Kobresia simpliciuscula (Wahlenberg) Mackenzie (simple bog sedge): A Technical Conservation Assessment

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

March 22, 2006

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

Peer Review Administered by
Center for Plant Conservation

Decker, K., D.R. Culver, and D.G. Anderson. (2006, March 22). *Kobresia simpliciuscula* (Wahlenberg) Mackenzie (simple bog sedge): a technical conservation assessment. [Online]. USDA Forest Service, Rocky Mountain Region. Available: http://www.fs.fed.us/r2/projects/scp/assessments/kobresiasimpliciuscula.pdf [date of access].

Acknowledgments

We appreciate the helpfulness and generosity of all who contributed time and information to this assessment, particularly Barry Johnston, Bonnie Heidel, Ken Houston, John Proctor, and Annette Miller. Tim Hogan (COLO), Ron Hartman and Ernie Nelson (RM), and the CSU herbarium provided herbarium specimen label data. Shannon Gilpin assisted with literature acquisition. Thanks also to Greg Hayward, Gary Patton, Jim Maxwell, Andy Kratz, Beth Burkhart, and Joy Bartlett for assisting with questions and project management.

Authors' Biographies

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

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

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

Summary of Key Components for Conservation of *Kobresia simpliciuscula*

Status

Kobresia simpliciuscula (simple bog sedge) is a sensitive species in USDA Forest Service Region 2. It is known from 28 documented occurrences within Region 2, all but one of which are in Colorado. Thirteen occurrences are entirely or partially on National Forest System land, including five occurrences in the Indian Peaks Wilderness Area on the Arapaho-Roosevelt National Forest, seven occurrences on the Pike-San Isabel National Forest, and one at the Swamp Lake Special Botanical Area on the Shoshone National Forest in Wyoming. One occurrence is on Bureau of Land Management land, two are on State of Colorado land, and the remaining twelve occurrences are on privately owned land. NatureServe (2005) ranks *K. simpliciuscula* globally as "demonstrably secure" (G5). State Natural Heritage Program ranks for this species are "critically imperiled" (S1) in Wyoming and "imperiled" (S2) in Colorado; it has not been documented in Kansas, Nebraska, or South Dakota (NatureServe 2005, USDA-Natural Resources Conservation Service 2005).

Primary Threats

The primary threats to *Kobresia simpliciuscula* and its habitat are hydrologic alterations, peat mining, grazing, and global climate change. A lack of basic information on this species' population genetics, dispersal biology, and demography adds to the potential severity of these threats because it hinders the development of appropriate management practices. Since several of the occurrences in Region 2 are small, stochastic processes are also a threat.

Primary Conservation Elements, Management Implications and Considerations

Current knowledge of the distribution and abundance of *Kobresia simpliciuscula* in Region 2 suggests that the species is vulnerable due to the small number of disjunct occurrences and its restriction to a relatively rare habitat. Region 2 occurrences are most vulnerable to changes in the environment that affect their wet alpine and fen habitats. Any management activities that maintain an appropriate hydrologic regime in these habitats will benefit *K. simpliciuscula*. This includes regulating and monitoring hydrological modifications, domestic grazing, and peat mining. *Kobresia simpliciuscula* should remain a species of concern and land managers should focus on expanding knowledge of its distribution and habitat.

Table of Contents

ACKNOWLEDGMENTS 2
AUTHORS' BIOGRAPHIES 2
SUMMARY OF KEY COMPONENTS FOR CONSERVATION OF *KOBRESIA SIMPLICIUSCULA* 3
Status 3
Primary Threats 3
Primary Conservation Elements, Management Implications and Considerations 3
LIST OF TABLES AND FIGURES 6
INTRODUCTION 7
Goal of Assessment 7
Scope of Assessment 7
Treatment of Uncertainty in Assessment 7
Treatment of This Document as a Web Publication 8
Peer Review of This Document 8
MANAGEMENT STATUS AND NATURAL HISTORY 8
Management Status 8
Existing Regulatory Mechanisms, Management Plans, and Conservation Strategies 8
Adequacy of current laws and regulations 13
Adequacy of current enforcement of laws and regulations 13
Biology and Ecology 13
Classification and description 13
Systematics and synonymy 13
Description 13
Published descriptions and other sources 15
Distribution and abundance 15
Population trend 17
Habitat 17
Reproductive biology and autecology 18
Life history and strategy 18
Reproduction 19
Pollination and pollination ecology 20
Dispersal mechanisms 20
Cryptic phases 20
Phenotypic plasticity 20
Mycorrhizal relationships 20
Hybridization 20
Parasites and disease 20
Demography 20
Community ecology 21
CONSERVATION 22
Threats 22
Altered hydrology 22
Grazing 22
Peat mining 23
Global climate change 23
Influence of management activities or natural disturbances on habitat quality 23
Influence of management activities or natural disturbances on individuals 23
Interaction of the species with exotic species 23
Threats from over-utilization 23
Conservation Status of *Kobresia simpliciuscula* in Region 2 24
Management of *Kobresia simpliciuscula* in Region 2 24
Implications and potential conservation elements 24
Tools and practices 24

Inventory and monitoring of populations and habitat 24
Beneficial management actions 26
Seed banking 26
Information Needs....26
Research priorities for Region 2....26
Additional research and data resources 27
DEFINITIONS....28
REFERENCES 29

EDITORS: Beth Burkhart and Janet Coles, USDA Forest Service, Rocky Mountain Region

LIST OF TABLES AND FIGURES

Tables:

Table 1. Documented occurrences of *Kobresia simpliciuscula* in Region 2..... 9

Table 2. Species associated with *Kobresia simpliciuscula* in Region 2..... 19

Figures:

Figure 1. Documented occurrences of *Kobresia simpliciuscula* in Region 2..... 12

Figure 2. Illustration of *Kobresia simpliciuscula* inflorescence. 14

Figure 3. Herbarium specimen of *Kobresia simpliciuscula*..... 15

Figure 4. Distribution of *Kobresia simpliciuscula* in North America..... 16

Figure 5. Photographs of *Kobresia simpliciuscula* habitat in extreme rich fens of South Park, Colorado. .. 18

Figure 6. Generalized life-cycle diagram for *Kobresia simpliciuscula*. 21

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). *Kobresia simpliciuscula* (simple bog sedge) is the focus of an assessment because it is a sensitive species in Region 2 (USDA Forest Service 2005). Within the National Forest System, a sensitive species is plant or animal whose population viability is identified as a concern by a Regional Forester because of significant current or predicted downward trends in abundance or significant current or predicted downward trends in habitat capability that would reduce its distribution (FSM 2670.5(19)). A sensitive species may require special consideration in management; therefore knowledge of its biology and ecology is critical. This assessment addresses the biology of *K. simpliciuscula* throughout its range in Region 2. This introduction defines the goal of the assessment, outlines its scope, and describes the process used in its production.

Goal of Assessment

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

Scope of Assessment

This assessment examines the biology, ecology, conservation status, and management of *Kobresia simpliciuscula* with specific reference to the geographic and ecological characteristics of Region 2. Although much of the literature on this species originates from field investigations outside the region, this document places that literature in the ecological and social context of the central Rocky Mountains. Similarly, this assessment is concerned with the reproductive behavior, population dynamics, and other characteristics of *K. simpliciuscula* in the context of the current environment rather than under historic conditions.

In producing the assessment, refereed literature, non-refereed publications, research reports, and data accumulated by resource management agencies were reviewed. All publications referring to *Kobresia simpliciuscula* in Region 2 are referenced in this assessment, and many references treating material from outside Region 2 are also included. Because many aspects of the biology and ecology of *K. simpliciuscula* have not been studied, literature on its congeners was used to make inferences. The assessment emphasizes refereed literature because this is the accepted standard in science. Non-refereed publications or reports were used, however, as they are often the only sources of information about *K. simpliciuscula* occurrences in Region 2; these references were regarded with greater skepticism. Unpublished data (e.g., herbarium specimen labels, Natural Heritage Program records and reports) contain the majority of useful information on *K. simpliciuscula* in Region 2, and they were important in estimating its geographic distribution. These data required special attention because of the diversity of persons and methods used in their collection.

Kobresia simpliciuscula specimens were viewed at University of Colorado Herbarium (COLO), Colorado State University Herbarium (CS), KDH (Kathryn Kalmbach Herbarium, Denver Botanic Gardens), and Rocky Mountain Herbarium (RM). University of Northern Colorado Herbarium (GREE) was searched, but no *K. simpliciuscula* specimens were found. Element occurrence data were obtained from the Colorado Natural Heritage Program and the Wyoming Natural Diversity Database.

Treatment of Uncertainty in Assessment

Science represents a rigorous, systematic approach to obtaining knowledge. Competing ideas regarding how the world works are measured against observations. However, because our descriptions of the world are always incomplete and our observations are limited, science focuses on approaches for dealing with uncertainty. A commonly accepted approach to science is based on a progression of critical experiments to develop strong inference (Platt 1964). However, it is difficult to conduct experiments that produce clean results in the ecological sciences. Often, observations, inference, critical thinking, and models must be relied

on to guide our understanding of ecological relations. In this assessment, the strength of evidence for particular ideas is noted, and alternative explanations are described when appropriate.

Treatment of This Document as a Web Publication

To facilitate the use of species assessments in the Species Conservation Project, they are being published on the Region 2 World Wide Web site (http://www.fs.fed.us/r2/projects/scp/index.shtml). Placing the documents on the Web avails them to agency biologists and the public more rapidly than publishing them as reports.

Peer Review of This Document

Assessments developed for the Species Conservation Project are peer reviewed before release on the Web. This assessment was reviewed through a process administered by the Center for Plant Conservation, employing 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

Kobresia simpliciuscula is a sensitive species in Region 2 (USDA Forest Service 2005). There are 28 documented occurrences within Region 2 administrative boundaries; all but one of these are in Colorado (**Table 1**, **Figure 1**). Thirteen occurrences are entirely or in part on National Forest System land. These include five occurrences in the Indian Peaks Wilderness Area on the Arapaho-Roosevelt National Forest, seven occurrences on the Pike-San Isabel National Forest, and one at the Swamp Lake Special Botanical Area on the Shoshone National Forest in Wyoming. One occurrence is on Bureau of Land Management (BLM) land, two are on State of Colorado land, and the remaining twelve occurrences are on privately owned land. The Summit Lake occurrence at Mt. Evans is located on a private inholding in the Mt. Evans Wilderness Area of the Arapaho-Roosevelt National Forest. Four of the privately owned occurrences are located on properties either owned by a conservation organization or protected by a perpetual conservation easement.

The current NatureServe (2005) global rank for *Kobresia simpliciuscula* is "secure" (G5). It is considered "critically imperiled" (S1) in Wyoming because it is known from only one verified occurrence (Fertig 2000, Wyoming Natural Diversity Database 2003). In Colorado, *K. simpliciuscula* is considered "imperiled" (S2); of the 27 occurrences, 12 have not been visited in more than 20 years. *Kobresia simpliciuscula* is also an indicator species in a globally "imperiled" (G2) plant community, *Kobresia simpliciuscula-Trichophorum pumilum* Saturated Herbaceous Vegetation (Sanderson and March 1996, Carsey et al. 2003, NatureServe 2005).

Existing Regulatory Mechanisms, Management Plans, and Conservation Strategies

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

Six of the thirteen documented occurrences in Region 2 are on National Forest System lands with special designations. Five Colorado occurrences are in the Indian Peaks Wilderness Area on the Arapaho-Roosevelt National Forest. This area is protected by the Wilderness Act of 1964 (16 U.S.C. 1131-1136, 78 Stat. 890), which prohibits the use of mechanized or motorized equipment in wilderness areas but still allows a variety of other activities, including hiking, horseback riding, camping, hunting, fishing and grazing. Although wilderness area designations do not explicitly protect *Kobresia simpliciuscula*, occurrences in wilderness areas are less likely to be at risk than occurrences on lands where more uses are allowed. The Wyoming occurrence is in the Swamp Lake Botanical Special Interest Area (SIA) on the Shoshone National Forest. A SIA designation is intended to protect or enhance an area with significant botanical, geological, historic, paleontological, scenic, or zoological characteristics.

Table 1. Documented occurrences of *Kobresia simpliciuscula* in USDA Forest Service Region 2.

	State County	Land Ownership/ Management	Year Observed	Location	Elevation (ft.)	Habitat	Source ID
1	CO Boulder	Private	1972	Arapaho Glacier cirque	11,300	Cirque.	V. Komarkova #sn
2	CO Boulder	USDA Forest Service (USFS) Arapaho-Roosevelt National Forest Boulder Ranger District, Indian Peaks Wilderness Area	1972	Coney Lake	10,050	Above and around the upper Coney Lake (north of Paiute Peak and Mt. Audubon).	V. Komarkova #sn
3	CO Boulder	USFS Arapaho-Roosevelt National Forest Boulder Ranger District, Indian Peaks Wilderness Area	1972	Mount Audubon	12,500	Saddle of northeast shoulder of Mount Audubon.	V. Komarkova #sn
4	CO Boulder	Unknown	1961, 1968	Niwot Ridge; vicinity of Ward	11,000 to 12,500	Wet tundra.	E. Dahl #sn. with A. Szlovak & W. Osburn; O. Ronning #308/ 67O; Ronning #68
5	CO Clear Creek	Private (inholding in Mt. Evans Wilderness Area, Arapaho-Roosevelt National Forest)	1953, 1960	Summit Lake, Mt. Evans	12,800	On gravels around ice-push ponds at outlet of Summit Lake; bogs along outlet stream eastward.	Weber, Porsild, and Holmen #11,133; L. and E.H. Kelso #6824
6	CO Grand	USFS Arapaho-Roosevelt National Forest Sulphur Ranger District, Indian Peaks Wilderness Area	1972	Buchanan Pass	11,250	Cirque with five small lakes.	V. Komarkova #sn
7	CO Grand	USFS Arapaho-Roosevelt National ForestSulphur Ranger District, Indian Peaks Wilderness Area	1972	Island Lake Valley, east side of Cooper Peak	11,350	Unknown	V. Komarkova #sn
8	CO Grand	USFS Arapaho-Roosevelt National Forest Sulphur Ranger District, Indian Peaks Wilderness Area	1972	Lake Envy cirque	11,000	Cirque	V. Komarkova #sn

Table 1 (cont.).

	State County	Land Ownership/ Management	Year Observed	Location	Elevation (ft.)	Habitat	Source ID
9	CO Gunnison	Private	2002	Cement Creek warm springs	9,300	Extreme rich fen.	F.J. Rocchio #02FJR10
10	CO Park	Private / USFS Pike-San Isabel National Forest South Park Ranger District	1985	Head of Pennsylvania Creek, Mosquito Range	12,700	Wet meadow.	B. Neely and S. O'Kane #3134
11	CO Park	Private	1990	Trout Creek Ranch	9,220	In hummocky extreme rich fen, dominating the tops of peat hummocks	D.J. Cooper #1911; CNHP community EO-7; Cooper 1990 survey
12	CO Park	Private	1995	Middle Fork of the South Platte River	9,500	Extreme rich fen.	CNHP community EO-10; Sanderson 1995 survey
13	CO Park	Private Owned by The Nature Conservancy since 1991	1989, 1995	High Creek Fen	9,200	Forming tussocks in less inundated portions of the fens; calcareous fens and scattered blue spruce, east of highway in rich fens.	W.A. Weber #18031 with D. Cooper and J. Sanderson #954; CNHP community EO-11
14	CO Park	Private	1995	Jefferson and Guernsey creeks	9,680 to 9,720	Extreme rich fen, hummocks throughout.	CNHP community EO-1; Sanderson 1995 survey
15	CO Park	Colorado State Land Board	1995	Old Railroad; north of Antero Reservoir	8,960 to 8,980	Extreme rich fen, hummocks throughout.	CNHP community EO-2; Sanderson 1995 survey
16	CO Park	Private	1995	South Fork of South Platte fen	9,140 to 9,160	Well developed peatland.	CNHP community EO-3; Sanderson 1995 survey
17	CO Park	Private Owned by The Nature Conservancy since 2000	1995	High Creek at Warm Springs	9,830 to 9,960	Riparian peatland.	CNHP community EO-4; Sanderson 1995 survey
18	CO Park	USFS Pike-San Isabel National Forest South Park Ranger District	1995	Crooked Creek Spring	10,040	Part of a series of fens fed by ground and surface water	CNHP community EO-5; Sanderson 1995 survey
19	CO Park	Private	1990, 2000	Silver Heels Ranch	9,830	Irrigated meadow with some large springs; peat and glacial outwash.	CNHP community EO-6; Cooper 1990 survey; Culver 2000 survey
20	CO Park	Bureau of Land Management Royal Gorge Field Office	1990, 2000	Tarryall Creek	9,630	Creek and associate springs on alluvium and peat.	CNHP community EO-8; Cooper 1990 survey; Culver 2000 survey
21	CO Park	Colorado State Land Board	1995	Fourmile Creek	9,860	Hummocky mire community.	CNHP community EO-9; Sanderson 1995 survey
22	CO Park	USFS Pike-San Isabel National ForestSouth Platte Ranger District	1995	Geneva Park	9,600	On hummocks in fen; common in rich fen at the lip of the park above the canyon.	N. Lederer #GP-95-60; W.A. Weber #18077 with Tim Hogan

Table 1 (concluded).

	State County	Land Ownership/ Management	Year Observed	Location	Elevation (ft.)	Habitat	Source ID
23	CO Park	USFS Pike-San Isabel National Forest South Park Ranger District	1960	Hoosier Ridge	12,000	South side of ridge, along streamlets of solifluction terraces.	Weber #11123 with Holmen and Porsild RM, CS
24	CO Park	Private	1990	Michigan Creek Ranch	Unknown	On hummocks in rich fen; in wetter sites than *Kobresia myosuroides*	D.J. Cooper #1839
25	CO Park	Private / USFS Pike-San Isabel National Forest South Park Ranger District	1998	Mosquito Range; south of Weston Pass, just west of Ruby Mine	11,875	Moist snowmelt scree; in moss filled rivulets on gravelly slope below melting snowbank	Rea Orthner #742 with T. Hogan, and L. Yeatts, D. Yeatts; L. Yeatts #4186 with T. Hogan and R. Orthner
26	CO Park	Private / USFS Pike-San Isabel National Forest South Park Ranger District	1984	West of Fourmile Creek Campground	10,760	Open willow bog, along a small rill, in a saturated mat of moss.	W.A. Weber #17468 with R.C. Wittmann
27	CO Park	Private / USFS Pike-San Isabel National Forest South Park Ranger District	1984	Basin at bottom of Horseshoe Cirque, five miles above Fourmile Campground	11,975	Wet tundra with scattered tarns; calcareous substrate (Leadville Limestone).	W.A. Weber #17406 with D. Randolph
28	WY Park	USFS Shoshone National Forest Clarks Fork Ranger District Swamp Lake Botanical Special Interest Area	1984, 1992 1999	Clarks Fork Valley, Swamp Lake	6,000 to 6,600	Open canopy, saturated marl wetlands surrounding moist hummocks, wet tundra with scattered tarns, calcareous substrate, gravelly openings in the tundra.	E.F. Evert #7503; W. Fertig 13402; Dorn, Fertig and Jones RM

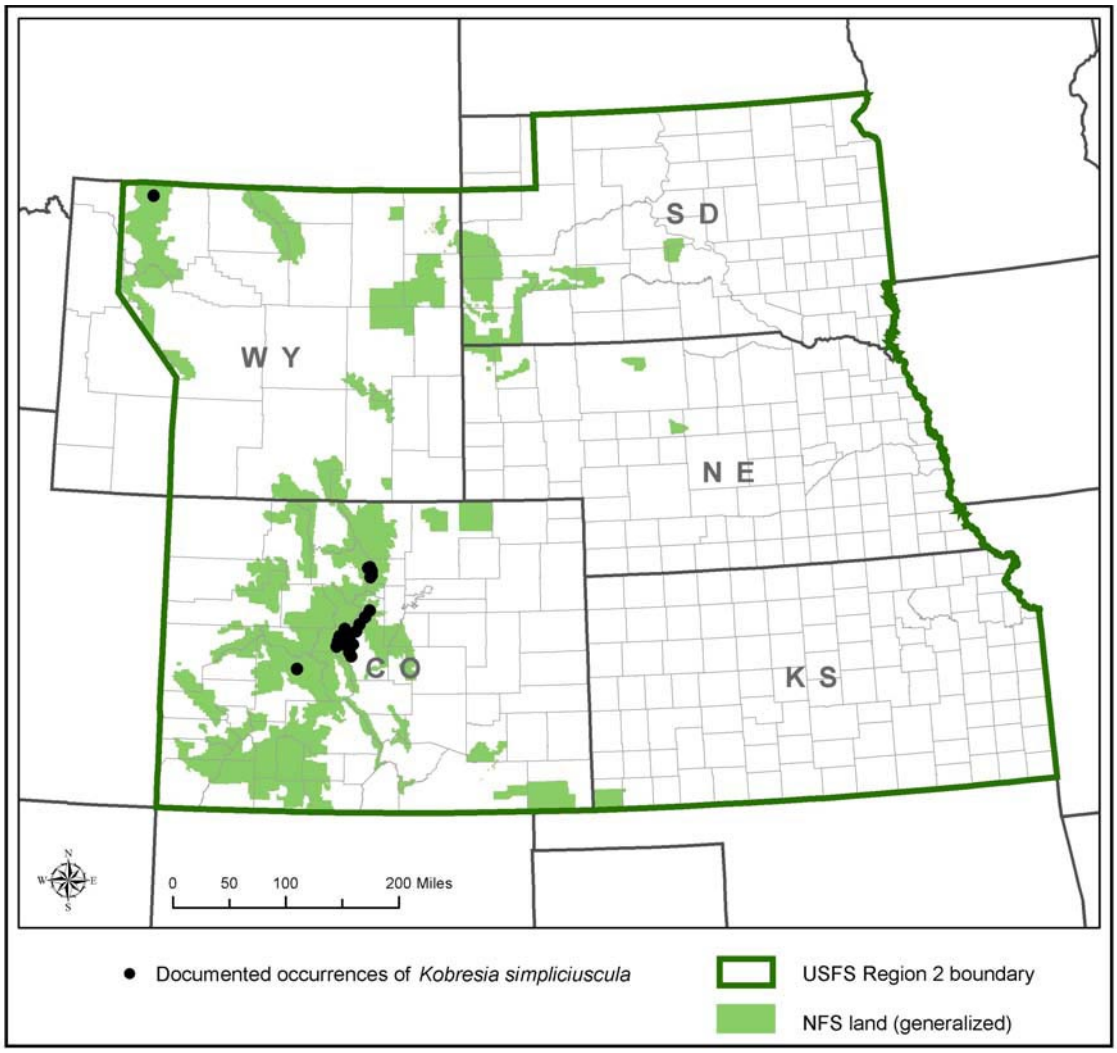

Figure 1. Documented occurrences of *Kobresia simpliciuscula* in USDA Forest Service Region 2.

An SIA can be designated to protect and manage threatened, endangered, and sensitive species habitats and other elements of biological diversity. *Kobresia simpliciuscula* was one of the species targeted when the Swamp Lake Botanical SIA was designated in 1987 (Neighbours and Culver 1990, Fertig 2000, Houston personal communication 2004).

In Colorado's Park County, four occurrences are protected by conservation easements or are owned by The Nature Conservancy. These occurrences are protected by legal agreements between the landowner and a qualified conservation organization or government agency resulting in permanent deed restrictions to limit the property's uses to protect its conservation values (Colorado Open Lands 2005). The remaining occurrences have no special protection in place.

According to the National Wetlands Inventory of the USDI Fish and Wildlife Service (1988), *Kobresia simpliciuscula* is designated as a Facultative Wetland (FACW) indicator species in Region 8 (Intermountain) and a Facultative (FAC) indicator species in Region 9 (Northwest). FACW species occur almost always (67 to 99 percent probability) within a wetland, but they are occasionally found outside of wetlands under natural conditions. FAC species occur equally (estimated probability 34 to 66 percent) in both wetlands and non-wetlands (USDI Fish and Wildlife Service 1988). There are a variety of federal regulations and policies that, although they do not directly address the conservation of *K. simpliciuscula*, could provide a degree of protection for wetlands where it occurs. The primary federal law regulating wetland habitats is Section 404 of the Federal Water Pollution Control Act ("Clean Water

Act") of 1977 (33 U.S.C. ss/1251 et seq.). Activities in wetlands regulated under this Act are required to avoid wetland impacts where practicable, to minimize potential impacts to wetlands, and to compensate for any unavoidable impacts through restoration or mitigation. In addition, environmental impact statements, required for major federal actions affecting the environment under the National Environmental Policy Act (NEPA) of 1969 (42 U.S.C. 4321-4347), can serve to focus attention on protection of wetland habitat. Federal codes and regulations specific to the national forests include the Organic Administration Act of 1897 (16 U.S.C. 475), the Multiple Use – Sustained Yield Act of 1960 (16 U.S.C. 528), the National Forest Management Act of 1976 (16 U.S.C. 1600-1602, 1604, 1606, 1608-1614), the Federal Land Policy and Management Act of 1976 (43 U.S.C. 1701-1782, FSM 2729), the Forest Service Manual, and individual Forest Management Plans. These codes and regulations all provide some degree of focus on the preservation of water resources, including wetlands. Finally, a policy of "no net loss" of wetlands has been a national goal since announced as an administration policy under President George H.W. Bush in 1989.

Adequacy of current laws and regulations

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

Adequacy of current enforcement of laws and regulations

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

Biology and Ecology

Classification and description

Systematics and synonymy

Kobresia simpliciuscula is a member of the family Cyperaceae (sedges) in the class Liliopsida (Monocotyledons) of division Magnoliophyta (flowering plants). The complete taxonomic classification of *K. simpliciuscula* is available online from the PLANTS Database (USDA Natural Resources Conservation Service 2005). The Cyperaceae is a family of grass-like herbs that often grow in damp or marshy habitats. Worldwide, the Cyperaceae is comprised of approximately 100 genera and approximately 5,000 species. In North America there are approximately 27 genera and 843 species as circumscribed by Ball et al. (2002).

The genus *Kobresia* was named for Paul von Kobres (1747-1823), naturalist and patron of botany (Hitchcock and Cronquist 1973). The genus includes about 40 species centered in the Himalayas, but with a few boreal species (Roalson et al. 2001). The three species occurring in North America are *K. myosuroides*, *K. sibirica*, and *K. simpliciuscula* (Ball 2002).

Wahlenberg (1803) originally described the type specimen of *Kobresia simpliciuscula* from Westmoreland, Anglia as *Carex simpliciuscula* (Swedish Museum of Natural History 2004). This material was later assigned to *K. caricina* Willd., and the two names were subsequently combined by Mackenzie (1923) as *K. simpliciuscula*. Mackenzie (1923) also relates that *K. caricina* Willd. was confounded by Bailey (1889) with *C. bipartita*, leading to the use of the name *K. bipartita*, now synonymous with *K. simpliciuscula*. A *K. simpliciuscula* var. *americana* was described by Duman (1956) but not widely adopted and is now synonymous with *K. simpliciuscula*.

Description

Kobresia is distinguished from other genera in Cyperaceae by the presence of open or split perigynia with overlapping margins, as compared to the closed

perigynia found in *Carex* (Weber and Wittmann 2001, Ball 2002). As described by Ball (2002) and Fertig (2000), *K. simpliciuscula* is a densely tufted, perennial graminoid with stems 10 to 35 cm tall, clothed with persistent leaves at the base (**Figure 2**, **Figure 3**). The thin leaves are 0.2 to 2 mm wide and 2 to 20 cm in length, erect to strongly curved, and shorter than the flowering stems. The inflorescence consists of three to 12 small spikes clustered at the top of the stem. The terminal spikes contain all staminate (male) flowers while the lower spikes may contain both sexes or only pistillate (female) flowers. Pistillate flowers have three stigmas. Flowering scales are brown and shorter than the perigynia, which are 2.5 to 3.2 mm long and split down the inner side nearly to the base to expose grayish brown achenes. The achenes are 2 to 3 mm long and there are typically 10 to 28 achenes per inflorescence. The ploidy of *K. simpliciuscula* is 2n = 70-75 (Ball 2002).

Kobresia myosuroides, a closely related species, is distinguished from *K. simpliciuscula* by having a solitary spike on each stem (Cronquist et al. 1977). *Kobresia simpliciuscula* also occurs in wetter habitats and often in less exposed sites than *K. myosuroides* (Aiken et al. 1999).

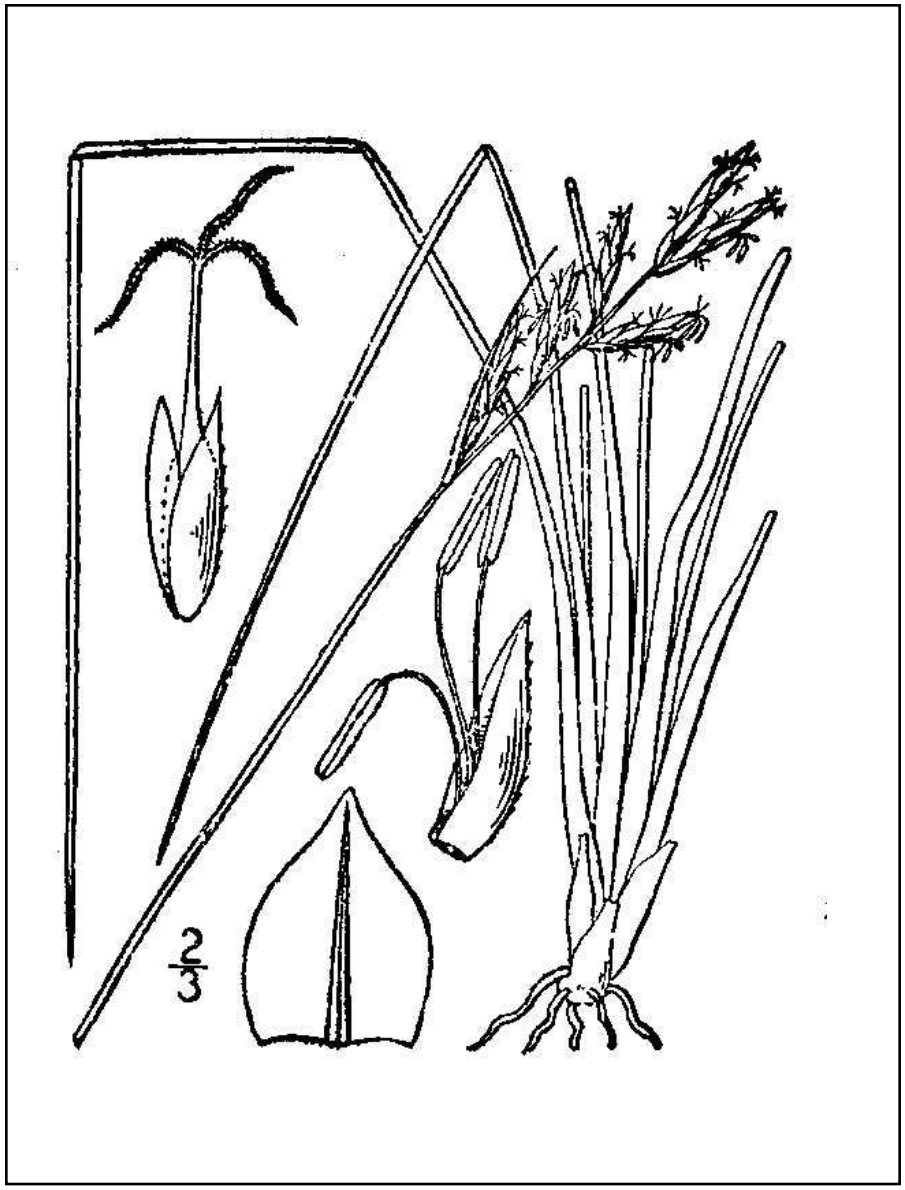

Figure 2. Illustration of *Kobresia simpliciuscula* inflorescence (Britton and Brown 1913). This image is not copyrighted and may be freely used for any purpose.

Figure 3. Herbarium specimen (Yeatts #4186 with Hogan & Orthner) of *Kobresia simpliciuscula*. Photograph by Karin Decker.

Published descriptions and other sources

The most recent technical description and illustration of *Kobresia simpliciuscula* are in the Flora of North America, Volume 23 (Flora of North America Editorial Committee 2002). Additional sources of descriptions, many with drawings, include Britton and Brown (1913), Polunin (1959), Hultén (1968), Hitchcock and Cronquist (1973), Porslid and Cody (1980), Welsh et al. (1993), Aiken et al. (1999), and Fertig (2000). In Brief descriptions of *K. simpliciuscula* are included in these regional floras: Cronquist et al. (1977), Dorn (1992), and Weber and Wittmann (2001).

Distribution and abundance

Kobresia simpliciuscula is a circumboreal species (Hultén 1968, Williams 1990, Ball 2002). In North America it has been reported from seven U.S. states and ten Canadian provinces (**Figure 4**). In the United States south of Canada, *K. simpliciuscula* is distributed in disjunct population centers in high-elevation alpine areas. Occurrences are found in the Rocky Mountains of central Colorado, the High Uintas of northeastern Utah, the Absaroka Mountains on the Wyoming-Montana border, the Teton Range on the Idaho-Wyoming Border, the Rocky Mountains of western Montana, and the

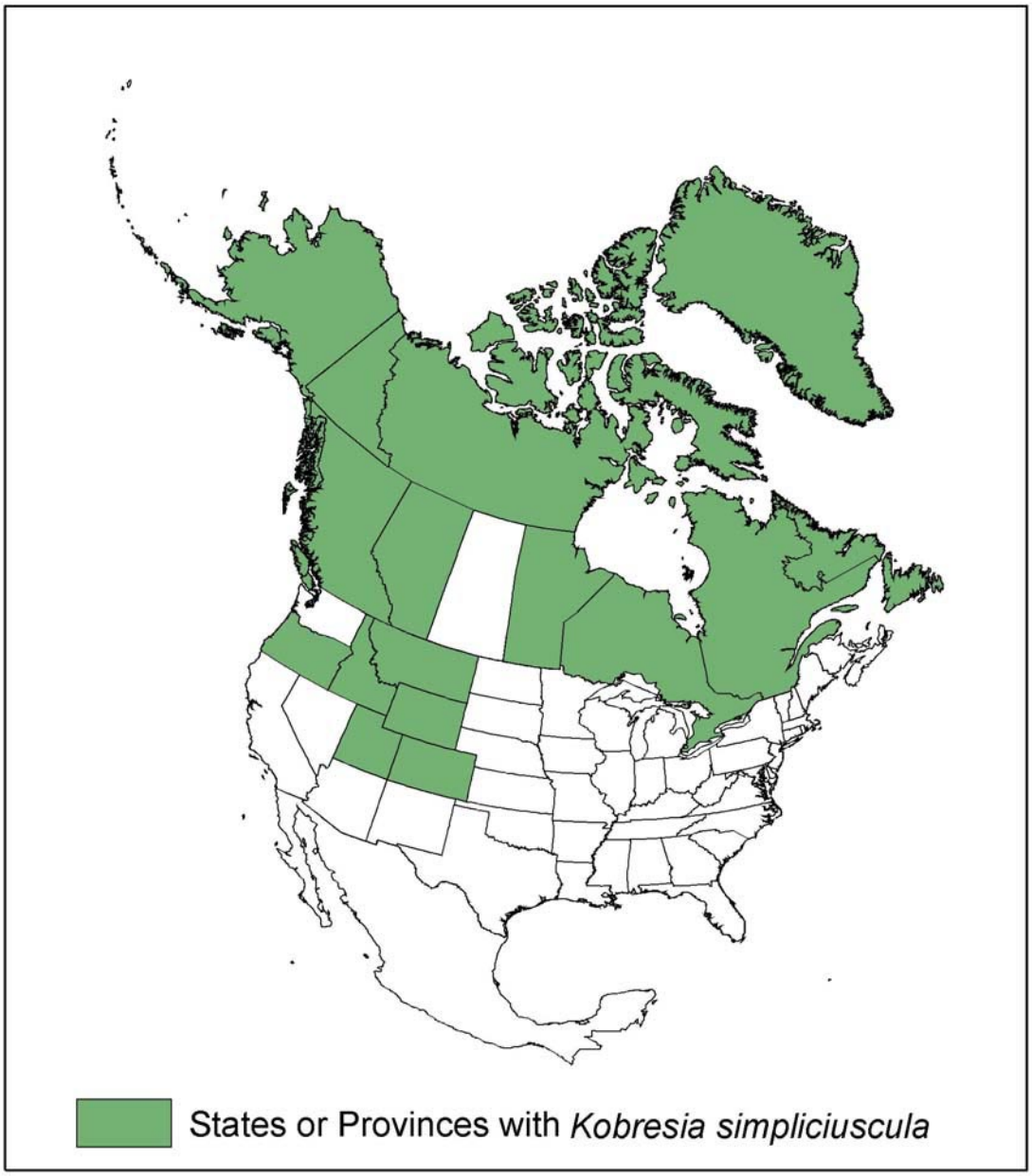

Figure 4. Generalized distribution of *Kobresia simpliciuscula* in North America.

Wallowa Mountains of northeastern Oregon (Welsh et al. 1993, Ball 2002, Montana Natural Heritage Program 2005). Although this species has a circumpolar distribution, it is described as uncommon to rare throughout its distribution (Böcher 1951, Tolmachev and Packer 1996, Jeffrey 2003).

In Region 2, *Kobresia simpliciuscula* is one of a suite of relictual arctic-alpine species that remained in the Central and Southern Rocky Mountains following the retreat of glaciers at the end of the Pleistocene Epoch, approximately 12,000 to 15,000 years ago. Many of these alpine disjunct species are rare because they are typically plants of mesic tundra, calcareous wetlands, or other habitats that are relatively rare in the Central and Southern Rockies (Weber 2003).

Region 2 occurrences are known only from northern Wyoming (Wyoming Natural Diversity Database 2003) and central Colorado (Colorado Natural Heritage Program 2005); these two areas are separated by approximately 600 miles (**Figure 1**, **Table 1**). The single Wyoming occurrence is at Swamp Lake in the Absaroka Range, near the border of Wyoming and

Montana. Colorado occurrences have been documented from alpine habitat roughly paralleling the crest of the Continental Divide from western Boulder County south to the Mosquito Range on the western edge of South Park. Lower elevation occurrences include calcareous fens on the floor of South Park, and a recently documented occurrence from Gunnison County is also in a fen. Although the majority of the well-documented occurrences in Region 2 are associated with the *Kobresia simpliciuscula-Trichophorum pumilum* Saturated Herbaceous Vegetation type, *K. simpliciuscula* is not entirely restricted to this calcareous fen community.

Abundance information for occurrences of *Kobresia simpliciuscula* in Region 2 is lacking. The clonal nature of *K. simpliciuscula* makes it impossible to obtain accurate field counts of genetic individuals in an occurrence or in Region 2. Reported numbers refer to the number of stems observed; the number of genetic individuals is probably much smaller. Observers report *K. simpliciuscula* as "probably locally abundant" in the single Wyoming occurrence (Wyoming Natural Diversity Database 2003), but the actual area of occupied or suitable habitat may be 20 acres or less (Fertig 2000). No stem counts have been reported for Colorado locations. In thirteen South Park fen plots, *K. simpliciuscula* had an average of 38 percent cover, with a range of 15 to 60 percent (Carsey et al. 2003). There is no information on the abundance of *K. simpliciuscula* in alpine habitats in Region 2.

Population trend

The population trend of *Kobresia simpliciuscula* cannot be determined by stem counts because the species is clonal. Most documented occurrences do not even include estimates of the number of flowering stems. Because *K. simpliciuscula* is potentially a long-lived perennial, changes in population size may occur slowly and be difficult to detect in the short term. In the absence of population monitoring, there is not enough information to evaluate *K. simpliciuscula* population trends. Although some occurrences have not been relocated in more than 20 years, there is no reason to believe that the occurrence has been extirpated at most of these locations. In South Park fens, there is a greater chance that occurrences have been lost or reduced in size due to hydrologic alterations and peat mining.

Habitat

In Region 2, *Kobresia simpliciuscula* grows in mesic to wet tundra, in shallow wetlands of glacial cirques, and in rich or extreme rich fens (**Table 1**, **Figure 5**). In all habitats, *K. simpliciuscula* is found in wetter situations than the related *K. myosuroides*, especially along rivulets below snow banks, in cirque basins where snowmelt collects, and on hummocks in calcareous fens. Non-fen occurrences are also often associated with calcareous substrates such as gravels derived from limestone. The Wyoming occurrence is at an elevation of 6,000 to 6,600 ft. In Colorado, fen occurrences in South Park range from 8,970 to 10,040 ft. while cirque and tundra occurrences range from 10,760 to 12,800 ft. **Table 2** is a list of plants associated with *K. simpliciuscula* in Region 2.

In fens, *Kobresia myosuroides* is an indicator of extreme rich conditions (Johnson and Steingraeber 2003). The extreme rich fens of Swamp Lake in Wyoming and South Park in Colorado are fed by cold groundwater springs with pH values ranging from 7.6 to 8.3 and calcium concentrations greater than 50 mg kg^{-1} (Cooper 1996, Fertig 2000, Johnson and Steingraeber 2003). Johnson and Steingraeber (2003) found *K. simpliciuscula* in a variety of microhabitat types in three South Park fens, including meadow, dry mire, fen lawns, hummocks, water tracks, and quagmire. Although *K. simpliciuscula* was occasionally present in some drier fen locations, their analysis indicated that it was most typical in two of the habitats on the wetter end of the spectrum (Johnson and Steingraeber 2003). *Kobresia simpliciuscula* was characteristic of the "hummocky fen lawn" and "water track" subclasses. The hummocky fen lawn is a perennially wet area where upwelling groundwater causes a slight dome in a quaking peat mat. In this habitat *K. simpliciuscula* was associated with *Trichophorum pumilum* or *Carex simulata*, the latter on less well-developed hummocks. Water tracks are linear features of quaking mats that are continually covered by shallow, slow-flowing water but sustain a robust mat of vegetation. In these areas, *K. simpliciuscula* was found on relatively dry hummocks and associated with *Eleocharis quinqueflora*. Fertig and Jones (1992) found similar associations of *K. simpliciuscula* at Swamp Lake in Wyoming. Here *K. simpliciuscula* was often co-dominant with *C. simulata* on floating mats, or associated with *Eleocharis* and *Triglochin* on marl hummocks and quaking ground (Fertig and Jones 1992). These two studies demonstrate that *K. simpliciuscula* is a microhabitat specialist in fens. There is no information on microhabitats of *K. simpliciuscula* in alpine situations in Region 2.

South Fork of the South Platte Fen

High Creek Fen

Figure 5. Photographs of *Kobresia simpliciuscula* habitat in extreme rich fens of South Park, Colorado. Photographs by Denise Culver.

Reproductive biology and autecology

Life history and strategy

In the Competitive/Stress-Tolerant/Ruderal (CSR) model of Grime (2001), other members of the Cyperaceae have been characterized as stress-tolerant competitors. Grime (2001) characterizes stress-tolerant competitors as rhizomatous or tussock-forming perennials that have a lower maximum potential relative growth rate and longer leaf life span than strict competitors, with a shoot morphology that is intermediate between the stress-tolerator and the competitor. Too little is known about these characters

Table 2. Species associated with *Kobresia simpliciuscula* in Region 2.

Colorado non-fen occurrences	Colorado fens	Wyoming fens
Carex pseudoscirpoidea	*Calliergon trifarium*	Reported with *Kobresia simpliciuscula:*
Eutrema penlandii	*Campylium stellatum*	*Aster borealis*
Juncus albescens	*Carex aquatilis*	*Aster junciformis*
Juncus castaneus	*Carex aurea*	*Carex buxbaumii*
Kobresia sibirica	*Carex capillaris*	*Carex diandra*
Moss	*Carex hassei*	*Carex limosa*
Noccaea montana	*Carex microptera*	*Carex livida*
Palustriella commutata	*Carex scirpoidea*	*Carex microglochin*
Polygonum viviparum	*Carex simulata*	*Carex scirpoidea* var. *scirpiformis*
Ranunculus adoneus	*Carex viridula*	*Carex simulata*
Salix brachycarpa	*Dasiphora floribunda*	*Eleocharis rostellata*
Salix planifolia	*Deschampsia caespitosa*	*Eleocharis pauciplora*
	Dodecatheon pulchellum	*Eriophorum viridicarinatum*
	Eleocharis quinqueflora	*Muhlenbergia glomerata*
	Gentiana fremonti	Moss
	Gentianopsis thermalis	*Primula egaliksensis*
	Hippochaete variegata	*Parnassia* sp.
	Juncus alpinoarticulatus	*Salix candida*
	Juncus balticus	*Sparganium minimum*
	Juncus balticus var. *montanus*	*Swertia perennis*
	Kobresia myosuroides	*Thalictrum alpinum*
	Moss	*Trichophorum pumilum*
	Muhlenbergia filiformis	*Triglochin maritimum*
	Parnassia palustris var. *parviflora*	
	Pedicularis groenlandica	For complete plant list of Swamp Lake Botanical area, see Fertig and Jones 1992.
	Polygonum viviparum	
	Primula egaliksensis	
	Primula incana	
	Ptilagrostis porteri	
	Salix brachycarpa	
	Salix candida	
	Salix planifolia	
	Sisyrinchium pallidum	
	Thalictrum alpinum	
	Trichophorum pumilum	
	Triglochin maritimum	
	Triglochin palustre	

in *Kobresia simpliciuscula* to be confident of its classification. As a long-lived perennial species that probably devotes several years to vegetative growth before reproducing, *K. simpliciuscula* can be regarded as a *K*-selected species in the classification scheme of MacArthur and Wilson (1967).

Reproduction

Kobresia simpliciuscula is a perennial graminoid that reproduces both sexually by seed and vegetatively through tussock formation (Ball 2002). Like most other species in the Cyperaceae, *K. simpliciuscula* is

monoecious, having separate male and female flowers on the same plant. Flowering and fruiting occur from July through August, and *K. simpliciuscula* produces numerous small achenes (Fertig 2000, Ball 2002). Seed production of *Kobresia* species appears to be lower than most of the Cyperaceae (Leck and Schütz 2005).

The majority of *Kobresia simpliciuscula* reproduction in Region 2 is via vegetative growth, with the possibility of sexual reproduction in rare cases. Arnold (1973) investigated the germinability of *K. simpliciuscula* seeds collected from Upper Teesdale, 250 miles north of London, England. Seeds did not germinate until 8 months of dry storage had elapsed, suggesting that seeds are dormant when dispersed and will not germinate until the next year. Seeds that had imbibed germinated only under conditions of immediate light or short periods (six days or less) of darkness. Arnold (1973) found that the highest germination rates (about 80 percent) were at a temperature of 18 ºC (64.4 ºF) and a day length of 18 hours. Region 2 occurrences attain a maximum day length of about 15 hours, depending on latitude. Attempts to germinate seeds of *K. myosuroides* and *K. simpliciuscula* collected in Colorado have not been successful (Bell and Bliss 1979, Cooper personal communication 2004). Although recruitment from seed is probably extremely rare in Region 2 populations, Ebersole (2002) reported colonization of bare patches at Niwot Ridge by *K. myosuroides*.

Pollination and pollination ecology

Kobresia species are wind-pollinated (anemophilous), as are almost all members of the Cyperaceae (Cronquist 1988, Cronk and Fennessy 2001). This trait is common among species that occupy habitats where pollinators may be scarce; it is also strongly associated with monoecy (Proctor et al. 1996). The anemophilous habit requires the production of large amounts of pollen, and this is the only realistic vector for gene flow between disjunct populations of *K. simpliciuscula*. Most pollen is deposited close to its source (Levin and Kerster 1974), but under weather conditions producing strong convection, pollen may be carried long distances from the source (Proctor et al. 1996). Even if pollen is occasionally dispersed among *K. simpliciuscula* occurrences, its limited viability would make successful long-distance pollination a rare event.

Dispersal mechanisms

There is little information available on seed dispersal of *Kobresia* species. Achenes of *K. simpliciuscula* do not appear to have any special adaptation for dispersal by wind or animals (e.g., bristles, plumes), and the presence of any other dispersal adaptations has not been determined.

Cryptic phases

The longevity of *Kobresia simpliciuscula* seeds has not been investigated. The presence of dormancy in *K. simpliciuscula* seeds (Arnold 1973) indicates that a seed bank could be present if viable seeds are produced.

Phenotypic plasticity

Phenotypic plasticity has not been reported for *Kobresia simpliciuscula*. In general, flowering plants are notable for their great phenotypic plasticity; this is especially true for arctic-alpine species (Savile 1972). Phenotypic variation could be investigated by examining the morphological characters (e.g., leaf size, length of rhizomes) among occurrences at different altitudes and from different habitats.

Mycorrhizal relationships

The Cyperaceae are generally non-mycorrhizal (Gardes and Dahlberg 1996). However, Massicotte et al. (1998) reported the presence of ectomycorrhizal fungi on roots of *Kobresia myosuroides* at Niwot Ridge, Colorado. *Kobresia simpliciuscula* has not been evaluated for mycorrhizal relationships.

Hybridization

Hybridization in *Kobresia simpliciuscula* has not been reported. *Kobresia myosuroides* and *K. sibirica* are sympatric with *K. simpliciuscula* in Region 2, with some potential for hybridization if no isolating mechanisms exist. There are no specimens of intermediate appearance that suggest that hybridization or introgression is taking place.

Parasites and disease

Kobresia myosuroides is affected by two smuts of the genus *Anthracoidea* in central Asia (Chlebicki 2002), but there are no reports of parasites or diseases of *K. simpliciuscula* in Region 2.

Demography

There are no known demographic studies of *Kobresia simpliciuscula*. Demographic studies of

clonal species usually develop models based on tiller development rather than on genetic individuals. Bell and Bliss (1979) reported some demographic parameters for *K. myosuroides*. In this sympatric species, the estimated normal life span of a tiller was about 5 years. During the first 3 years of growth, tillers produced new leaves each year, and in the fourth year they produced new tillers. Tillers typically died after producing a flowering stalk in their fifth year. Using the observation that the number of tillers in a tussock increased by about 3.3 percent yearly, Bell and Bliss (1979) estimated the ages of tussocks in their study area in Rocky Mountain National Park as ranging from 70 to 250 years. **Figure 6** shows a generalized tiller life-cycle diagram for *K. simpliciuscula* based on the work of Bell and Bliss (1979), with the addition of sexual reproduction. Although there has been no similar investigation of *K. simpliciuscula*, it is likely to share the long life span and growth patterns of *K. myosuroides*.

No Population Viability Analysis (PVA) has been performed for *Kobresia simpliciuscula*. Identification of a minimum viable population size could assist in the formation of quantitative management objectives (Brackley 1989). However, the analysis would be difficult to complete with current levels of knowledge of *K. simpliciuscula* life history. Information on tiller growth rates and lifespan, seed production and longevity, and variables controlling these parameters would help to reveal potential vulnerable points in the life history of *K. simpliciuscula*.

Community ecology

Although there have been no studies of the community ecology and interspecific relationships of *Kobresia simpliciuscula* in Region 2, some work has been done on the species in Britain. Jeffrey (1971) investigated the effects of fertilization in a *K.*

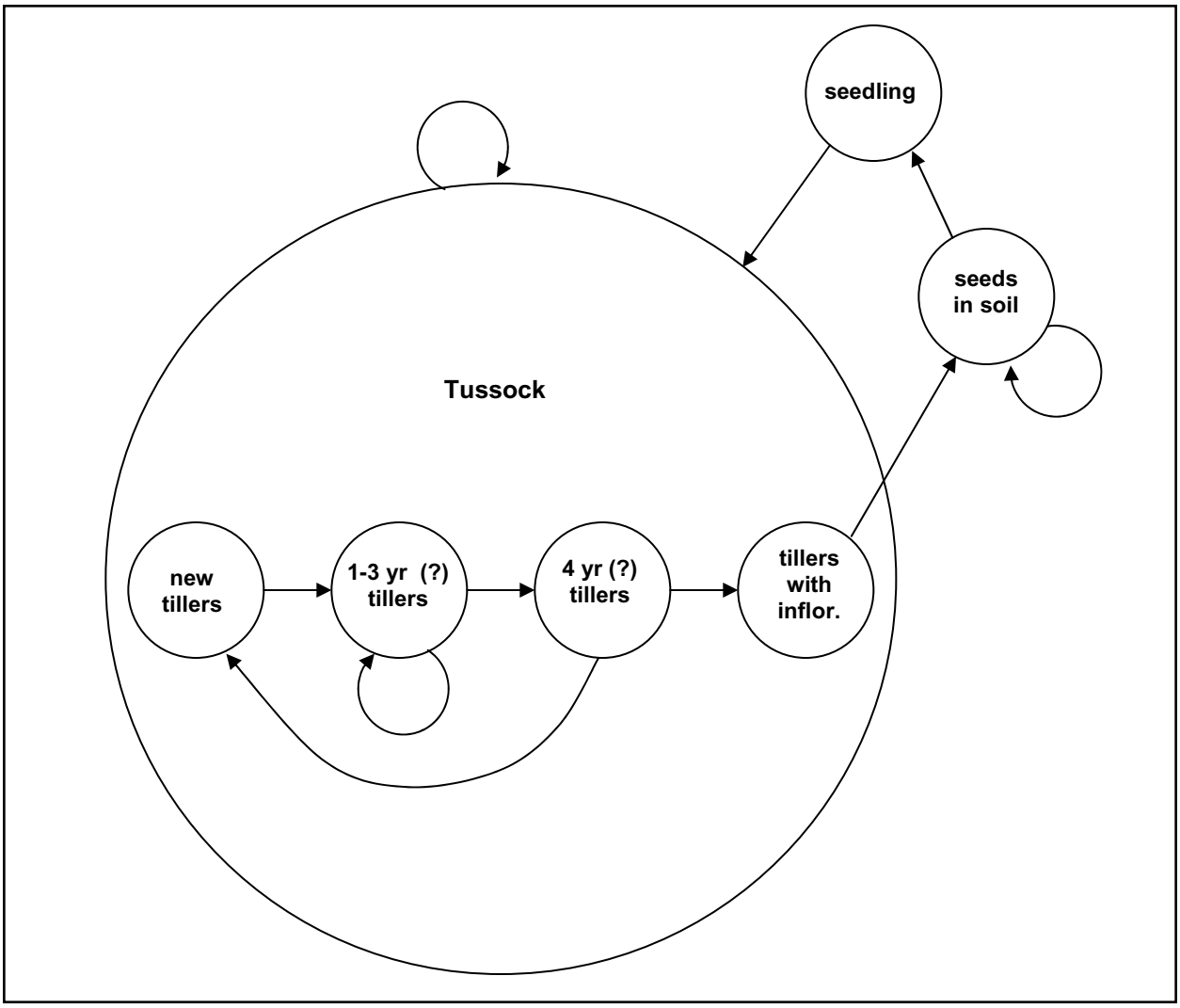

Figure 6. Generalized life-cycle diagram for *Kobresia simpliciuscula*.

simpliciuscula-dominated meadow in Teesdale. Jeffrey speculated that the slow-growing *K. simpliciuscula* was able to dominate the community due to long-term grazing by domestic animals that selectively consumed more palatable grasses. He also hypothesized that *K. simpliciuscula* was better able to compete with grasses in the nutrient-limited calcareous soils of the sward. Jeffrey's experiments did not address the effects of grazing, but under conditions of augmented nitrogen and phosphorus, *K. simpliciuscula* was outcompeted by grasses. Although it is not clear that *K. simpliciuscula* is restricted to calcareous substrates in Region 2, it may have a competitive advantage in these sites.

Herbivory of *Kobresia simpliciuscula* in Region 2 has not been documented. Other species of *Kobresia* are known to be subject to herbivory. McIntire and Hik (2002) investigated the effects of herbivory by collared pikas (*Ochotona collaris*) on *K. myosuroides* in the Yukon. Half of all plants in the study were grazed by pikas, and plants were able to tolerate grazing levels of nearly 60 percent of aboveground leaves during the growing season by a shift to earlier leaf production compared with historically ungrazed occurrences (McIntire and Hik 2002). A similar tolerance mechanism in *K. simpliciuscula* has not been documented but is likely. In Region 2 *K. simpliciuscula* is exposed to grazing both by domestic and wild vertebrate herbivores, including cattle, sheep, elk, deer, rodents, and waterfowl. The occurrence of invertebrate herbivory or seed predation in *Kobresia* species has apparently not been investigated.

CONSERVATION

Threats

The identification of threats to *Kobresia simpliciuscula* is complicated by the lack of information regarding its biology and ecology. Because we know very little about this species' response to disturbance, it is difficult to assess the severity of threats. In approximate order of decreasing priority, primary threats to *K. simpliciuscula* are hydrologic alterations, peat mining, grazing, and global climate change.

Altered hydrology

Because *Kobresia simpliciuscula* is found in wet habitats, hydrologic alteration is the greatest threat to the species, and this threat interacts to some degree with all the other threats. Any alterations to a site or watershed that affect water quality or quantity will almost certainly negatively impact *K. simpliciuscula*. Hydrologic alteration can result from trenching, ditching, logging, mining, fire, and grazing (Bursik and Moseley 1992). Changes in hydrologic regime can influence nutrient cycles, soil and water chemistry, sedimentation, species composition, and habitat quality in wetland systems (Mitsch and Gosselink 1993). Other threats, such as grazing, peat mining, and global climate change, can influence the hydrology of *K. simpliciuscula* habitat, as well as affect occurrences and individual plants. The only *K. simpliciuscula* site on National Forest System land known to be affected by altered hydrology is Crooked Creek Spring, where a ditch has dried out the lower portion of the fen (Sanderson and March 1996). *Kobresia simpliciuscula* occurrences on privately owned fen sites in South Park have all been hydrologically altered to some extent (Sanderson and March 1996). The effects of these alterations on *K. simpliciuscula* have not been documented.

Grazing

Cattle and sheep grazing has significantly impacted subalpine and montane wetlands throughout the Rocky Mountains (Windell et al. 1986). Major impacts of grazing include removal and reduction of vegetation, soil compaction, and increased erosion. These impacts have been shown to affect hydrology, water chemistry, and other variables (Menke 1977, Johnston and Brown 1979, Johnson and Gerhardt 2002). The presence of domestic livestock in fens can negatively affect plant species sensitive to trampling (Pearson and Leoschke 1992, as cited in Austin 2003), alter fen hydrology, and damage the edges of fens (Mullen et al. 1992, as cited in Austin 2003). Grazing animals create paths in peaty soils, eventually channelizing water that would otherwise move through the peatlands in a sheet (Windell et al. 1986, Bursik 1993, Chadde et al. 1998). If the grazing regime is intense enough to produce channelization, then these habitats may dry out and cattle use will further increase (Bursik 1993, USDA Forest Service 1924 as cited in Bursik 1993). Improper grazing can often trigger a species shift due to the removal of native species or the introduction of non-native species.

High Creek Fen and High Creek at Warm Springs in South Park were grazed before The Nature Conservancy's acquisition of these properties. As of 2004, trespass grazing due to inadequate fence maintenance was still occurring (Moorehead personal communication 2004). The privately owned Silver Heels Ranch occurrence is located within an irrigated

hay meadow that is also grazed. Intense grazing and cattle paths have been documented in the Trout Creek Ranch occurrence as well.

Peat mining

Where *Kobresia simpliciuscula* is found in fens, it is potentially threatened by peat mining activities. Peat mining destroys *K. simpliciuscula* habitat by removing the substrate, reducing vegetation cover and species richness, altering species composition, eliminating microtopography, and altering edaphic and hydrologic properties (Johnson 2000). Once damaged, the hydrologic alterations may result in permanent degradation (Johnson 2000). Furthermore, restoration of fens that support *K. simpliciuscula* is thought to be difficult or impossible due to their reliance on groundwater and snowmelt sources (Windell et al. 1986) and slow rates of peat accumulation (20 to 28 cm per 1,000 years; Cooper 1986).

Colorado is the only state in Region 2 where commercial peat mining is permitted and is currently occurring (USDI Bureau of Mines 1994, Austin personal communication 2004). Peat mining is occurring in Region 2, for example at Kennicott Slough in the Grand Mesa National Forest (Federal Register 2002). The U.S. Fish and Wildlife's Region 6 Policy on the Protection of Fens states that mitigation for fens is not feasible due their irreplaceability (USDI Fish and Wildlife 1999). The Colorado occurrences especially threatened by peat mining are North of Antero Reservoir and Tarryall Creek, both privately owned. High Creek Fen and High Creek at Warm Springs were mined for peat before their acquisition by The Nature Conservancy in 1991 and 2000, respectively (Sanderson and March 1996, The Nature Conservancy 1999).

Global climate change

The disjunct distribution of *Kobresia simpliciuscula* in Region 2 is due in part to changes in global climate patterns since the Pleistocene. Although ongoing global climate change is potentially the most serious threat to the persistence of *K. simpliciuscula* in Region 2, it appears last on the list of priority threats because of the uncertainty surrounding its regional effects and severity. Global climate change is likely to have wide-ranging effects in the near future for all habitats, especially high elevation wetlands. Projections based on current atmospheric CO_2 trends suggest that average temperatures will increase while precipitation will decrease in the West (Manabe and Wetherald 1986). These changes will significantly affect hydrology, nutrient cycling, vapor pressure gradients, and a suite of other environmental variables. In particular, a decrease in precipitation (snowpack) would lead to lower water tables, reduced wetland habitat, and drier conditions for wet tundra habitats.

Influence of management activities or natural disturbances on habitat quality

There have been no studies of the effects of management activities or natural disturbances on *Kobresia simpliciuscula*. Occurrences in cirque wetlands and extreme rich fens depend on a functional hydrologic regime to maintain suitable habitat. Any natural or anthropogenic disturbance that disrupts the hydrologic dynamics is likely to have a negative effect on habitat quality for *K. simpliciuscula*.

Influence of management activities or natural disturbances on individuals

In general, management activities or natural disturbances that affect habitats are likely to have similar or parallel effects on individuals or subpopulations. In particular, hydrological modification associated with road building, livestock grazing, motorized vehicle use, or mining is likely to have a direct impact on individuals and occurrences of *Kobresia simpliciuscula*. Plants may be killed or damaged as a result of these activities, and occurrence remnants may be unable to recolonize disturbed areas. Surface disturbance may also affect the survival and reproductive success of individuals by altering local patterns of erosion and drainage, and by eliminating safe sites for germination.

Interaction of the species with exotic species

There are no exotic species documented within any *Kobresia simpliciuscula* occurrences. This absence may in part be due to *K. simpliciuscula*'s affinity for calcareous soils. However, on the drier, outer edges of the wetlands, exotic species can become established, especially after peat mining and grazing disturbances.

Threats from over-utilization

There are no known current commercial uses for *Kobresia simpliciuscula* (Simpson 2001). In Colorado, fens are mined for horticultural ("mountain") peat. Most peat is beneficial to gardens, but peat extracted from Colorado's fens is composed primarily of grasses and sedges, not mosses. Mountain peat has a high pH, and if mixed with clay soils, it can act as glue instead of improving soil texture (Johnson 1996).

Conservation Status of Kobresia simpliciuscula in Region 2

The lack of population monitoring of *Kobresia simpliciuscula* occurrences, especially in non-fen habitats, and the likely but unconfirmed existence of additional occurrences makes it difficult to substantiate a population decline in Region 2. There is likewise no evidence that populations are expanding. The current perception of the insecure status of the species in Region 2 arises from the low number of documented occurrences, the rarity and vulnerability of extreme rich fen and calcareous tundra habitat, and the disjunct nature of these occurrences.

Due to the difficulties of determining the number of individuals in an occurrence, and a tendency for observers to focus on *Kobresia simpliciuscula* primarily as a member of a rare community, we have no clear idea of abundance for any occurrence in Region 2. *Kobresia simpliciuscula* is especially threatened in the extreme rich fens of South Park, but the real degree of threat to other occurrences is unknown. Because wet alpine and tundra habitats are likely to be less common than dry tundra, *K. simpliciuscula* is also vulnerable to the effects of any environmental variation that reduces or alters these habitat patches.

Kobresia simpliciuscula is closely tied to a small-patch type of habitat that is found only in a narrow range of environmental conditions. Documented occurrences are found in habitats of intact natural landscapes that are largely unaltered by anthropogenic effects. Occurrences are isolated from each other, making the recolonization of extirpated sites unlikely without human intervention. Stochastic processes and normal environmental variation could easily result in extirpation of any Region 2 occurrences, regardless of current levels of protection. On the other hand, the fact that these occurrences appear to have persisted for at least 12,000 years indicates that they are able to survive historic levels of change.

Management of Kobresia simpliciuscula in Region 2

Implications and potential conservation elements

Although current knowledge of the distribution and abundance of *Kobresia simpliciuscula* in Region 2 suggests that the species is vulnerable due to its restriction to a relatively rare suite of habitats and the small number of disjunct occurrences, additional information is needed to clarify its status. We also know very little about patterns of abundance throughout the main part of its range outside Region 2, which makes it difficult to determine the importance of Region 2 occurrences.

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

Occurrences in Region 2 are most vulnerable to changes in the environment that affect their wet alpine and fen habitats. Any management activities that maintain an appropriate hydrologic regime for these habitats will benefit *Kobresia simpliciuscula*. This includes regulation and monitoring of hydrological modifications, domestic grazing, and peat mining. Hydrological modifications are pervasive throughout the range of *K. simpliciuscula* but have been forestalled by wilderness area designations in much of the potential habitat of Region 2. Natural environmental changes may also affect the wetland and fen habitats favored by *K. simpliciuscula*. Changes in precipitation patterns and effects of natural disturbances elsewhere in the watershed may also lead to altered hydrology that is detrimental to the persistence of *K. simpliciuscula*. In these instances, management policy should focus on mitigating these effects when feasible. Desired environmental conditions for *K. simpliciuscula* include an intact natural hydrological regime with little or no evidence of alteration due to increased or decreased drainage, clearing, livestock grazing, anthropogenic nutrient inputs, or mining (especially peat mining).

Tools and practices

Inventory and monitoring of populations and habitat

Species and habitat inventory: Relocating historic occurrences and searching potential habitat for additional occurrences are high priorities for *Kobresia simpliciuscula*. Areas with the highest probability of new occurrences include extreme rich fens and wet

alpine areas, especially those with calcareous substrates. Infrared and natural color aerial photography, soil maps, topographic maps, and geology maps help to refine search areas when conducting wetland inventories. Searches for *K. simpliciuscula* could also be aided by predictive habitat modeling based on the characteristics of known occurrences. The intersection of elevation, climate, geology, hydrology, and soils data layers in using Geographic Information System (GIS) software can generate a map of likely *K. simpliciuscula* habitat within Region 2 that would guide searches. Other techniques for predicting species occurrences are reviewed extensively by Scott et al. (2002). Habitat modeling has been done for other sensitive plant species in Wyoming (Fertig and Thurston 2003) and Colorado (Decker et al. 2005).

The best time to conduct surveys for *Kobresia simpliciuscula* is from August to September when achenes are present. Ideally, surveys should be conducted by trained professionals who are familiar with the species. In addition, USFS personnel who visit potential habitat in the course of other work should be alerted to check for the presence of *K. simpliciuscula*, and to record their observations (positive or negative) carefully. Collection of voucher specimens is appropriate to ensure correct identification.

Preparatory work should take into account the remoteness and difficult access of many potential occurrences. Personnel for the initial survey should be familiar with methods of soil and habitat characterization. Surveyors should use Global Positioning System (GPS) instruments for delineating the location and extent of the occurrence. Discussions of the need for further inventory, the extent of occurrences, and critical habitat characteristics should be shared among state and federal agencies, natural heritage programs, local and regional experts, and interested members of the public.

Kobresia simpliciuscula could benefit greatly from visits of known occurrences that determine their abundance and extent. Counting the number of genetic individuals in each occurrence would be nearly impossible; stem counts can be used as a surrogate for population estimates. Even rough population estimates based on numbers of flowering stalks and spatial extent would be useful in determining population trends and provide land managers with data for management planning.

Population monitoring: Monitoring population trends and the effects of management would provide the most immediately useful information for land managers. It is important to identify the most appropriate occurrences of *Kobresia simpliciuscula* on federal lands for monitoring, depending on the results of species inventories. Monitoring sites under a variety of land use scenarios will help to identify best management practices for *K. simpliciuscula*. To be effective, monitoring must be accompanied by a commitment by the managing agency to adjust management practices based on the results. Monitoring that collects demographic data on growth patterns, recruitment, seed production, plant longevity, and population variability can also provide useful information for both management and the scientific community, but this may be a lower priority.

Monitoring clonal growth poses practical problems for plant researchers and managers. *Kobresia simpliciuscula* is easily observed in the field, but it is impossible to count individuals and difficult to count stems. Tracing underground connections (i.e., rhizomes) between clonal plants may destroy the occurrence (Liston et al. 2003). Individual plants within a clonal tuft are difficult to identify without resorting to sophisticated genetic analyses such as gel electrophoresis (Sawada 1999). Monitoring population size can be done by measuring the diameter of clones and comparing subsequent measures over time. By estimating clonal spread over time, one can estimate the rate of growth or decline (Liston et al. 2003).

Presence/absence monitoring could give early warning of declining population trends. These data should be collected annually at established stations and would be most useful if combined with habitat monitoring. Ideally, monitoring stations would coincide with locations already visited by agency personnel in the course of other duties, and for which information on the effects of current management practices is most needed. In Region 2, Wyoming's Preacher Rock Bog SIA and Colorado's Geneva Park and Crooked Creek Spring sites are of particular interest, since all are accessible and have been subjected to management changes or restoration. Non-fen habitats should also be monitored.

The design of a population monitoring program for *Kobresia simpliciuscula* should take into account the long-lived, perennial, clonal character of the species, and recognize that accumulation of demographic data will be a long-term process. Other considerations include small population sizes, few disjunct locations, and sensitive habitat. The effects of disturbance and management practices on *K. simpliciuscula* are of

particular interest. Estimates of stem numbers can be made at each station (see Elzinga et al. 1998), and photographs could provide an idea of habitat condition.

Habitat monitoring: *Kobresia simpliciuscula* habitat monitoring should be conducted concurrently with population monitoring. Monitoring soil moisture, water table, and water chemistry would be useful since *K. simpliciuscula* relies on a narrow range of hydrologic conditions. Documenting the scope and severity of any disturbance in monitored occurrences will alert managers to new impacts and allow management to change in time to prevent serious damage. Changing environmental variables might not cause measurable demographic repercussions for several years, so periodic re-sampling of the chosen variables may help to identify underlying causes of population trends.

Beneficial management actions

The primary consideration for any management action in or around *Kobresia simpliciuscula* habitat is to maintain an intact hydrology, both within the occurrence and in the watershed surrounding it. In general, management actions that maintain the hydrology of fens or wet alpine areas and promote connectivity between them will benefit occurrences of *K. simpliciuscula*. In order to minimize anthropogenic disturbance in these areas, access by domestic grazing animals to fens and wet tundra should be limited whenever possible. Motor vehicle use should be prohibited in the immediate habitat, and its effects scrutinized in the surrounding watershed for possible hydrologic impacts. Effects of other management activities that may affect hydrology and sedimentation of wetland habitat, including fire suppression or reclamation, logging, mining, and road construction, should also be considered both in the immediate habitat as well as the surrounding watershed. Surveys prior to management actions in watersheds with potential habitat would help to minimize impacts to this species.

The establishment of protected areas and perpetual conservation easements that are managed for the conservation of *Kobresia simpliciuscula* is an important conservation strategy. Some type of protective designation (e.g., research natural area, special interest area) for occurrences on the Pike-San Isabel National Forest (Crooked Creek Spring, Fourmile Creek Campground and Horseshoe Cirque) could help to ensure the protection of this species on National Forest System lands.

Seed banking

No *Kobresia simpliciuscula* seeds or genetic material are currently stored at the National Center for Genetic Resource Preservation (Miller personal communication 2003). It is not among the National Collection of Endangered Plants maintained by the Center for Plant Conservation (2002). Due to the difficulties of germinating seeds of *K. simpliciuscula*, it is not clear that seed banking would be a useful contribution to conservation of the species in Region 2. Propagation of tiller cuttings or plugs has potential for producing material to revegetate damaged areas. Cooper and MacDonald (2000) reported survival of 26 percent of transplanted *K. simpliciuscula* rhizomes at High Creek Fen.

Information Needs

Our knowledge regarding the extent of *Kobresia simpliciuscula*'s distribution in Region 2 is incomplete. In particular, it would be useful to survey for occurrences on USFS lands in non-fen habitats, and to relocate occurrences from those areas that have not been observed for decades. Additional information on the non-fen habitats of *K. simpliciuscula* in Region 2 is needed. This type of habitat characterization could be extremely useful in modeling potential distribution of the species, and in formulating management strategies. Furthermore, accurate information on the real abundance of the species within its Region 2 range is needed. It would also be useful to document the extent to which occurrences are found on National Forest System lands, in order to clarify the extent to which the USFS can protect the species in Region 2. Population trends of *K. simpliciuscula* are not known and may be difficult to quantify given its clonal growth form. Techniques for monitoring population trends of this species need to be field tested. Basic research specific to *K. simpliciuscula* is needed to understand its phenology, fertility, reproduction, and seed bank viability.

Research priorities for Region 2

The primary research priority for *Kobresia simpliciuscula* in Region 2 is the identification of potential habitat and location of additional occurrences, especially in the subalpine and alpine zones. Other important topics are the development and utilization of practical population monitoring methods in concert with habitat monitoring, quantification of the effects of disturbance and land management practices on the

survival and persistence of the species, and investigation of the growth and reproductive requirements of individual plants.

Additional research and data resources

There are likely to be additional specimens of *Kobresia simpliciuscula* held by herbaria throughout its North American range, as well as an informal body of knowledge of its distribution and abundance among land managers in the area. The collation of this information could clarify the global distribution and abundance patterns of *K. simpliciuscula*, which would enable a clearer perspective of its status in Region 2. This information would be most useful if linked to investigation and explication of the disjunct post-glacial remnant communities in which it occurs.

Definitions

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

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

Caespitose – growing in clumps (Weber and Wittmann 2001).

Calciphile – a plant species confined to, or most frequently found on, soils containing free calcium carbonate (Allaby 1992).

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

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

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

Element Occurrence – an animal, plant, or plant community occurrence (NatureServe 2004).

Imbibition – uptake of water (Hale and Margham 1991).

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

Perigynium – the inflated sac enclosing the ovary of *Carex*, represented in *Kobresia* by an open sheath (Weber and Wittmann 2001).

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

Rill – a very small brook (Allaby 1992).

References

Aiken, S.G., M.J. Dallwitz, L.L. Consaul, C.L. McJannet, L.J. Gillespie, R.L. Boles, G.W. Argus, J.M. Gillett, P.J. Scott, R. Elven, M.C. LeBlanc, A.K. Brysting, and H. Solstad. 1999. Flora of the Canadian Arctic Archipelago: Descriptions, illustrations, identification, and information available online at http://www.mun.ca/biology/delta/arcticf/.

Allaby, M. 1998. A Dictionary of Plant Sciences. Oxford University Press. New York, NY.

Arnold, S.M. 1973. Interactions of light and temperature on the germination of *Plantago maritima* L. New Phytologist 72:583-593.

Austin, G. 2003. Draft USDA Forest Service Rocky Mountain Region Fen Policy. Course: Peatland Conservation in the Western United States, Gunnison National Forest, Gunnison, CO.

Austin, G. 2004. Personal communication with Range Management Specialist, Grand Mesa-Uncompahgre National Forest, Gunnison Ranger District regarding extreme rich fens.

Bailey, L.H. 1889. Mem. Torr. Bot. Club 1:63.

Ball, P.W. 2002. *Kobresia* Pages 252-253 *in* Flora of North America, Vol. 23. Magnoliophyta: Commelinidae (in part): Cyperaceae. Oxford University Press, Oxford, UK.

Ball, P.W., A.A. Reznicek, and D.F. Murray. 2002. Cyperaceae Pages 3-4 *in* Flora of North America, Vol. 23, Magnoliophyta: Commelinidae (in part): Cyperaceae. Oxford University Press, Oxford, UK.

Barbour, M.G., J.H. Burk, and W.D. Pitts. 1987. Terrestrial Plant Ecology. Benjamin/Cummings Publishing Company, Inc., Menlo Park, CA.

Bell, K.L. and L.C. Bliss. 1979. Autecology of *Kobresia bellardii*: Why winter snow accumulation limits local distribution. Ecological Monographs 49(4):377-402.

Böcher, T.W. 1951. Distribution of plants in the circumpolar area in relation to ecological and historical factors. Journal of Ecology 39:376-395.

Brackley, F.E. 1989. Jesup's Milkvetch Recovery Plan. U.S. Fish and Wildlife Service, New England Field Office, Concord, NH.

Britton, N.L. and A. Brown. 1913. Illustrated Flora of the Northern United States and Canada. Vol. 1. Charles Scribner's Sons. New York. NY. Reprinted (1970) by Dover Publications, Inc. New York, NY.

Bursik, R.J. 1993. Fen vegetation and rare plant population monitoring in Cow Creek Meadows and Smith Creek Research Natural Area, Selkirk Mountains, Idaho. Report prepared for the Idaho Department of Fish and Game, Boise, ID by Conservation Data Center, Boise, ID.

Bursik, R.J. and R.K. Moseley. 1992. Forty-year changes in Hager Lake Fen, Bonner County, ID. Report prepared for the Idaho Department of Fish and Game, Boise, ID by Conservation Data Center, Boise, ID.

Carsey, K., G. Kittel, K. Decker, D.J. Cooper, and D. Culver. 2003. Field Guide to the Wetland and Riparian Plant Associations of Colorado. Colorado Natural Heritage Program, Fort Collins, CO.

Center for Plant Conservation. 2002. National Collection of Endangered Plants. Available at http://www.mobot.org/CPC/NC_Choice.html.

Chadde, S.W., J.S. Sheely, R.J. Bursik, R.K. Moseley, A.G. Evenden, M. Mantas, F. Rabe, and B. Heidel. 1998. Peatlands on National Forests of the Northern Rocky Mountains: Ecology and Conservation. General Technical Report, RMRS-GTR-11, Rocky Mtn. Research Station, Ogden, UT.

Chlebicki, A. 2002. Two cypericolous smut fungi (*Ustilaginomycetes*) from the Tian Shan and their biogeographic implications. Mycotaxon Vol. LXXXIII: 279-286.

Colorado Natural Heritage Program. 2005. Biodiversity Tracking and Conservation System (BIOTICS). Colorado Natural Heritage Program, Fort Collins, CO.

Colorado Open Lands. 2005. Website. Available online at: http://www.coloradoopenlands.org.

Cooper, D.J. 1986. Community structure and classification of Rocky Mountain wetlands. *In*: J.T. Windell and B.E. Willard, editors. An ecological characterization of Rocky Mountain montane and subalpine wetlands. USDI, FWS, Biological Report No. 86(11):66-147.

Cooper, D.J. 1996. Water and soil chemistry, floristics, and phytosociology of the extreme rich High Creek fen, in South Park, Colorado, U.S.A. Canadian Journal of Botany 74:1801-1811.

Cooper, D.J. 2004. Personal communication with professor at Colorado State University regarding *Kobresia simpliciuscula*.

Cooper, D.J. and L.H. MacDonald. 2000. Restoring the vegetation of mined peatlands in the southern Rocky Mountains of Colorado, USA. Restoration Ecology 8:103-111.

Cronk, J.M. and M.S. Fennessy. 2001. Wetland Plants Biology and Ecology. Lewis Publishers, New York, NY.

Cronquist, A. 1988. The Evolution and Classification of Flowering Plants. The New York Botanical Garden, New York, NY.

Cronquist, A., A.H. Holmgren, N.H. Holmgren, J.L. Reveal, and P.K. Holmgren. 1977. Intermountain Flora. Vascular Plants of the Intermountain West, USA. Vol. 6. The Monocotyledons. New York Botanical Garden, Columbia University Pres, New York, NY.

Decker, K., A. Lavender, J. Handwerk, and D.G. Anderson. 2005. Modeling the potential distribution of *Phacelia scopulina* var. *submutica* (Debeque phacelia) and *Astragalus debequaeus* (Debeque milkvetch) in western Colorado. Colorado Natural Heritage Program, Colorado State University, Fort Collins, CO. Available online at: http://www.cnhp.colostate.edu/reports.html.

Dorn, R.D. 1992. Vascular Plants of Wyoming. Second Edition. Mountain West Publishing, Cheyenne, WY.

Duman, M.G. 1956. Three new North American varieties of *Kobresia*. Bulletin of the Torrey Botanical Club 83:192-195.

Ebersole, J.J. 2002. Recovery of alpine vegetation on small, denuded plots, Niwot Ridge, Colorado, USA. Arctic Antarctic and Alpine Research 34 (4):389-397.

Elzinga, C.L., D.W. Salzer, and J.W. Willoughby. 1998. Measuring and Monitoring Plant Populations. BLM/RS/ST-98/005+1730 ed. USDI, BLM, National Applied Resource Sciences Center, Denver, CO.

Federal Register. 2002. Volume 67, Number 96. Grand Mesa, Uncompahgre and Gunnison National Forest, CO, Kennicott Reservoir Peat Removal Project.

Fertig, W. 2000. State Species Abstract, *Kobresia simpliciuscula*. Wyoming Natural Diversity Database, Laramie, WY.

Fertig, W. and G. Jones. 1992. Plant communities and rare plant species of the Swamp Lake Botanical Area, Clark's Fork Ranger District, Shoshone National Forest. Wyoming Natural Diversity Database, Laramie, WY.

Fertig, W. and R. Thurston. 2003. Modeling the Potential Distribution of BLM sensitive and USFWS Threatened and Endangered Plant Species. Wyoming Natural Diversity Database Laramie, WY.

Flora of North America Editorial Committee. 2002. Magnoliophyta: Commelinidae (in part): Cyperaceae. Vol. 23. Oxford University Press, Oxford, NY.

Gardes, M. and A. Dahlberg. 1996. Mycorrhizal diversity in Arctic and Alpine tundra: an open question. New Phytologist 133:147-157.

Grime, J.P. 2001. Plant Strategies, Vegetation Processes, and Ecosystem Properties. John Wiley & Sons, LTD, London, UK.

Hale, W.G. and J.P. Margham. 1991. The Harper Collins Dictionary of Biology. Harper Collins Publishing, New York, NY.

Hitchcock, C.L. and A. Cronquist. 1973. Flora of the Pacific Northwest. An Illustrated Manual. University of Washington Press, Seattle, WA.

Houston, K. 2004. Personal communication with Ecologist, Shoshone National Forest regarding Swamp Lake Botanical Interest Area.

Hultén, E. 1968. Flora of Alaska and Neighboring Territories: A Manual of the Vascular Plants. Stanford University Press, Stanford, CA.

Jeffery, D.W. 1971. The experimental alteration of a *Kobresia*-rich sward in Upper Teesdale. *In*: E. Duffey and A. S. Watt, editors. The Scientific Management of Animal and Plant Communities for Conservation. Blackwell Scientific Publications, Oxford, UK.

Jeffrey, D.W. 2003. Grasslands and heath: A review and hypothesis to explain the distribution of barren plant communities. Biology and Environment: Proceedings of the Royal Irish Academy. 103B(3):111-123.

Johnson, J.B. 1996. Environmental function, vegetation, and the effects of peat mining on a calcareous fen in Park County, CO. Prepared for the U.S. EPA, Region VIII, Denver, CO.

Johnson, J.B. 2000. The ecology of calcareous wetlands in Park County, CO. Dissertation. Department of Biology, Colorado State University. Fort Collins, CO.

Johnston, B. 2004. Personal communication with Botanist/Ecologist, Gunnison National Forest, Gunnison, CO.

Johnson, J.B. and T.D. Gerhardt. 2002. Mapping and characterization of mires and fens in South Park, Park County, Colorado. Unpublished report submitted to the U.S. BLM.

Johnson, J.B. and D.A. Steingraeber. 2003. The vegetation and ecological gradients of calcareous mires in the South Park valley, Colorado. Canadian Journal of Botany 81(3): 201-219.

Johnston, R.S. and R.W. Brown. 1979. Hydrologic aspects related to the management of alpine areas. Pages 65-70 *in* Special management needs of alpine ecosystems. USDA Forest Service General Technical Report R672.

Jones, G.A. Robertson, J. Forbes, and G. Hollier. 1992. Environmental Science Dictionary. Harper Collins Publishers, New York, NY.

Leck, M.A. and W. Schütz. 2005. Regeneration of Cyperaceae, with particular reference to seed ecology and seed banks. Perspectives in Plant Ecology, Evolution and Systematics 7:95-133.

Levin, D.A. and H.W. Kerster. 1974. Gene flow in seed plants. Evolutionary Biology 7:139-220.

Liston, A., B. Wilson, W. Robinson, P. Doescher, N. Harris, and A. Svejcar. 2003. The relative importance of sexual reproduction versus clonal spread in an aridland bunchgrass. Oecologia 137 (2):216-225.

MacArthur, R.H. and E.O. Wilson. 1967. The Theory of Island Biogeography. Princeton University Press, Princeton, NJ.

Mackenzie, K.K. 1923. Notes on Carex—XIII, *Kobresia simpliciuscula*. Bulletin of the Torrey Botanical Club. 50: 349.

Manabe, S. and R.T. Wetherald. 1986. Reduction in summer soil wetness induced by an increase in atmospheric carbon dioxide. Science 232:626-628.

Massicotte, H.B., L.H. Melville, R.L. Peterson and D.L. Luoma. 1998. Anatomical aspects of field ectomycorrhizas on *Polygonum viviparum* (Polgonaceae) and *Kobresia bellardii* (Cyperaceae). Mycorrhiza 7:287-292.

McIntire, E.J.B. and J.S. Hik. 2002. Grazing history versus current grazing: leaf demography and compensatory growth of three alpine plants in response to a native herbivore (*Ochotona collaris*). Journal of Ecology 90:348-359.

Menke, J., editor. 1977. Symposium on livestock interaction with wildlife, fisheries and their environments. Sparks, NV. USDA Forest Service, Pacific Southwest Forest and Range Experimental Station, Berkeley, CA.

Miller, A. 2003. Personal communication with Research Associate, National Center for Genetic Resource Preservation, Ft. Collins, CO regarding *Kobresia simpliciuscula*.

Mitsch, W.J. and J.G. Gosselink. 1993. Wetlands. Second Edition. Van Nostrand Reinhold, New York, NY.

Montana Natural Heritage Program. 2005. Montana Plant Field Guide, *Kobresia simpliciuscula*. Available online at: http://nhp.nris.mt.gov/plants/plantguide.asp.

Moorehead, M. 2004. Personal communication with Stewardship Ecologist, The Nature Conservancy, Boulder, CO regarding High Creek Fen.

National Research Council. 2001. Compensating for Wetlands Losses Under the Clean Water Act. National Academy Press, Washington, D.C.

NatureServe. 2005. NatureServe Explorer: An online encyclopedia of life, version 4.6. NatureServe, Arlington, VA. Available online at: http://www.natureserve.org/explorer.

Neighbours, M. and D. Culver. 1990. Floristic survey of Preacher Rock Bog, Bighorn National Forest, Wyoming. Report prepared for the Tongue Ranger District, Bighorn National Forest by the Wyoming Natural Diversity Database, Laramie, WY.

Platt, J.R. 1964. Strong inference. Science 146:347-353.

Polunin, N. 1959. Circumpolar Arctic Flora. Oxford University Press, London, UK.

Porslid, A. E. and W. J. Cody. 1980. Vascular Plants of Continental Northwest Territories, Canada. National Museums of Canada, Ottawa, Canada.

Proctor, M, P. Yeo, and A. Lack. 1996. The natural history of pollination. Timberland Press, Portland, OR.

Roalson, E.H., J.T. Columbus, and E.A. Friar. 2001. Phylogenetic Relationships in Cariceae (Cyperaceae) based on ITS (nrDNA) and *trnT-L-F* (cpDNA) region sequences: Assessment of subgeneric and sectional relationships in *Carex* with emphasis on section *Acrocystis*. Systematic Botany 26:3318-341.

Sanderson, J. and M. March. 1996. Extreme Rich Fens of South Park, CO: Their Distribution, Identification, and Natural Heritage Significance, Colorado Natural Heritage Program. Fort Collins, CO.

Savile, D.B.O. 1972. Arctic Adaptations in Plants. Monograph No. 6. Canada Department of Agriculture, Ottawa, Canada.

Sawada, H. 1999. Genetic variation in clonal traits of *Trifolium repens* and species interactions. Plant Species Biology 14 (1):19-24.

Scott, M.J., P.J. Heglund, M.L. Morrison, J.B. Haufler, M.G. Raphael, W.A. Wall, and F.B. Samson. 2002. Predicting Species Occurrences- Issues of Accuracy and Scale. Island Press, Washington, D.C.

Simpson, D.A. 2001. Cyperaceae of economic importance. Kew Bulletin 43:423-430.

Swedish Museum of Natural History. 2004. Type specimen of *Kobresia simpliciuscula*. Stockholm, Sweden. Available at: http://www2.nrm.se/wise/fbotypes_se.php?id=1943.

The Nature Conservancy. 1999. Greater High Creek Watershed Site Conservation Plan. Colorado Field Office, Boulder, CO.

Tolmachev, A.I. and J.G. Packer, editors. 1996. Flora of the Russian Arctic. Vol. II. University of Alberta Press, Edmonton, Canada.

USDA Forest Service, Rocky Mountain Region. 2005. Region 2 Regional Forester's Sensitive Species List. Available online at: http://www.fs.fed.us/r2/projects/scp/evals/sensitivelist.shtml.

USDA-Natural Resource Conservation Service. The PLANTS Database Web Page. [Accessed 2005]. Located at; National Plant Data Center, Baton Rouge, LA. Available online at: http://plants.usda.gov/plants/index.html.

USDI Bureau of Mines. 1994. Minerals Yearbook: Metals and Minerals. U.S. Government Printing Office. 1:583-590.

USDI Fish and Wildlife Service. 1988. National List of Plant Species that occur in Wetlands Intermountain (Region 4, 8, 9). Biological Report 88 (26.8).

USDI Fish and Wildlife Service. 1999. Peatland mitigation policy considerations, Region 6. Policy document available through the Ecological Services Center, Colorado Field Office, Lakewood, CO.

Wahlenberg, G. 1803. *Carex simpliciuscula*. Vet.-Akad. Nya Handl. Stockholm (Memoirs of the Royal Academy of Sciences at Stockholm) 141.

Weber, W.A. 2003. The middle Asian element in the Southern Rocky Mountain flora of the western United States: a critical biogeographical review. Journal of Biogeography 30:649-685.

Weber, W.A. and R.C. Wittmann. 2001. Colorado Flora: Eastern Slope. University Press of Colorado, Niwot, CO.

Welsh, S.L, N.D. Atwood, S. Goodrich, and L.C. Higgins, editors. 1993. A Utah Flora, Revised. Brigham Young University Press, Provo, UT.

Williams, T.Y. 1990. *Kobresia simpliciuscula. In*: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fire Sciences Laboratory. Fire Effects Information System. Available online at http://www.fs.fed.us/database/feis/.

Windell, J.T., B.E. Willard, D.J. Cooper, C.F. Knud-Hansen, L.P. Rink, and G.N. Kiladis. 1986. An Ecological Characterization of Rocky Mountain Montane and Subalpine Wetlands. National Ecology Center, USDI, Washington, D.C.

Wyoming Natural Diversity Database. 2003. Element occurrence records for *Kobresia simpliciuscula*.

The U.S. Department of Agriculture (USDA) prohibits discrimination in all its programs and activities on the basis of race, color, national origin, age, disability, and where applicable, sex, marital status, familial status, parental status, religion, sexual orientation, genetic information, political beliefs, reprisal, or because all or part of an individual's income is derived from any public assistance program. (Not all prohibited bases apply to all programs.) Persons with disabilities who require alternative means for communication of program information (Braille, large print, audiotape, etc.) should contact USDA's TARGET Center at (202) 720-2600 (voice and TDD). To file a complaint of discrimination, write to USDA, Director, Office of Civil Rights, 1400 Independence Avenue, S.W., Washington, DC 20250-9410, or call (800) 795-3272 (voice) or (202) 720-6382 (TDD). USDA is an equal opportunity provider and employer.