Eriophorum* species, including *E. scheuchzeri*, *E. angustifolium*, and *E. latifolium*, undergo physiological dormancy (Mass 1989, Baskin and Baskin 2001). Cold stratification was the trigger breaking dormancy in *E. latifolium* where the length of the stratification period was 42 days and the optimum germination temperature was 22°/12 °C (Maas 1989). A seed sample from Scotland had an optimum germination temperature of 20 °C (Wein 1973). Studies with *E. vaginatum* indicated that a higher percentage of seeds germinated in the light than in the dark (Baskin and Baskin 2001) suggesting that some degree of soil disturbance may be needed to promote large numbers, or "a flush", of seeds to germinate. However, even though more seed germinated in the light, some germinated in the dark indicating some flexibility in seed germination requirements. Seed of many *Eriophorum* species, including that of *E. altaicum* var. *neogaeum*, appears to germinate readily, but successful establishment may be more elusive (Wein 1973, Cardamone personal communication 2002). Dry conditions were very detrimental to *E. vaginatum* seedling establishment after germination *in situ*. It is thus important to know the fate of the transplanted populations at the proposed Warren Lakes RNA, White River National Forest, that were planted in 2001 prior to the excessively dry year, 2002. Transplanted seedlings with a developed root system are more likely than germinated seeds to tolerate a dry season.

The seed bank may be a significant source of viable seed. Bryophyte sod was brought to an area in Canada that had been severely disturbed by heavy-tracked bulldozer-like vehicles (Streng 1999). After the restoration effort, no further disturbance occurred in this isolated region. After 18 years the restoration plots were checked. Abundant *Eriophorum scheuchzeri* plants were blooming despite the fact that it was not present in any of the adjacent undisturbed areas of the meadow. It was concluded that the *E. scheuchzeri* had germinated from seeds in the seed bank that had been stored in the bryophyte sod (Streng 1999). Thus, the seed bank may be very important in re-establishing a population after extirpation of an original patch. However, it is interesting to consider that the replacement patch may be genetically different from the original population. A study on *E. vaginatum* indicated that plants grown from seed in the seed bank differed from the established plants with regard to morphological, growth, and flowering characteristics. The differences were attributed to genetics and not apparently to any genetic deterioration in the old seeds (McGraw 1993). The reason for this observation was not clear. Seeds with different genetic composition may be prompted to germinate on different cues, and such diversity in the seed bank may provide a buffer to a changing environment.

Unlike some plants in which the physiologically active root system is a perennial structure, *Eriophorum* species have adventitious root systems that are repeatedly replaced by new roots. These roots arise from the perennating rhizomes at the soil surface, often from points close to the buds from which aerial leaves and stems are formed (Ingram 1983). It is not clear if new roots are continuously produced throughout the growing season. Root production shows two maxima in *E. vaginatum*, the greatest production being in June and July when the roots grow most deeply and a lesser production of shallower roots during the winter (Wein 1973). Vegetative expansion by rhizomes and stolons implies that there is a period of attachment between parent and offspring, and therefore frequent and severe soil disturbance may be detrimental. However, studies of species occurring in Great Britain and the arctic show tolerance to, or even benefit from, moderate disturbance and burning (Wein 1973, Grime et al. 1988). Superficial burning apparently stimulates flowering and seed production in some species (Wein and MacClean 1973). It is probably prudent to only consider testing whether this situation applies to *E. altaicum* var. *neogaeum* when *E. altaicum* var. *neogaeum* populations fail to demonstrate vigorous flowering and reproduction over several consecutive years.

As indicated in the Habitat section, *Eriophorum scheuchzeri* prefers sites adjacent to open water (Crawford 1983). This situation appears to be related to a physiological requirement of the species. Lack of oxygen can promote toxic concentrations of metabolites to accumulate within the roots. Near open water, the adventitious roots will be bathed by free water, and

therefore the toxic metabolites will be able to rapidly dissipate by diffusion (Crawford 1983). This process may be particularly important because, at least for *E. angustifolium*, the internal oxygen supply will support root respiration for only one hour when plants are kept in the dark (Armstrong 1975). The aerenchyma tissue of *Eriophorum* species roots may provide an oxygen reserve (Williams and Barber 1961). However, it apparently can only provide oxygen for very short term needs (Crawford 1983).

Eriophorum altaicum var. *neogaeum* is a perennial species occurring in stable habitat that matches the profile of a k-selected species with a stress-tolerant life strategy (MacArthur and Wilson 1967, Grime et al. 1988). The high proportion of assimilates that is directed toward sustaining vegetative vigor and the long habitat tenure are typical of a k-selected species (Harper and White 1974). *Eriophorum altaicum* var. *neogaeum* is also likely competitive in low-nutrient bogs because certain nutrients are salvaged from dying tissues by translocation to the perennating organ and the extensive, renewable root system must also provide a certain degree of dynamic foraging behavior (Dickinson 1983, Jonasson and Chapin 1985). Therefore, in some circumstances, *E. altaicum* var. *neogaeum* may have an intermediate strategy between stress-tolerator and stress-tolerant competitor, as has been reported for another *Eriophorum* species, *E. vaginatum* (Grime et al. 1988).

Demography

Eriophorum altaicum var. *neogaeum* reproduces sexually by seed and asexually, or vegetatively, via rhizome production. It is not documented, although it is likely, that the juveniles arising from rhizome nodes routinely break from the parent and live as independent individuals. The rhizomatous and adventitious root systems form a mat that can make differentiating individuals difficult. The frequency with which seed germination occurs has not been documented for *E. altaicum* var. *neogaeum*. The rhizomatous growth habit suggests that the patches observed over a contiguous area may be derived from only a few individuals. The patch dynamics, or the dynamics of individuals within patches, have not been investigated. Patches of 50 to 150 individual seedlings were planted between, but several hundred feet from, existing patches of *E. altaicum* var. *neogaeum* at the proposed Warren Lakes RNA, White River National Forest (Cardamone personal communication 2001). This work provides an ideal basis for further studies on aspects of demography and interaction.

Populations appear to largely comprise flowering adults. In general, where phenology was reported at the occurrences, approximately 80 percent of stems were observed to be flowering. It is not clear as to how old the plant must be before flowering occurs. In northern Russia, results from dating *Dryas* woody tissue to estimate *Eriophorum vaginatum* age and growth suggested that the juvenile stage could last for 20 years and the generative stage from 40 to 60 years; discrete patches could remain active for over 100 years (Polozova 1970 in Wein 1973).

Unfortunately, there are more questions than facts available pertaining to the life cycle of this species, and speculation is accepted as a poor substitute for facts. A simple life cycle model of *Eriophorum altaicum* var. *neogaeum* is described in diagrammatic terms (**Figure 4**). Heavy arrows indicate phases in the life cycle that appear most critical, and lighter weight arrows indicate the phases that maybe less significant or unknown. The steps that particularly need to be clarified are noted by "?" at the appropriate arrow. No demographic studies have been undertaken and transition probabilities between the different stages, from seed germination to the flowering adult, are unknown. There is no information to suggest the relative importance of asexual to sexual reproduction in its life history although it is reasonable to speculate that the rhizome organ is very important to the long-term sustainability of the population. It is also not known if plants flowering one year revert to vegetative plants in following years or if patch size reflects age. Patch size is also likely to reflect microhabitat conditions. In drought conditions it is not known if the rhizome can undergo a prolonged dormancy period. Limits to population growth are not well defined.

Community ecology

Population sizes of this species are quite variable. Less than 15 individuals to several hundred may comprise a population. In some cases several small patches or "clumps" of plants that are separated by several tens of meters are distributed over 1 to 3 acres and comprise a population. However, in some instances patches less than 1 m^2 are found in isolation. Because of the highly rhizomatous growth habit it is likely that theses patches only represent a few, or even only one, genetically unique individuals. Other than habitat availability, the causes of the difference in population size are unknown.

The position of *Eriophorum altaicum* in community succession is not documented. It appears

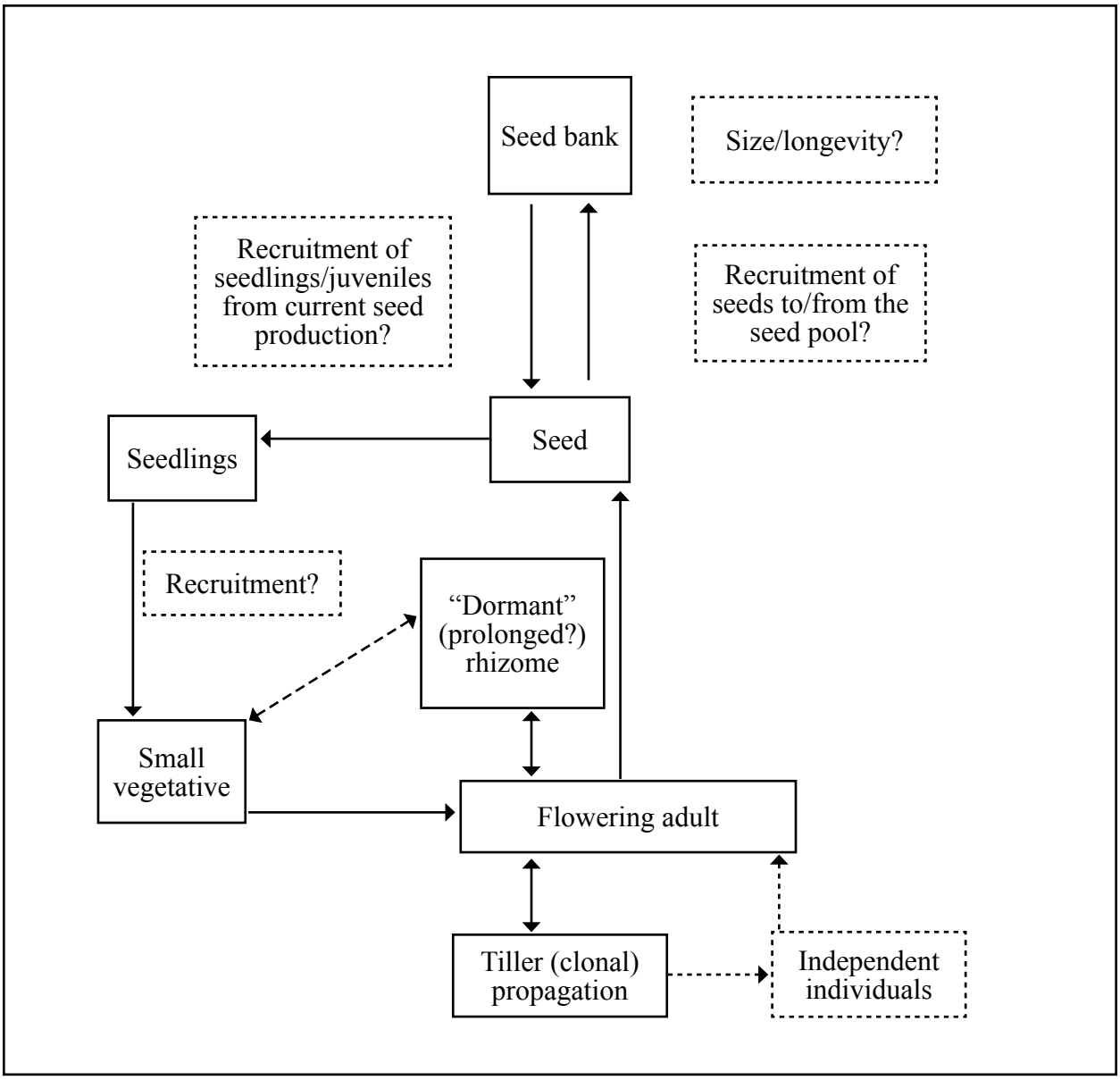

Figure 4. Life cycle diagram for *Eriophorum altaicum* var. *neogaeum*.

Eriophorum species are generally pioneers (Tallis 1983). However, some species are earlier colonizers than others. *Eriophorum angustifolium*, which is found with *E. altaicum* var. *neogaeum* in Colorado, appears to be a particularly early colonizer (Taylor 1983). For example, studies on the vegetational succession of bogs and fens in Great Britain showed that *E. angustifolium* is an earlier colonizer than the tussock-forming *E. vaginatum*. After colonization by *E. vaginatum*, the diversity of both plants and animals increases (Moore and Bellamy 1974). *Eriophorum* species also show marked preferences for a specific habitat niche at the same location. For example, in Finland *E. russeolum*, recently placed in synonymy with *E. chamissonis* (Ball and Wujek 2002), is one of the dominant species in the field layer whereas *E. vaginatum* is a dominant species at the bog margins (Ruuhijärvi 1983). However, there are also geographical differences in habitat preferences. *Eriophorum angustifolium* grows in both poor and rich fens but is never found in ombrotrophic bogs in Sweden; in the British Isles it grows in ombrotrophic sites as well as other fen sites (Sjörs 1983).

No specific associations between *Eriophorum altaicum* var. *neogaeum* and animals have been reported. However, the association between *Eriophorum* species and invertebrate animals may be highly complex and an integral part of the chemistry of functioning wetlands.

A wax-producing aphid, *Colopha compressa*, lives on the roots of some *Eriophorum* species (Wheatley et al. 1975, Clymo 1983). This wax, which is composed of paraffins, carbohydrates, and secondary amides, forms interlinked fibers that become a white-colored aggregate of up to 3 mm in diameter and can be found to depths of at least 6 m within the peat substrate. The purpose of this wax or the benefit of the relationship to the individual is unknown. Wind-pollinated species are less likely to be immediately recognized as having important arthropod associations, but in many parts of the world, *Eriophorum* species are specific foods for many species of Lepidoptera larvae (FUNET 2002). In the United Kingdom, *E. vaginatum* is critical to the life cycle of the large heath butterfly, *Coenonympha tullia*, of which the larval stage feeds on the tips of young growth (Joy and Pullin 1999). Despite a substantial microflora around the roots, *Eriophorum* species often lack mycorrhizal infections (Dickinson 1983, Grime et al. 1988, Emmerton et al. 2001). Powell (1975) suggested that the long branched roots that bear numerous large root hairs obviate the need for mycorrhizal associations.

The root system of *Eriophorum* species may have important functions in the ecosystem in which it occurs. Root systems of *Eriophorum* species penetrate the substrate to depths of at least 1 m (Moore and Bellamy 1974, Clymo 1983, Dickinson 1983, Ingram 1983). They therefore contribute to continuously altering the peat layers that were formed decades previously and influence the nutrient cycling in these layers. The adventitious roots also physically contribute to the fragmentation of material in the bog. Leaf bases of bog plants, such as *Scirpus*, are partially fragmented and *Sphagnum* leaves are often pierced by the adventitious roots of *Eriophorum* species (Dickinson 1983). Certain nutrients are translocated back into the perennating rhizome prior to litter fall at the end of each growing season (Moore and Bellamy 1974, Mitsch and Gosselink 1993; see Reproductive biology and autecology section). Therefore, nutrients are captured in the plants until death, and the disintegration of the rhizome likely plays a critical role in the nutrient budget of the system.

An envirogram is a graphic representation of the components that influence the condition of a species and reflects its chance of reproduction and survival. Envirograms have been used especially to describe the conditions of animals (Andrewartha and Birch 1984) but may also be applied to describe the condition of plant species. Those components that directly impact *Eriophorum altaicum* var. *neogaeum* make up the centrum, and the indirectly acting components comprise the web (**Figure 5** and **Figure 6**). Unfortunately, much of the information to make a comprehensive envirogram for *E. altaicum* var. *neogaeum* is unavailable. The envirograms in **Figure 5** and **Figure 6** are constructed to outline some of the major components known to directly impact the species and also include additional speculative factors. Dotted boxes indicate factors that are either likely but not proven, or of a regional nature. There is a lack of direct studies on this species that leads to stretching the significance of observations and to forming opinions from inference rather than fact. Inferences must be tested and are dangerous to use in predicting responses to management decisions.

Resources that have been listed include water-saturated soils providing a suitable edaphic environment for adequate growth. Open water may be a specific resource, as it may reduce the impact of toxic metabolite accumulation (see Habitat and Reproductive biology and autecology sections). At the present time it appears that the availability of free water is one of the factors that restrict localized population expansion. Snow cover has been included because *Eriophorum angustifolium* exhibited positive responses to various measures of snow cover (Aiken et al. 1999). It was thought that snow cover may reduce the rate of desiccation, protect plants from abrasion, and insulate them from low temperatures during the winter season. This may apply to *E. altaicum* var. *neogaeum* as well. Fire or freeze/thaw disturbance is likely tolerated and may benefit seed germination. The effect of fire on other *Eriophorum* species depends on the severity of the burn (Tallis 1983). Because the impact of fire on the life history of *E. altaicum* var. *neogaeum* is very speculative, it is not included in the envirogram. Some types of disturbance may also have a role in seed germination and the establishment of independent plants from rhizome nodes (see Reproductive biology and autecology and Demography sections). However, other than microswell of the substrate, disturbance is also omitted from the envirogram because of a lack of pertinent information.

CONSERVATION

Threats

Wet habitats are generally in decline throughout the southern Rocky Mountains (Knight et al. 2000). This species only grows in bogs, fens, marshes, and wetlands, which are all very vulnerable to modification from most anthropogenic activities, such as mining, livestock grazing, outdoor recreation, and water development projects (Knight et al. 2000, USDA Forest

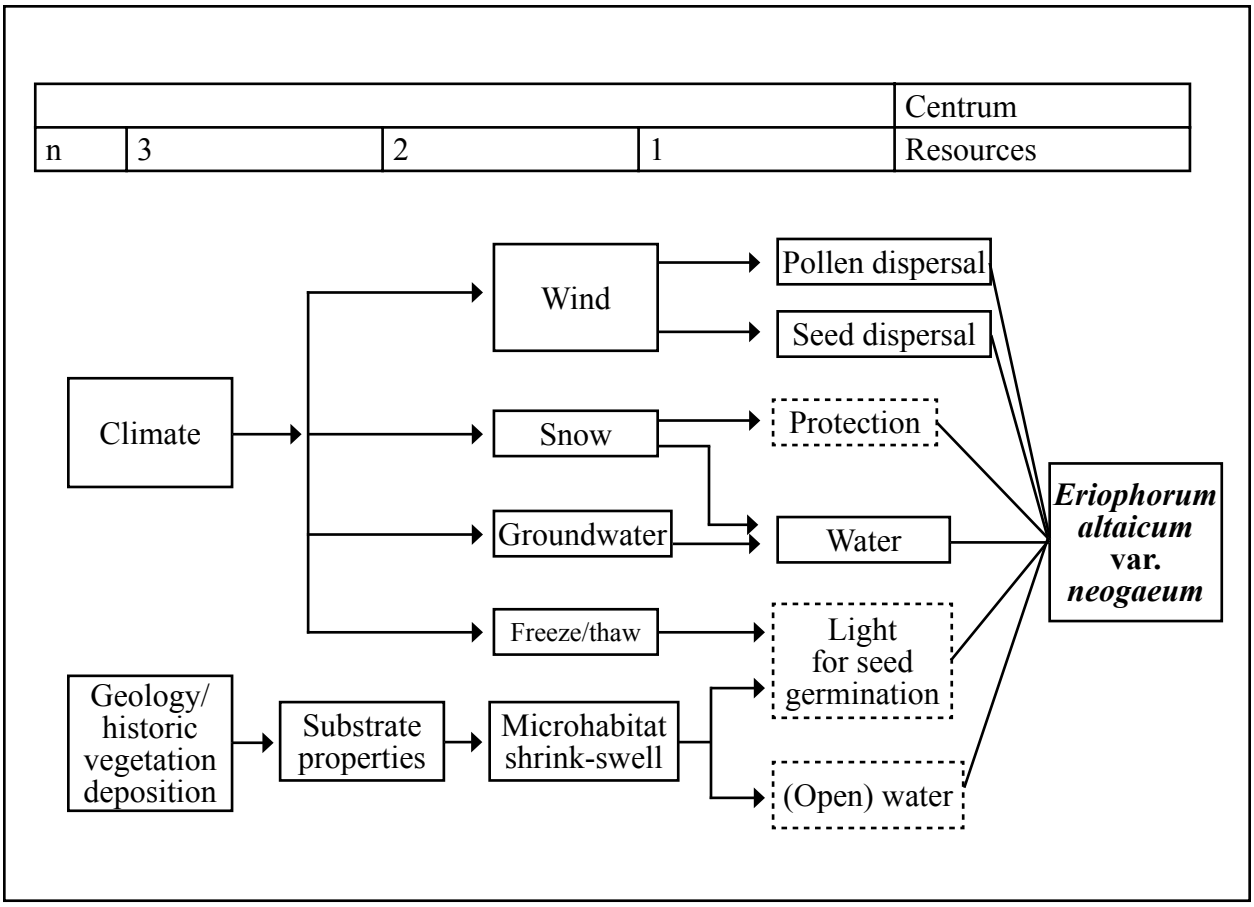

Figure 5. Envirogram of the resources of *Eriophorum altaicum* var. *neogaeum*. Dotted boxes indicate resources or malentities that are either likely but not proven, or of a regional nature.

Service 2001, Chimner and Cooper 2003). Another potential threat may be housing development. Mountain sites are becoming very popular with a burgeoning urban population, and "borderline" appropriate homesites are being developed. For example, the Fourmile Creek area, southwest of Fairplay, which provides habitat for *Eriophorum*, is experiencing housing developments that extend up into the mountains.

The extent to which mining activities have affected *Eriophorum altaicum* var. *neogaeum* populations has not been documented, but several occurrences have been reported from areas where mining has been prevalent, for example in Horseshoe Cirque, above Fourmile Creek southwest of Fairplay and the Mary Mine area on BLM land near Silverton (see occurrences 1, 9, and 15 in **Table 3**). As well as physically disturbing the ground surface, some mining activities affect the hydrology of an area and may indirectly, but significantly, impact *E. altaicum* var. *neogaeum*, which is an obligate wetland species.

Peat mining has not been as developed in Colorado as in many other parts of the world, but evidence of significant past activities exists (Cooper and MacDonald 2000). One example on USFS land is in the Warren Lakes area on the White River National Forest (occurrence 3 in **Table 3**) where several ditches ranging from 2 to over 10 feet wide were machine-dug many decades ago to extract peat. Such activity influences edaphic conditions, microbial as well as non-vascular and vascular plant species composition, and the hydrology of the sites. Currently peat mining is discouraged (Hoelter 2002).

Some recreational activities may threaten certain populations. *Eriophorum altaicum* var. *neogaeum* habitat is vulnerable to expansion, and new construction of ski resorts, for example on the Uncompahgre National Forest (occurrence 27 in **Table 3**). Ski lifts or other structures are likely to be able to span or to avoid wetlands, and thus modification of the hydrology of an area is probably the principal potential threat.

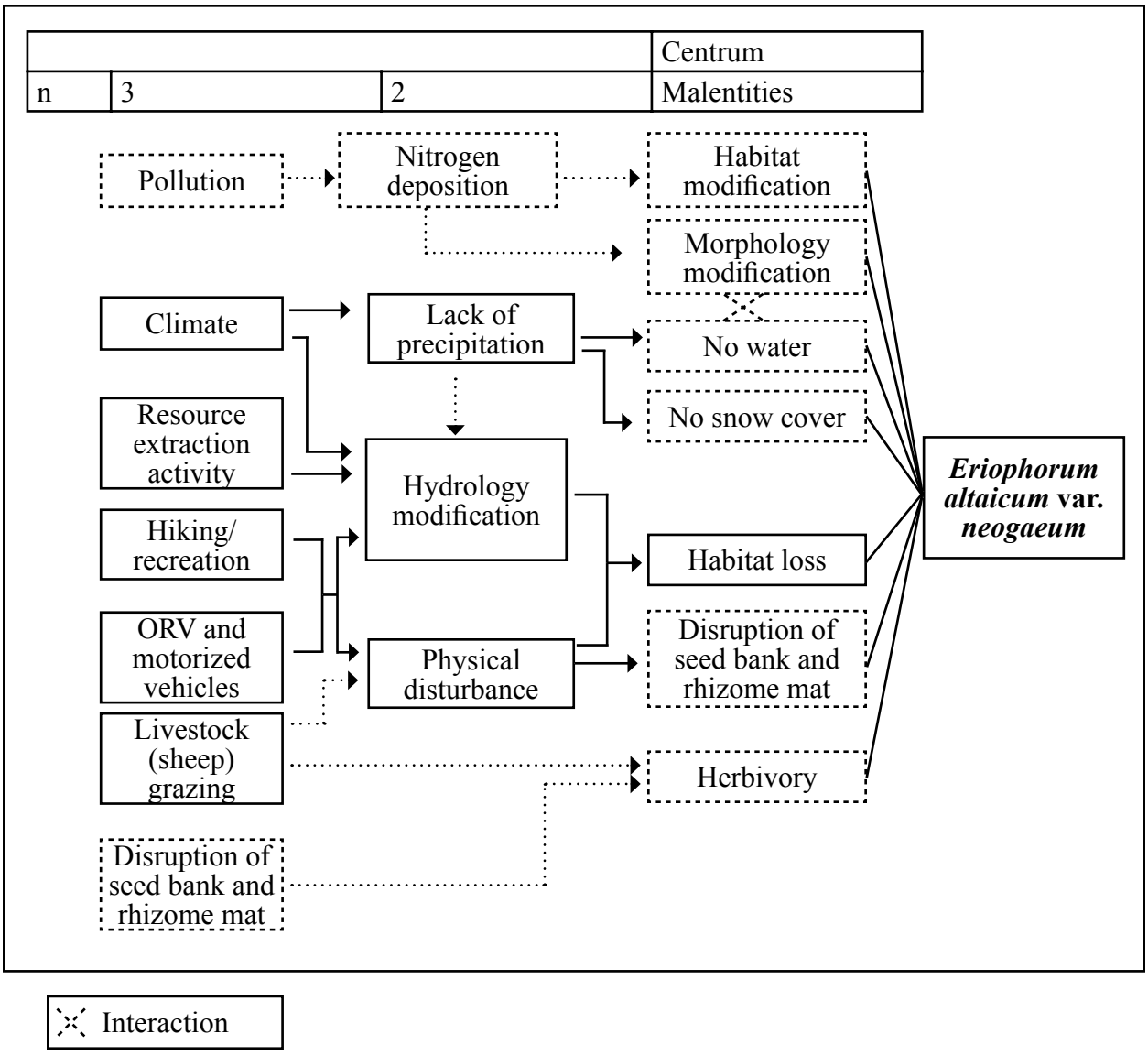

Figure 6. Envirogram outlining the malentities to *Eriophorum altaicum* var. *neogaeum*. Dotted boxes indicate resources or malentities that are either likely but not proven, or of a regional nature.

For example, supporting road networks can impact the hydrology of an area. In addition, even though boggy areas would appear unsusceptible to hiking and outdoor activities that use motor vehicles and horses, this species frequently grows at the edge of wetlands where trails, both unofficial and official, are often established (for example on the San Juan National Forest at occurrence 9 in **Table 3**).

Eriophorum species provide browse for musk oxen in the arctic (Streng 1999) and for caribou and reindeer in North America (Wein 1973). Lemmings utilize *E. vaginatum* in Canada (Krebs 1964). However, there is little reported use of *Eriophorum* species by vertebrate herbivores in other regions (Mason and Standen 1983). Impacts from sheep grazing activity have been specifically noted at one occurrence on the San Juan National Forest in Colorado (occurrence 20 in **Table 3**). However, it is not clear how palatable sheep find *Eriophorum* species. Erhard (1994) reported little significant use of *Eriophorum* species in the Rio Grande National Forest and suggested that one reason is the extremely wet conditions of that particular area. In Scotland, sheep are reported to specifically graze *Eriophorum* species (Wein 1973). In England, however, sheep did not appear to utilize the *Eriophorum* community substantially (Mason and Standen 1983). In both areas, the availability of alternative forage,

the particular *Eriophorum* species, or even the breed of sheep may have affected the herbivores' behavior. One study on *E. scheuchzeri* suggests that some level of grazing is likely tolerated, at least in the short term. Beaulieau et al. (1996) studied the response of *E. scheuchzeri* to geese grazing in the arctic. The grazed plants compensated for the loss of leaves and maintained production of leaves and tillers (biomass) to a level similar to the ungrazed plants. However, the compensation resulted in reduced belowground reserves that were likely deleterious if grazing was repeated over successive years. Beaulieau et al. (1996) concluded that grazing was not beneficial but that the plants responded in such a way that damage was minimized. Conversely, studies on muskox herbivory and *E. angustifolium* ssp. *triste* in the high arctic, demonstrated that although the density of *E. angustifolium* ssp. *triste* remained the same, the biomass was lower relative to that in ungrazed meadows. In addition, *E. angustifolium* ssp. *triste* was inadequately buffered against grazing due to its low underground biomass and early disintegration of rhizomes. Apparently, this species allocates more resources to sexual reproduction than some other *Eriophorum* species (Tolvanen and Henry 2000). These two examples demonstrate the differences between the responses of *Eriophorum* species due to life cycle strategy; they also demonstrate that precise demographic and growth conditions of *E. altaicum* var. *neogaeum* should be examined before assumptions are made.

Invasion by non-native, aggressive species is also a potential threat. Although *Eriophorum* species appear less susceptible to competition by invasive weeds due to their tall growth habit and habitat preferences, it is probably good management practice to eliminate non-native invasive species swiftly. Several invasive species, for example exotic thistles, teasel (*Dipsacus* spp.), purple loosestrife, and oxeye daisy, have invaded wetland regions at lower elevations, and new invasive species are continuously being introduced within the United States. At the present time, invasive species have not been observed in habitat occupied by *E. altaicum* var. *neogaeum*, but they have been found 0.5 miles downstream of occurrence 29 (**Table 3**) on the White River National Forest.

Interspecific hybridization may occur. Hybridization between *Eriophorum scheuchzeri* and *E. chamissonis* appears to occur in the Canadian arctic (Aiken et al. 1999). *Eriophorum angustifolium* x *E. chamissonis* and *E. angustifolium* x *E. vaginatum* hybrids have also been reported (Kartesz 1994). The frequency with which hybridization occurs is unclear. In addition, chromosome number may influence hybrid success. The chromosome number of *E. scheuchzeri* is reported to be 2n = 60 (Aiken et al. 1999) while for *E. angustiflolium*, *E. chamissonis*, and *E. vaginatum*, it is 2n = 58 (Grime et al. 1988, Ball and Wujek 2003). *Eriophorum* species can be successfully used in restoration projects (Gorham and Rochefort 2003). Use of non-local seed of *Eriophorum* species where the plant is native does raise the potential for genetic modification, or "dilution," of locally adapted genotypes by genotypes originally adapted to another region. Genetic contamination may pose a threat. However, because of the slow growth and apparent low turnover of individuals, the effects would be a long time in becoming apparent. For example, the cultivated genotypes may have particularly high fecundity and may be physiologically robust but not have the genetic composition to be resistant to environmental or biological (e.g. disease or insect infestation) events that are periodic (perhaps decades apart) in the local area.

Few comments can be made on the influence of demographic stochasticity on individual populations because there is no information on the survival probability of individuals at any given life-stage or age (see Demography section). Small populations are often considered genetically depauperate as a result of changes in gene frequencies due to inbreeding, or founder effects (Menges 1991), and locally endemic species tend to exhibit reduced levels of polymorphism (Karron 1991). However, while rare species can have statistically less genetic variation than their widespread congeners, there is a large range in values (Gitzendanner and Soltis 2000). In fact, some rare species exhibit levels of diversity equal to, or exceeding, that of widespread congeners (Gitzendanner and Soltis 2000). Without genetic evaluation, it is difficult if not impossible to predict the genetic vulnerability of *Eriophorum altaicum* var. *neogaeum*.

Natural catastrophes and environmental stochasticity are likely the primary threats to *Eriophorum altaicum* var. *neogaeum* at the rangewide scale. Global climate change threatens to cause a significant reduction in available habitat for alpine plants. Warming could affect alpine areas, causing tree lines to rise by roughly 350 feet for every degree Fahrenheit of warming. Mountain ecosystems such as those found in the Rocky Mountains could shift upslope, reducing habitat for many sub-alpine and alpine tundra species (U.S. Environmental Protection Agency 1997). In the last one hundred years the average temperature in Fort Collins, Colorado has increased 4.1 °F, and the amount of precipitation has decreased by up to 20 percent in many parts of the state. Based on

projections made by the Intergovernmental Panel on Climate Change and results from the United Kingdom Hadley Centre's climate model, by 2100 temperatures in Colorado could increase by 3 to 4 °F in spring and fall, with a range of 1 to 8 °F, and 5 to 6 °F in summer and winter, with a range of 2 to 12 °F (U.S. Environmental Protection Agency 1997).

Atmospheric deposition of nitrogen oxides and ammonium is increasing throughout the world. The western United States has been less affected than the east, but there are hotspots of elevated wet nitrogen (acid rain) deposition in southern California and along the Colorado Front Range when compared with the rest of the West (Baron 2001). Wet nitrogen deposition occurring in the high mountain areas of the Colorado Front Range is high enough to cause chemical and ecological change (Baron et al. 2000, Baron 2001, Rueth and Baron 2002). Some areas in the Colorado Rocky Mountains, such as the Maroon Bells-Snowmass Wilderness in the White River and Grand Mesa-Uncompahgre-Gunnison national forests, are at risk from deposition from emissions originating in southern California and Mexico as well as from the coal-fired power generation plants in Colorado and adjacent states (Hudnell et al. 1988-93). Experiments have indicated that nitrogen additions in alpine tundra influence the species composition of the community (Bowman et al. 1993, Theodose and Bowman 1997). In dry-meadows, grasses particularly increased in abundance, at the expense of forb species, in response to additional nitrogen. Vegetation composition in nutrient-rich sites, such as bogs, may be less affected by an increase in nitrogen than in nutrient-poor sites (Theodose and Bowman 1997). The consequence of increased nitrogen deposition on *Eriophorum altaicum* var. *neogaeum* is unknown, but additional nitrogen fertilization to *E. vaginatum* was reported to lead to a decrease in the xeromorphic characteristics (Müller-Stoll 1947 in Wein 1973). Therefore, increased nitrogen deposition may increase the vulnerability of *E. altaicum* var. *neogaeum* to drier conditions caused by global climate change.

Given the remote locations of most occurrences, other forms of pollution seem an unlikely threat. However, a study sponsored by the Colorado School of Mines, the National Park Service, and Public Counsel of the Rockies analyzed the chemical content of snow near a snowmobile route (Skid Marks Newsletter 2000, Ray 2001). It reported "an unnatural level of pollution", and at least 20 hydrocarbon compounds, some toxic and carcinogenic, were located 50 feet above the snowmobile route. As mentioned previously, trails frequently run alongside wetland and riparian areas. Because the presence of water may influence the distribution of pollutants in unexpected ways, the significance of this finding cannot be evaluated without further information.

Eriophorum altaicum var. *neogaeum* may accumulate some metal pollutants as well as certain minerals (Goodman and Perkins 1959). Copper, cadmium, aluminum, lead, potassium, insoluble ash, sodium, iron, and calcium were all higher in peat derived from *E. vaginatum* than that from *Sphagnum cuspidatum* (Clymo 1983). There was also an indication that the accumulation of ions is discriminatory because zinc levels were lower in *E. vaginatum*-derived peat than in *S. cuspidatum*-derived peat. This may have particular significance in mining areas where large stands of *Eriophorum* species could potentially become a repository for mining by-products and thus specifically contribute to "clean" water quality.

In summary, the threats to *Eriophorum altaicum* var. *neogaeum*, including those concerned with global climate change, likely depend upon the extent and intensity of the activity and the rarity of the species. At the present time, all threats appear to be at tolerable levels for this taxon. However, the emphasis is on "at the present time". Even if the intensity of a threat remains the same, an increase in its area of impact will have negative consequences on the species. Impacts from recreational pressures are becoming increasingly apparent. For example, thousands of people are estimated to walk in the alpine tundra regions in Colorado each weekend during the spring, summer, and autumn (Morrow 2002). On one trail alone, 250 people were counted on one weekend day, and hiking trails have become 12 to 15 feet wide in some areas; this widening is caused by people walking at the sides of established trails that have become slippery (Morrow 2002). In addition, Morrow (2002) reported some people were so averse to following designated trails that they destroyed trail markers. Low levels of herbivory and grazing are unlikely to substantially impact populations, but higher levels that reoccur on an annual basis may be more detrimental. Hydrological changes resulting in less available water and removal of the peat substrate either by erosion or extraction are probably the most critical threats. Although *E. altaicum* var. *neogaeum* habitat is typical of many alpine tundra systems that are relatively fragile and unable to recover rapidly from destructive forces, a positive factor is that the water-saturated nature of the habitat facilitates a more immediate recovery than very dry areas. The potential colonization by invasive and competitive plant species that will be exacerbated by anthropogenic

disturbances and warming temperatures should also not be underestimated.

At the current time, malentities and threats tend to be of local, rather than rangewide, importance and are indicated as such in the envirogram by dotted lines (**Figure 6**). Disturbance from recreational activities, for example trampling by hikers and recreational vehicles, directly contributes to habitat destruction. Sheep grazing or browsing appears a potential problem at only a few occurrences (Colorado Natural Heritage Program element occurrence records 2002). Air pollution has been included in the envirogram, as it is a significant threat to some populations. For example, the population in the vicinity of the Maroon Bells/Snowmass Wilderness may be vulnerable to pollutant sources from the west, southwest, and south (Hudnell et al. 1988-93). It is speculated that there may be a deleterious interaction between increased nitrogen deposition from pollution and global climate change. When nitrogen was applied to *Eriophorum vaginatum*, a decrease in the xeromorphic characteristics resulted (Müller-Stoll 1947 in Wein 1973). Therefore, plants would be less drought-resistant at a time of increased temperature and lower precipitation. In the future, invasive plant species may be direct competitors for resources such as water, nutrients, and light. The extent and duration of malentities are important factors and need further study.

Conservation Status of the Species in Region 2

There is no evidence that the distribution or abundance of *Eriophorum altaicum* var. *neogaeum* is changing, but it appears to be relatively rare. The majority of known occurrences are on land managed by the USFS Region 2. Sustainability of *E. altaicum* var. *neogaeum* populations may rely on relatively long-lived mature individuals and populations. Thus management practices that increase either the frequency or intensity of natural perturbations, or provide additional stresses, may significantly negatively impact population viability. The importance of maintaining a suitable hydrological status is paramount to the longevity of all occurrences. At the present time, within Region 2 jurisdiction, there appear to be several occurrences that, because of specific designation of land management unit, for example wilderness status or remote location, are relatively secure (see Existing Regulatory Mechanisms, Management Plans, and Conservation Strategies section).

Management of the Species in Region 2

Implications and potential conservation elements

The name *Eriophorum altaicum* var. *neogaeum* has been placed in synonymy with *E. chamissonis* (Ball and Wujek 2002). However, while some plant specimens initially identified as *E. altaicum* var. *neogaeum* in Region 2 have been reevaluated and identified as *E. chamissonis*, others cannot be classified as such (see discussion in Systematics and synonymy section). These specimens may represent a unique taxon, or alternatively they may be *E. scheuchzeri*.

Eriophorum scheuchzeri is relatively widespread, being a circumboreal species that ranges south to Newfoundland in Canada, and the Pacific Northwest in the United States, where it is rare (Ladyman 2005). This taxon appears to have a substantial number of disjunct occurrences. It is found in the alpine zones in the Alps of central Europe (Ellenberg 1988) and on Mt. Daisetu in Hokkaiko, Japan where it is also reported as rare and is described as *E. scheuchzeri* var. *tenuifolium* (Ohwi 1965). In the 48 contiguous states it has been found in small isolated mountain locales in the high mountains of Montana, Utah, Colorado (Cronquist et al. 1977), and Wyoming (Dorn 2001). Although widespread, *E. scheuchzeri* appears to be particularly rare in the more disjunct locations. Its distribution suggests that it is a relic from the Pleistocene, or last "ice-age." Similarly, *E. chamissonis* is more widespread, but it is also rare in several states (see Distribution and abundance section).

Essentially, all *Eriophorum* species with a single-spikelet per stem are rare within the range that includes Region 2. The majority of known occurrences of both *E. altaicum* var. *neogaeum* and *E. chamissonis* in Colorado are located on land managed by the USFS (**Table 3**). In addition, *E. chamissonis* is known from only four extant occurrences and five historical records in Wyoming (Welp and Fertig 2000). Several of the historical sites could not be relocated in recent years, suggesting a possible downward trend (Welp and Fertig 2000). *Eriophorum chamissonis* has been reported from Yellowstone National Park and the Bighorn and Shoshone national forests (Welp and Fertig 2000). One population is found in the Preacher Rock Bog Special Interest Area in the Bighorn National Forest (Welp and Fertig 2000). The USFS defines special

interest areas (SIAs) as areas that are managed to protect unusual characteristics (Native Plant Conservation Campaign undated). Typically, SIAs have been designated as botanical, geological, historical, cultural, paleontological, scenic, or zoological areas. Management emphasis is on protecting or enhancing, and where appropriate, developing and interpreting for public education and recreation, the unusual characteristics of these areas. Unusual characteristics may include threatened, endangered, or sensitive species; other elements of biological diversity; or emotional significance, scenic values, or public popularity. SIAs vary in size from small to fairly large (Native Plant Conservation Campaign Undated).

Eriophorum altaicum var. *neogaeum* grows in fragile alpine tundra habitat, which is slow to recover from disturbance (Willard 1979). The growing season is very short, and environmental conditions can be severe. It is likely that some practices, such as mining and certain recreational activities, have impacted populations in the past. Minimizing hydrological changes that result in drier conditions and maintaining the water-saturated peat substrates are likely to be primary management goals. The problem is that there is little information on which to base predictions as to the taxon's response to specific disturbance types or levels, so the vulnerability of *E. altaicum* var. *neogaeum* is unclear (see Demography and reproductive biology and autecology sections).

It is likely that the most geographically separate populations of any taxon will have the greatest genetic divergence, and a significant loss of genetic diversity will likely result if populations at the edge of the range, or in obviously disjunct localities, are lost. The commercial availability of *Eriophorum* species raises an important issue for restoration. Introduction of a non-local *Eriophorum* species into an area where native plants are already established may be detrimental. There may be a high degree of differentiation into local races (Grant 1981). The impact of introducing *Eriophorum* species to an area with no apparent current population is also unclear (see Reproductive biology and autecology section). Observations on a related species indicated that the genetic composition of seeds in the seed bank was different from that of an extant population (see Reproductive biology and autecology section). This raises questions as to the age of the seeds in the seed bank, the triggers involved in their germination, and the frequency of natural recruitment.

The reasons for the patchy nature of *Eriophorum altaicum* var. *neogaeum*'s distribution are unknown. Studies of the populations at the proposed Warren Lakes RNA on the White River National Forest may provide insight into the rate of colonization, the preferred habitat conditions, and the response to disturbance. There is evidence that *Eriophorum* species require some disturbance for seed germination, and burning has been shown to prompt flowering in some species (Wein and MacClean 1973). However, increasing flowering may not be particularly advantageous because, in most cases, 80 percent of each occurrence of *E. altaicum* var. *neogaeum* in Colorado has been observed to be flowering.

It is critical to remember that most observations reported here have been made on related species in other geographical areas and that there is evidence that even the same species has different habitat niches and, by extrapolation, different physiological mechanisms depending on geographical location (see Community ecology section). The information on the wide variety of *Eriophorum* species in this assessment has been provided in order to present an understanding of the genus and also to suggest some of the factors to consider for either future study or when developing a management strategy.

Tools and practices

Documented inventory and monitoring activities are needed for *Eriophorum altaicum* var. *neogaeum* and other species with solitary spikelets in Colorado and Wyoming. Careful identification of specimens deposited with herbaria accessible to the public is essential. Much of the available occurrence information is derived from herbarium specimens or relatively casual observations by botanists and does not provide quantitative information on abundance or spatial extent of the populations. In addition, there is little information on population structure and persistence of either individuals or populations.

Species inventory

Relatively little information has been collected on *Eriophorum altaicum* var. *neogaeum*. An important consideration in inventorying this particular species is that it might be confused with other species, particularly when access to individuals is difficult because of wet, boggy conditions. For example, it might be confused with the non-rhizomatous *E. callitrix*. This species is not currently reported to grow in Colorado but does occur in Wyoming (see History of species section). It is also important to remember during field identification that *E. altaicum* var. *neogaeum* grows in close association with

other species of *Eriophorum*, such as *E. angustifolium*; this may make estimates of abundance more difficult. The current field survey forms for endangered, threatened, or sensitive plant species used by the Gunnison National Forest and the Colorado Natural Heritage Program both request observations that are appropriate for inventory purposes. The number of individuals (stems), the area they occupy, and the area of apparent potential habitat is important information for occurrence comparison. The easiest way to describe populations over a large area may be to count patches, make note of their extent, and estimate or count the numbers of individual stems within patches, recognizing that a patch may be genetically homogeneous and may contain more than one species. Collecting information on phenology, especially flowering, is also valuable in assessing the vigor of a population. Observations on habitat should also be recorded.

Habitat inventory

The available information on habitat supplied with descriptions of occurrences is generally too diverse and in insufficient detail to make accurate analyses. Habitat descriptions suggest that, within the restrictions of geology and the eco-climate zones in which it exists, this species grows in both bogs and fens. It would likely be prudent to consider essentially any areas with permanently water-saturated conditions in alpine tundra and sub-alpine regions above 3,000 m as potential habitat. However, there is an insufficient understanding of all the features that comprise "potential" habitat to be able to make a rigorous inventory of areas that will actually be colonized. There are no studies that relate the abundance or vigor of populations to habitat conditions or even elevation. The patchy and sparse distribution pattern of *Eriophorum altaicum* var. *neogaeum* suggests that certain microclimate conditions need to be met to support plants. However, what those specific conditions are is unknown.

Population monitoring

No long term monitoring or demographic studies have been reported. In 2001, an effort was made to map and describe patches comprising populations in the Warren Lakes RNA of the White River National Forest. These data will provide an excellent baseline on which to design a monitoring program in this area. Although monitoring patches may be very valuable, using permanent transects or some other scheme to avoid autocorrelation induced by the sampling method may be the most accurate way to study long-term trends. Elzinga et al. (1998) and Goldsmith (1991) have discussed using transect lines to effectively monitor the clumped-gradient nature of populations; this method would apply to the most abundant populations.

Habitat monitoring

The relative lack of information on habitat requirements makes it premature to consider that habitat monitoring in the absence of plants can effectively occur. Habitat monitoring in the presence of plant occurrences should be associated with population monitoring protocols. Descriptions of habitat should always be recorded during population monitoring activities in order to link environmental conditions with abundance over the long term. Conditions several years prior to the onset of a decrease or increase in population size may be more important than conditions during the year the change is observed. Current land use designation and evidence of land use activities are important to include with monitoring data. For example, it should be noted if there is evidence of mining, grazing, or recreational use. Observations on the impacts on individuals at the extreme edges of the wetlands as compared to those in the wettest areas would be valuable.

Population or habitat management approaches

There have been no systematic monitoring programs for the populations in protected areas, and therefore the benefits of protection cannot be evaluated. Beneficial management practices that have been generally implemented within national forests include restricting recreational vehicle traffic and routing hikers to designated trails. In many cases, such policies have been relatively recently initiated, and their consequences have not been documented. Creating designated trails is particularly important to populations that are on heavily used routes.

Information Needs

The highly variable morphological descriptions and the speciation pressures that are likely to have occurred to *Eriophorum* species within their localized and disjunct populations suggest that they are good candidates for genetic analyses at the molecular level. Speciation of isolated populations is well documented (Grant 1981). Molecular studies may clarify the taxonomic distinctions between *E. altaicum* var. *neogaeum* (in Colorado), *E. chamissonis*, and *E. scheuchzeri* and lead to new interpretations of the morphological variation within the latter two taxa.

At the present time *Eriophorum altaicum* var. *neogaeum*, *E. chamissonis*, and *E. scheuchzeri* all appear to be uncommon in the Rocky Mountains in the United States. If *E. altaicum* var. *neogaeum* represents a unique genotype in Colorado, then it would be particularly rare. Although one cannot say with certainty that *E. altaicum* var. *neogaeum* has not experienced a decline in the last century, for example due to peat mining, it appears to exist in several healthy and relatively stable wetland environments in Colorado. More information on the numbers and distribution of this species is required. Its perceived rarity in Colorado is obviously influenced by its relatively rare habitat. However, its rarity within suitable habitat may be due to a lack of surveys or it may have been overlooked or misidentified in the field. Monitoring pre-existing sites is essential in order to understand the implications of existing and new management practices. Where management practices are likely to change, inventory should be taken to collect baseline data, and periodic monitoring should be conducted after the new practice is initiated. Therefore, inventory and periodic monitoring of existing sites appear to be the most important needs.

Habitat requirements of this species need to be more rigorously defined; it is unclear as to what constitutes optimal, adequate, and marginal (implying unsustainable) habitat. Facts pertaining to *Eriophorum altaicum* var. *neogaeum*'s reproductive biology are generally based upon studies of other species. The relative importance of different stages of the life cycle is also inferred by morphological characteristics and by comparison with other *Eriophorum* species rather than through direct studies on the species occurring in Region 2. The factors that limit population size and abundance and that contribute to the variable occurrence sizes are not known and should be determined. The spatial dynamics of populations are also unknown. Because of the peat building processes associated with its environment, it is assumed that populations are long-lived, but the reasons for its patchy distribution need to be better defined. Management practices may also consider that this is an important arthropod host species and therefore may be important to the ecology of the Palustrine System.

In summary, information needs are as follows:

- The identification of the *Eriophorum* species needs clarification in many populations in Colorado.
- Further surveys are needed for populations of solitary-headed *Eriophorum* taxa while ensuring that accurate identifications are made.
- Habitat requirements need to be more rigorously defined.
- The factors that limit population size and abundance and that contribute to the variable occurrence sizes should be determined.

DEFINITIONS

Achene — Dry, usually single-seeded fruit. "Seed" in common terminology.

Acuminate — Tapering to the apex but with the sides pinched in before reaching the tip (Harrington and Durrell 1957).

Bog — A peatland that only derives water and nutrients from the atmosphere. Bogs are highly acidic and nutrient-poor and dominated by sphagnum mosses and ericaceous shrubs. Bogs occur on peat elevated above the water table. Compare to "fen".

Culm — Stem of a grass, sedge, or rush.

Cuneate — Wedge-shaped (Harrington and Durrell 1957).

Fen — A peatland that receives significant inputs of water and dissolved solids from a mineral source such as runoff from mineral soil or ground water discharge. A fen is considered geogenous and its vegetation minerotrophic. Compare to "bog".

Globose — Spherical like a "globe."

Hyaline — Translucent or transparent (after Allaby 1992).

Lanceolate — Shaped like a lance that is broader at the base and tapering towards the apex (Harrington and Durrell 1957).

Marshes — These are wetlands dominated by graminoids on mineral soils, for example around the edges of a lake or on an undrained flood plain of a river (after Allaby 1992). Marshes are distinct from bogs, which have peaty soils, but colloquially the term is often used interchangeably with bog (Allaby 1992).

Mire development — For a good illustration of the different mire development processes and explanations of concave and convex phase see Botch and Masing 1983.

Ovate — Egg-shaped in outline and attached at the wide end (Harrington and Durrell 1957). Sub-ovate indicates the object is "almost ovate".

Ranks — NatureServe and the Heritage Programs Ranking system (Internet site: http://www.natureserve.org/explorer/granks.htm).

> G4 designation indicates that the species is "Apparently Secure—Uncommon but not rare (although it may be rare in parts of its range, particularly on the periphery), and usually widespread. Apparently not vulnerable in most of its range, but possibly cause for long-term concern. Typically more than 100 occurrences and more than 10,000 individuals."
>
> The "?" after G4 rank indicates that the numeric rank is questionable, or "inexact" and is subject to modification when more information on the taxon is gathered.
>
> The T designation is applied to subspecies or varieties, "the status of infraspecific taxa (subspecies or varieties) are indicated by a "T-rank" following the species' global rank. The global rank of a critically imperiled subspecies of an otherwise widespread and common species would be G5T1."
>
> T3 designation indicates that the subspecies is "Vulnerable"—"Vulnerable in the nation or subnation either because it is rare and uncommon, or found only in a restricted range (even if abundant at some locations), or because of other factors making it vulnerable to extirpation. Typically 21 to 100 occurrences or between 3,000 and 10,000 individuals". "T4" indicates the same as G4, that is the subspecies is apparently secure.
>
> T3T4 indicates the rank is uncertain between "vulnerable" and "apparently secure".

S3 indicates that the taxon in Colorado it is "Vulnerable—Vulnerable in the nation or subnation [state] either because rare and uncommon, or found only in a restricted range (even if abundant at some locations), or because of other factors making it vulnerable to extirpation. Typically 21 to 100 occurrences or between 3,000 and 10,000 individuals."

Rhizome — A trailing stem growing partly or completely beneath the ground surface and usually rooting at the nodes (Harrington and Durrell 1957).

Stolon — A trailing stem that grows aboveground and roots at the nodes (Harrington and Durrell 1957).

Subobtuse — Somewhat rounded or blunt at the apex.

Swamp — A wet area that is normally covered by water all year and is not subject to drying out during the summer (Allaby 1992).

Terete — "Circular in cross-section and more or less elongated. Like cylindrical but may be slightly tapering" (Harrington and Durrell 1957).

Tiller — Typically used for grasses to describe a lateral shoot arising at ground level.

Trigonal — Three-angled. Subtrigonal indicates the object is "almost trigonal." In this case the angles may not be well defined.

Xeromorphic — Applied to organisms that show morphological adaptations that enable them to withstand drought (Allaby 1992).

COMMONLY USED SYNONYMS OF PLANT SPECIES

Commonly used synonyms of plant species mentioned in this report (Kartesz 1994).

The reference in parenthesis refers to a flora in Region 2 in which the synonym is used:

Geum rossii	*Acomastylis rossii* (Weber and Wittmann 2001a and 2001b)
Saxifraga oregana	*Micranthes oregana* (Weber and Wittmann 2001a and 2001b)

Common synonyms of other *Eriophorum* species (Kartesz 1994) in USDA Forest Service – Region 2:

Eriophorum angustifolium Honck.	*Eriophorum polystachion* L. p.p.
Eriophorum callitix Cham. ex Meyer	None
Eriophorum gracile Koch	None
Eriophorum russeolum ssp. *rufescens* (E. Anders.) Hyl.	*Eriophorum chamissonis* Meyer
Eriphorum viridicarinatum (Engelm.) Fern	None

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