Carex leptalea Wahlenberg (bristly-stalked sedge): A Technical Conservation Assessment

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

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COVER PHOTO CREDIT

Carex leptalea (livid sedge). Cover photograph by D. Cooper; inset photo © S. Mattson, used with permission.

Summary of Key Components for Conservation of *Carex leptalea*

Status

Carex leptalea (bristly-stalked sedge) is broadly distributed throughout North America and is therefore considered globally secure (G5). However, it is considerably rarer within the Rocky Mountain Region (Region 2) of the USDA Forest Service (USFS), with isolated occurrences in Wyoming and South Dakota where it is considered imperiled (S2) and in Colorado where it is considered critically imperiled (S1). While *C. leptalea* is not listed as a sensitive species in Region 2, it was recommended for possible placement on “other emphasis” species lists (USDA Forest Service 2006). *Carex leptalea* is an obligate wetland species although the habitats that it occupies vary, including open herbaceous fens, shrub-dominated carrs, and swamps. Within Region 2, it occurs in two principal habitats: (1) herbaceous-dominated transitional and rich fens, and (2) forested wetlands, including but not limited to treed fens. Wetlands supporting known occurrences of *C. leptalea* are primarily located on public lands managed by either the National Park Service or the USFS. Most populations appear to be secure from direct impacts, but many are vulnerable to indirect and cumulative impacts from land uses that alter their hydrologic or sediment dynamics.

Primary Threats

Carex leptalea occurrences in Region 2 are documented from a limited range of relatively uncommon habitats and are often highly disjunct from one another. Since seed dispersal distances for this species are likely small and its key habitats discontinuously distributed, the fate of the species in the region is intimately intertwined with that of the wetlands in which it occurs. Wetlands are among the most heavily impacted ecosystem types in Region 2 and elsewhere in North America. Impacts to fens include hydrologic modification, typically through construction of ditches or other engineering structures; inundation as a result of reservoir construction; peat mining; livestock grazing; and invasive species. During the last 40 years, increased recognition of the important functions provided by wetlands, codified in various regulatory and management contexts, has reduced the rate of wetland loss on public lands. However, numerous wetlands impacted historically still exhibit impaired function, and many remain vulnerable to direct and indirect impacts. How past anthropogenic impacts have affected the distribution and abundance of *C. leptalea* in Region 2 is unknown as data regarding the species in the region are limited.

With the exception of localized trampling due to livestock use, we found no specific instances of threats to Region 2 *Carex leptalea* occurrences. However, impacts from a wide variety of activities are known to indirectly impact wetland structure and function, with potential implications for the species. Since the wetlands supporting *C. leptalea* are fed primarily by groundwater inflows, any activity that significantly alters the water or sediment yields from surrounding watersheds, such as forest harvest, fire, or road construction, could deleteriously affect the species. Climate change also has the potential to negatively impact *C. leptalea* by altering the hydrologic and sediment regimes of the wetlands where it occurs.

Primary Conservation Elements, Management Implications and Considerations

Conserving an individual species is generally best accomplished through conserving its habitat. Like many wetland species in Region 2, *Carex leptalea* was likely more widespread historically than at present. Future expansion of its range in Region 2, at least under current and predicted climate scenarios, appears unlikely due to limited habitat and potentially low dispersal distances. Consequently, conservation efforts for *C. leptalea* should be directed towards the preservation of extant occurrences.

A key desired environmental condition for *Carex leptalea* is stable and wet hydrologic regimes. The kinds of sites providing these conditions include fens as well as spring and seeps with mineral substrates. Inflows of cold, minerotrophic groundwater are critical components to the functioning of each of these specific habitats. Management directed towards the conservation of *C. leptalea* should therefore focus on actions that minimize impacts to groundwater flow systems. These impacts include direct hydrologic alterations, such as groundwater pumping or diversions, as well as indirect effects that result from changes to the vegetation cover of contributing watersheds.

Other disturbances can directly affect *Carex leptalea* by causing plant mortality and altering the microsites that support the species. Trampling effects from native ungulates and livestock are one possible cause of disturbance. Desired conditions may therefore include minimal use by large grazers. Because many occurrences are found in sites with varying degrees of tree cover, factors that affect overstory communities, such as fire (prescribed or natural) or logging, may negatively affect the species. Many of the sites supporting occurrences appear to be of significant age, as indicated by the presence of accumulated peat deposits. This suggests that the species does best in sites with relatively low levels of disturbance, a factor that should be included when identifying desired environmental characteristics.

Additional research regarding *Carex leptalea* is needed on a range of topics. Broad-scale inventories are needed to better understand the abundance, distribution, and functional diversity of wetland types supporting *C. leptalea* in Region 2. These studies can provide a useful framework for more fine-scaled investigations of hydrology, vegetation, and geochemistry, which represent the primary variables driving wetland structure and function. In preparing this assessment, it has also become clear that more studies of *C. leptalea* demography and extensive population monitoring are needed in order to improve understanding of the species and potential threats.

TABLE OF CONTENTS

EDITORS: Richard Vacirca and Kathy Roche, USDA Forest Service, Rocky Mountain Region

List of Tables and Figures

Tables:

Figures:

INTRODUCTION

Goal of Assessment

The USDA Forest Service (USFS) is legally mandated to manage for the full complement of species occurring on National Forest Service lands. To effectively predict and mitigate for potential environmental consequences of management activities such as timber harvest, livestock grazing, energy development, or recreation use on an individual species, the USFS requires basic information about that species' biology, ecology, and conservation status. Unfortunately, there is a paucity of information for many species, and what information is available is scattered among a variety of disparate sources, largely unavailable to the forest managers and planners needing the information. To address these information gaps, the USFS Region 2, through its Species Conservation Project, has initiated the development of Species Conservation Assessments for a number of plant and animal species.

The main goal of this document is to provide a comprehensive and synthetic review of the biology, ecology, and conservation status of the wetland sedge *Carex leptalea* (bristly-stalked sedge) in Region 2. Consistent with previous assessments, topics such as the species' taxonomy, distribution, life history characteristics, physiology, and population biology, as well as known habitat relationships are presented. Since *C. leptalea* occurs in specific wetland types, topics such as hydrology and wetland geochemistry are discussed as these represent key ecological variables driving the structure and function of wetlands. Lastly, an assessment of the conservation status of the species in Region 2 is presented, and possible approaches for future management, research, and monitoring of the species are suggested.

The goal of this assessment is not to make specific management recommendations per se, but rather to synthesize knowledge of *Carex leptalea*, its habitat, and potential threats. Wetlands supporting *C. leptalea* are functionally diverse and the basic data regarding the species' habitat requirements are largely lacking, making specific predictions of the direct and indirect effects of management activities on the species impossible. However, the general principles presented should provide a useful context for managers to identify, evaluate, and mitigate for the potential impacts of management actions before they have been realized.

Scope of Assessment

In this assessment, we detail current knowledge regarding the biology, ecology, conservation status, and management of *Carex leptalea* in the USFS Rocky Mountain Region, which encompasses 17 national forests and 7 national grasslands throughout Colorado, Kansas, Nebraska, South Dakota, and Wyoming. For this assessment, Region 2 refers to all lands within the general administrative boundaries of the USFS Rocky Mountain Region, regardless of ownership or management. However, because much of the literature available for *C. leptalea* comes from outside of Region 2, data and information from a broader geographic area are included where appropriate. Likewise, while the temporal scope of the assessment is on current conditions, we also include relevant information from historical and evolutionary perspectives.

Treatment of Uncertainty in Assessment

Ecological systems and the biota inhabiting them are, by nature, exceedingly complex and unpredictable. Typically, multiple variables influence any given ecological attribute, whether it be community composition, biogeochemical cycling rates, or patterns of species invasion, persistence, or extinction. Important variables are frequently strongly interdependent and difficult to isolate and effectively measure, complicating data collection and analysis. Moreover, ecological patterns and processes are frequently strongly scale dependent, with generalizations appropriately made at one scale inappropriate at larger or smaller ones.

Considering the broad scope of this assessment, both topically and geographically, we have drawn upon a wide variety of information sources. These include qualitative and quantitative sources, ranging from the peer-reviewed literature to informal discussions with managers and scientists familiar with the species, its habitat, or potential management threats. Where available, we have incorporated quantitative data, such as hydrology, vegetation, or water chemistry parameters from wetlands known to support *Carex leptalea* occurrences. Relatively few peer-reviewed studies directly pertaining to *C. leptalea* have been published from the region. Consequently, we also drew from the more extensive "gray literature", such as unpublished reports and graduate theses and dissertations, as well as from studies conducted outside of Region 2.

When preparing broad-scale assessments such as this, where rigorous, quantitative data are largely unavailable, it is important to explicitly address issues of uncertainty and to draw upon whatever substantive forms of information are available. In this assessment, we have placed the greatest weight upon information gleaned from the peer-reviewed scientific literature; however, we have also relied upon the impressions and ideas of scientists and managers familiar with the species or its habitats. These more informal information sources are cited in the text as personal communication.

Publication of Assessment on the World Wide Web

To facilitate their use in the Species Conservation Project, species assessments will be published on the USFS Region 2 World Wide Web site (http://www.fs.fed.us/r2/projects/scp/assessments/index.shtml). Placing documents on the Web makes them available to agency biologists and the public more rapidly than publishing them as reports. More importantly, it facilitates revision of the assessments, which will be accomplished based on guidelines established by USFS Region 2.

Peer Review of This Document

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

Management Status and Natural History

Management Status

Due to its wide distribution in North America, *Carex leptalea* is considered globally secure (G5). Likewise, the national rank of N5 has been given to the species in the United States and Canada. The species is relatively abundant in northern latitudes and is unranked or ranked S4 (apparently secure) or S5 (secure) in all Canadian provinces (NatureServe 2004). *Carex leptalea* is also widely distributed within the continental United States, occurring in every state except Arizona, Hawaii, Kansas, Nebraska, and Nevada (**Table 1**; USDA Natural Resources Conservation Service 2006).

Carex leptalea is considered to be of conservation concern in both Montana and Washington (Moseley 1989), and it is currently included on the sensitive species list for USFS Region 1 (USDA Forest Service 2004). Within the states encompassed by Region 2, *C. leptalea* is considered critically imperiled (S1) in Colorado and imperiled (S2) in Wyoming and South Dakota (**Table 1**; NatureServe 2004). The species was briefly placed on the sensitive species list in Region 2 (USDA Forest Service 2003), but it was removed after a significant number of new occurrences were discovered on the Black Hills National Forest (USDA Forest Service 2006).

Existing Regulatory Mechanisms, Management Plans, and Conservation Practices

Carex leptalea is not listed as either threatened or endangered under the Endangered Species Act, nor is the species listed as sensitive in USFS Region 2. Consequently, no specific regulations concerning the conservation of the species apply. Several occurrences are found in wilderness areas or national parks; these may provide a conservation reserve for the species (Falkner and Stohlgren 1997, Crist et al. 2005).

As an obligate wetland species (Reed 1988), *Carex leptalea* and its habitat receive limited protection under some existing federal, state, and local statutes. Section 404 of the Clean Water Act has historically placed regulatory oversight on a range of activities impacting wetlands with the U.S. Army Corps of Engineers (USACE). However, the Supreme Court's decision in Solid Waste Agency of Northern Cook County (SWANCC) vs. USACE has effectively removed the USACE's regulatory oversight for wetlands lacking connections to surface water bodies such as streams. Many wetlands supporting *C. leptalea*, such as those occurring adjacent to small seeps or springs, lack surface water connections to navigable waters. Therefore, they may be considered isolated under USACE jurisdiction through the Clean Water Act (Bedford and Godwin 2003, Tiner 2003). However, the scope of USACE jurisdiction on geographically isolated wetlands is still undetermined, with cases currently under review in the courts. Also relevant to wetlands management on USFS lands is Executive Order 11990; this order instructs agencies to "take action to minimize the destruction, loss or degradation of wetlands, and to preserve and enhance the natural and beneficial values of wetlands."

Table 1. States supporting *Carex leptalea* occurrences and the conservation rank assigned to the species, if any. See **Definitions** section for explanation of Natural Heritage Program ranks. Region 2 states are in bold and italics. Source: NatureServe 2004.

State (rank)	State (rank)	State (rank)
Alabama (SNR)	Maine (SNR)	Oregon (S3)
Alaska (SNR)	Maryland (S5)	Pennsylvania (SNR)
Arkansas (SNR)	Massachusetts (SNR)	Rhode Island (SNR)
California (S2)	Michigan (SNR)	South Carolina (SNR)
Colorado (S1)	Minnesota (SNR)	**South Dakota (S2)**
Connecticut (SNR)	Mississippi (S5)	Tennessee (SNR)
Delaware (S4)	Missouri (SNR)	Texas (SNR)
District of Columbia (SNR)	Montana (S3S4)	Utah (S1)
Florida (SNR)	New Hampshire (SNR)	Vermont (SNR)
Georgia (S4)	New Jersey (SNR)	Virginia (SNR)
Idaho (S2)	New Mexico (SNR)	Washington (SNR)
Illinois (S2S3)	New York (SNR)	West Virginia (S4)
Indiana (S3)	North Carolina (S3)	Wisconsin (SNR)
Iowa (S1)	North Dakota (S2S3)	**Wyoming (S2)**
Kentucky (S3S4)	Ohio (SNR)	
Louisiana (SNR)	Oklahoma (S1)	

Region 2 *Carex leptalea* occurrences generally occur in forested or herb-dominated fens. USFS memo 2070/2520-72620, signed by the Director of Renewable Resources for Region 2, provides regional guidance on fens and emphasizes the protection, preservation, and enhancement of fens to all Region 2 forest supervisors (Proctor personal communication 2004). However, the memo is not a directive and does not limit the kinds of management activities that can be pursued in wetlands supporting *C. leptalea*. In addition, within Region 2, the Watershed Conservation Practices Handbook (FSH 2509.25) sets standards and guidelines to meet state water quality standards and to conserve watershed processes, streams, and wetlands.

Biology and Ecology

Classification and description

Systematics and synonymy

The genus *Carex* has nearly 2,000 species globally and 480 in the North American flora (Ball and Reznicek 2004). Species in the genus occupy a diverse range of habitats and are found across broad edaphic, hydrologic, and elevational gradients. Although they occur in uplands as well, *Carex* species are prevalent in wetlands where they are often the dominant taxa. Species in the genus may be similar morphologically, and many are largely indistinguishable by vegetative characteristics alone, making sedge taxonomy difficult and field identification impossible if plants are not fruiting (Metcalfe 1969, Standley 1990). Full taxonomy for *C. leptalea* is presented in **Table 2**.

Carex leptalea, a perennial member of the family Cyperaceae, was first described by Wahlenberg in 1803 in Kongl. Vetenskaps Academiens Nya Handlingar (24: 139) (IPNI 2005). In his review of *Carex* nomenclature, Reznicek (2001) placed *C. leptalea* in Section Leptocephalae, with *C. leptalea* as the lectotype. This is a revision of Mackenzie's earlier treatment, which placed *C. leptalea* in section Polytrichoideae (Mackenzie 1940).

Several infra-specific taxa have been identified. These include *Carex leptalea* ssp. *harperi* (Fern.) W. Stone (Harper's sedge), *C. leptalea* ssp. *leptalea*, and *C. leptalea* ssp. *pacifica* Calder & Taylor (Pacific bristly stalked sedge). Two varieties, *C. leptalea* var. *harperi* (Fern.) Weatherby & Grisc. and *C. leptalea* var. *tayloris* Boivin, have been also been used, but these are no longer accepted (ITIS 2004). Common names used for *C. leptalea* include bristly-stalked sedge (USDA Natural Resources Conservation Service 2006) and flaccid sedge (Hurd et al. 1998).

Table 2. Taxonomy and nomenclature of *Carex leptalea* (bristly-stalked sedge). Source: ITIS 2004.

Kingdom	Plantae
Subkingdom	Tracheobionta
Division	Magnoliophyta
Class	Liliopsida
Subclass	Commelinidae
Order	Cyperales
Family	Cyperaceae
Genus	*Carex*
Species	*Carex leptalea*

Morphological characteristics

Carex leptalea stems, 15 to 70 cm tall, are typically densely clustered from slender, freely branching rhizomes (**Figure 1**). Leaf blades are deep green and glabrous, thin and wide in cross-section, and measure 0.5 to 1.3 mm wide. Sheaths are membranous, brownish-tinged at maturity, and concave at the mouth. *Carex leptalea* bears solitary, androgynous, green to yellowish-green spikes that measure 4 to 16 mm long and 2 to 3 mm thick; the staminate portion is often short and slender, measuring 0.5 to 0.8 mm wide. *Carex leptalea* produces relatively few perigynia; these are generally arranged in a subalternate fashion on the rachis (Hurd et al. 1998). Small, deciduous pistillate scales, shorter in length than the perigynia, are ovate-orbicular in shape and green to brown in color. Plants bear a solitary, terminal staminate spike 0.7 to 1.5 cm long. Perigynia are oval-elliptic in shape, 2.5 to 5 mm long, 1 to 1.5 mm, and circular in cross section. The pale green or yellowish-green perigynia taper slightly to a rounded, entire, or emarginate apex. Perigynia bear many fine nerves on both surfaces and along their margins. The achenes in *C. leptalea*, which are oblong-ovoid in shape and glossy and yellow to brown in appearance, nearly fill the perigynium. They are typically 1.3 to 2 mm long and 0.8 to 1 mm wide and bear three stigmas (Hurd et al. 1998).

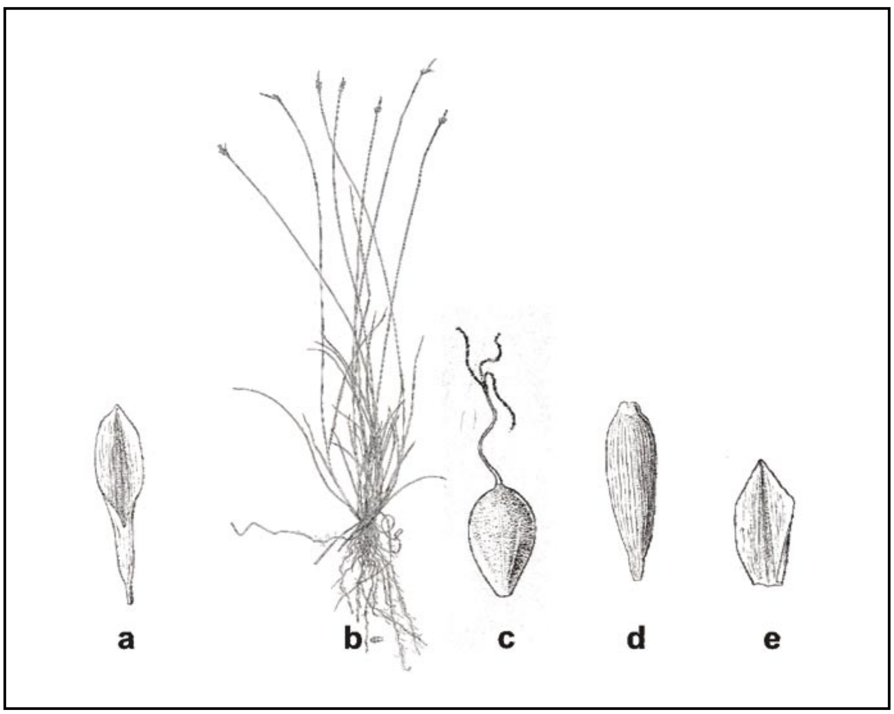

Figure 1. *Carex leptalea* (a) perigynium, dorsal view, (b) habit, (c) achene, (d) staminate scale, and (e) pistillate scale (Mackenzie 1940; used with permission)

Across the broad geographic and ecological range of *Carex leptalea*, there are significant variations in the color, stature, length of spikes, length, shape, and degree of overlap of perigynia (Ball and Reznicek 2004). Three general morphotypes have been described. The typical phase, *C. leptalea* ssp. *leptalea* is generally smaller and bears more narrow culms and smaller spikes and perigynia than either ssp. *harperi* or ssp. *pacifica* (Ball and Reznicek 2004). This phase appears to be relatively uniform and occurs throughout much of the continent; all of the occurrences in Region 2 are of this type.

In contrast to *Carex leptalea*, the similar looking *C. tenuiflora* has more than one spike per head, and its spikes are broader. *Carex dioica* var. *gynocrates* has fatter and more reflexed perigynia than *C. leptalea*, and *C. geyeri* is a more robust plant with much wider leaves and bearing only 1 to 3 large perigynia separated on the rachis from the staminate flowers (Spackman et al. 1997).

Distribution and abundance

Carex leptalea is widely distributed throughout North America north of Mexico. Indeed, it has one of the widest geographic ranges of any North American sedge (Ball and Reznicek 2004). *Carex leptalea* is common in Canada, occurring in all provinces, and it is widespread in the United States, occurring in 45 states and the District of Columbia (**Figure 2**; **Table 1**).

Within Region 2, *Carex leptalea* is known from Colorado, South Dakota, and Wyoming. All occurrences are found on, or adjacent to, public lands managed by either the USFS or the National Park Service (**Figure 3**; **Appendix**). In Colorado, occurrences are found on the Pike, Arapaho, and Routt national forests and in Rocky Mountain National Park. All South Dakota occurrences are located on the Black Hills National Forest. In Wyoming, areas managed by Region 2 that support the species include the Medicine Bow and Shoshone national forests. The species also occurs in Wyoming within the Targhee National Forest and Grand Teton and Yellowstone national parks, none of which fall within the administrative boundaries of Region 2.

Many occurrences of *Carex leptalea* in Region 2 are found in wilderness or other special management areas, including the Absaroka-Beartooth Wilderness Area and Swamp Lake Special Botanical Area on the Shoshone National Forest, the Never Summer Wilderness on the Arapaho National Forest, the Mount Evans Wilderness on the Pike National Forest, and the Black Elk Wilderness on the Black Hills National Forest.

While *Carex leptalea* is found across a wide elevation range globally, from near sea level to the over 3,000 m (9,842 ft.), all occurrences in Region 2 are at relatively high elevation, from approximately 1,525 m (5,000 ft.) in South Dakota to 3140 m (10,300

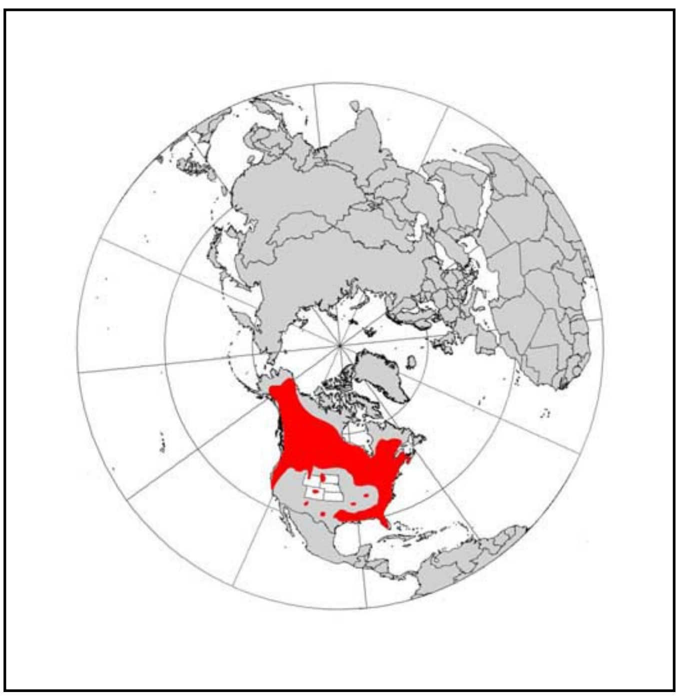

Figure 2. Approximate distribution of *Carex leptalea* in the northern hemisphere based on Hultén (1968).

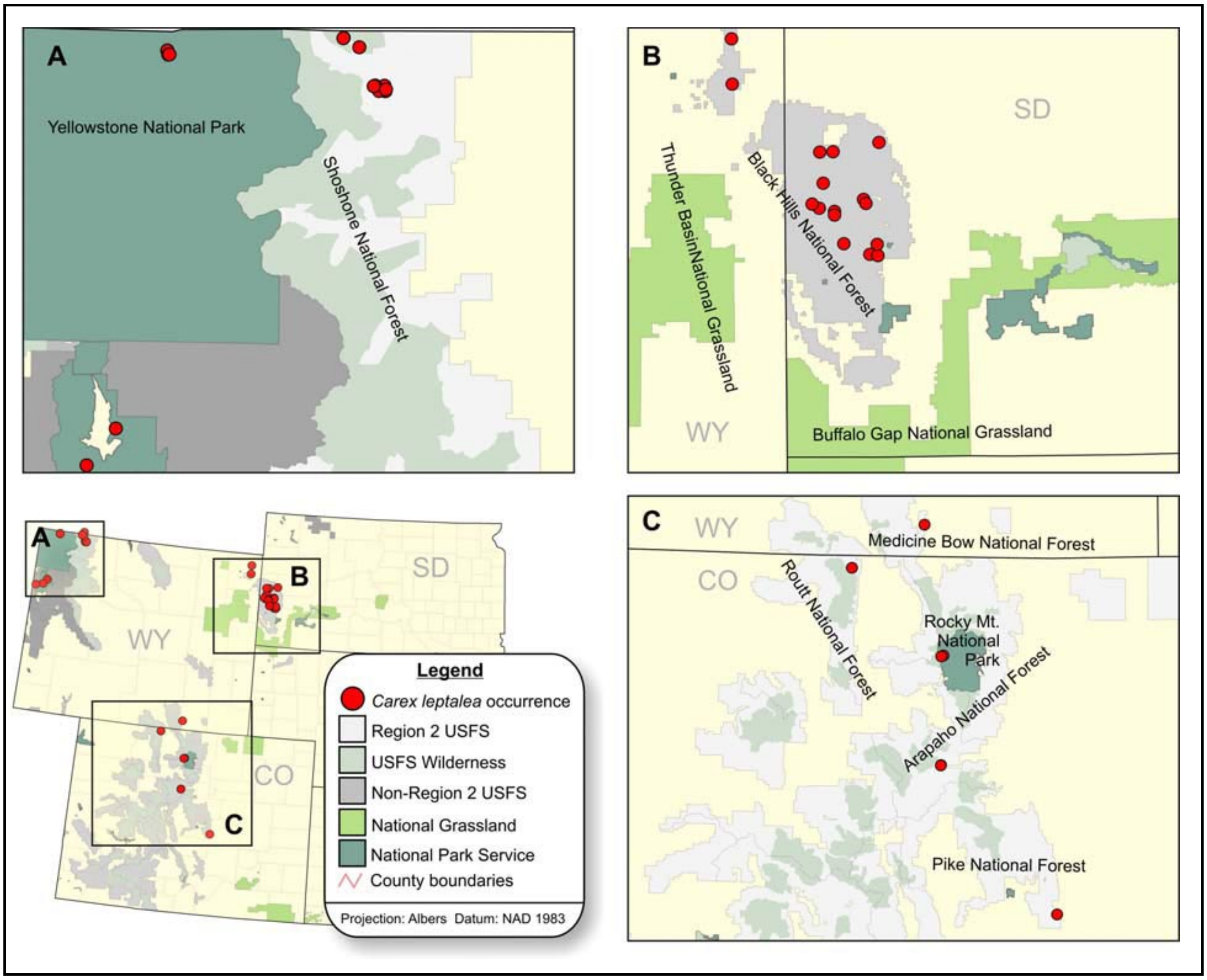

Figure 3. Distribution of *Carex leptalea* within USDA Forest Service Region 2 and adjacent areas in Wyoming.Record sources include Wyoming Natural Diversity Database, South Dakota Natural Heritage Program, and Colorado Natural Heritage Program element occurrence records, herbarium specimen label information, and unpublished occurrence records from recent field surveys by Lemly and Cooper in Yellowstone National Park and various USDA Forest Service personnel for the Black Hills National Forest.

ft.) in Colorado. The lower evapotranspiration rates and greater precipitation at these altitudes support the wetlands types that provide *C. leptalea* habitat.

Abundance estimates for *Carex leptalea* occurrences in Region 2 are mostly anecdotal (**Appendix**). For example, several records describe abundance with vague language such as "numerous clumps", "several dozen tussocks", or "10 clumps". Although limited, these reports do provide some sense of relative abundance.

The largest number of occurrences of *Carex leptalea* in Region 2 is found on the Black Hills National Forest, and the majority of these are in the southern portion of the forest (Zacharkevics personal communication 2006). Prior to 2004, approximately 35 occurrences of this species were documented on the Black Hills National Forest. Following its placement on the Region 2 sensitive species list in December 2003, a monitoring program was instituted. Surveys conducted during the 2004 field season resulted in the discovery of 24 new occurrences on lands administered by the Black Hills National Forest (Black Hills National Forest 2005) and the consequential removal of the species from the current Region 2 sensitive species list.

Population trends

Few occurrences of *Carex leptalea* in Region 2 have been visited more than a couple of times or have been visited specifically to evaluate the species' abundance or habitat. The absence of quantitative data, therefore, severely limits our ability to confidently estimate population trends. Although abundance estimates are included with some element occurrence records, they do not appear to have been the product of quantitative sampling and so are of limited value as a baseline for future monitoring. These estimates can, however, help managers or scientists to formulate a search image when making future field visits.

Habitat

Wetland classification and habitat characterization

Ecological classification can be difficult regardless of the ecosystem type being analyzed. Many different criteria, alone or in combination, can be used to differentiate classes; ultimately, the choice of which classifying variable(s) to use dictates the utility of the resulting classification. At fine to intermediate spatial scales, the most intuitive and commonly used approaches are based on vegetation structure and composition. Examples include the numerous habitat-type classifications developed by the USFS (e.g., Alexander et al. 1986, Hess and Alexander 1986) and the National Vegetation Classification System developed by The Nature Conservancy and used by Natural Heritage Programs (e.g., Comer et al. 2003, NatureServe 2003).

Although vegetation is certainly useful for wetland classification, because of the importance of hydrologic and chemical gradients for controlling wetland community composition and structure and ecological function, additional approaches to wetland classification and description have been developed (Cowardin et al. 1979, Brinson 1993). For example, some classification schemes emphasize chemical or hydrologic variables (e.g., pH, cation or nutrient concentrations; groundwater vs. precipitation), vegetation, and in the case of peatlands, peat composition (bryophyte vs. sedge).

Habitat characteristics

Carex leptalea is an obligate wetland species (i.e., it occurs exclusively in wetlands). Not surprising given its large geographic range, the species is known from a relatively wide range of specific habitats. Globally, *C. leptalea* has been documented from such diverse environments as mossy or wet woods, conifer swamps and bogs, wet and often calcareous meadows and fens, swales, lakeshores, stream banks, as well as damp, shaded rock ledges, marshy fields, and swampy ditches (Ball and Reznicek 2004).

In Region 2, *Carex leptalea* has been described from two principle habitats: graminoid-dominated transitional rich and rich fens, and shrub or tree-dominated wetlands associated with springs or small streams. The latter type of habitat is characteristic of the occurrences in the Black Hills; many of these sites may not support significant peat accumulations, but anecdotal accounts suggest that water-logged organic soils are common (Burkhart 2006 personal communication, Zacharkevics personal communication 2006). Elsewhere in the region, many *C. leptalea* occurrences are associated with localized areas of peat accumulation, but not necessarily extensive peatlands. Where dominated by overstory species such as conifer trees, such wetlands could be called treed fens or swamps (**Figure 4**). These include relatively large wetlands as well as small wetlands associated with minerotrophic seeps or springs.

In contrast to these sites, other occurrences are in wetlands dominated by grasses and forbs. Examples of sites where *Carex leptalea* can be found in more open herbaceous-dominated fens include the Swamp Lake and Little Moose Lake (Figure 5) occurrences on the Shoshone National Forest in Wyoming. Although there are significant floristic and hydrogeochemical differences between sites, both are dominated largely by herbaceous plant species and are representative of basin-type fens with anchored or floating peat mats.

Reproductive biology and autecology

Life history and strategy

Carex leptalea is a perennial species, but it is not known how long individual plants live. We found no studies examining the life history of this species, and although other members of the genus have been examined in detail (Bernard 1976, Noble et al. 1979, Bernard 1990), it is unclear how the life history strategy of *C. leptalea* may differ. Although caespitose in habit, the species produces short rhizomes, a likely means of asexual establishment.

In **Figure 5**, we present a generalized overview of the life cycle of *Carex leptalea* featuring four primary stages: (1) seed, (2) seed bank, (3) seedling, and (4) mature plant. Although researchers working with other

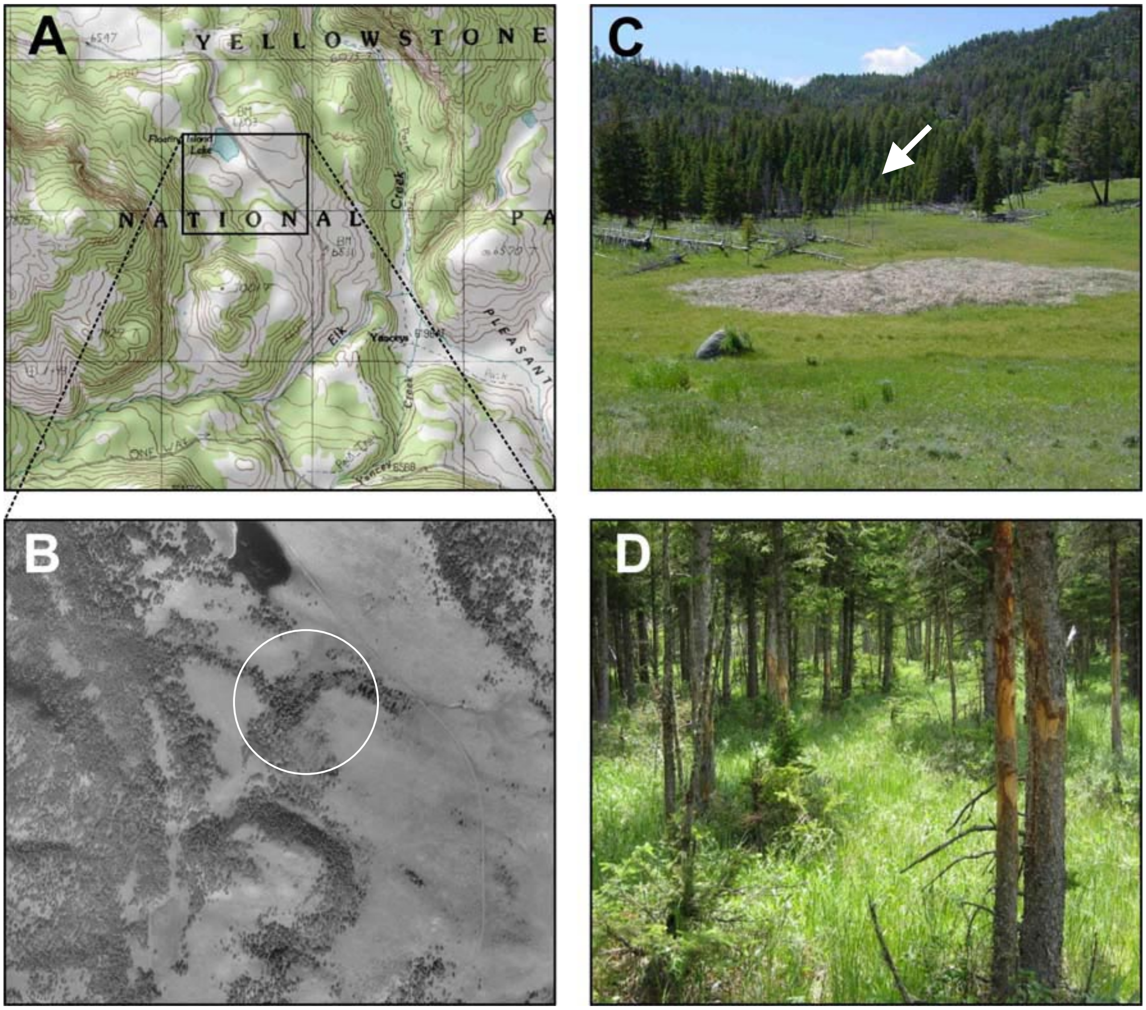

Figure 4. Map (A) and aerial photograph (B) of Little Island Lake fen in Yellowstone National Park. *Carex leptalea* occurs in a treed fen dominated largely by *Picea glauca* (indicated by arrow in C; close up of stand (D)). Photographs by D. Cooper.

clonal sedge species have described up to six distinct age classes, insufficient demographic data specific to *C. leptalea* are available to warrant such an approach in this assessment.

Reproduction, pollination, and phenology

Species of *Carex*, including *C. leptalea*, are wind-pollinated (Gleason and Cronquist 1991), but there are no data describing out-crossing distances or other aspects of *C. leptalea* pollination ecology. *Carex leptalea* typically flowers in late spring or early summer, and plants bear fruit from approximately July to August (Johnston 2001).

Seed dispersal, viability, and germination requirements

Carex leptalea must establish at least occasionally from seed although no studies have examined how often this occurs. Likewise, no studies of *C. leptalea* seed dispersal were found. As with other sedges, it is likely that multiple dispersal mechanisms may be involved, including wind (amenochory), water (hydrochory), and animals, birds in particular (zoochory) (Ridley 1930). Although there are no studies examining *C. leptalea* seed germination requirements, research from other *Carex* species suggests that seeds have at least limited dormancy and are capable of forming a persistent

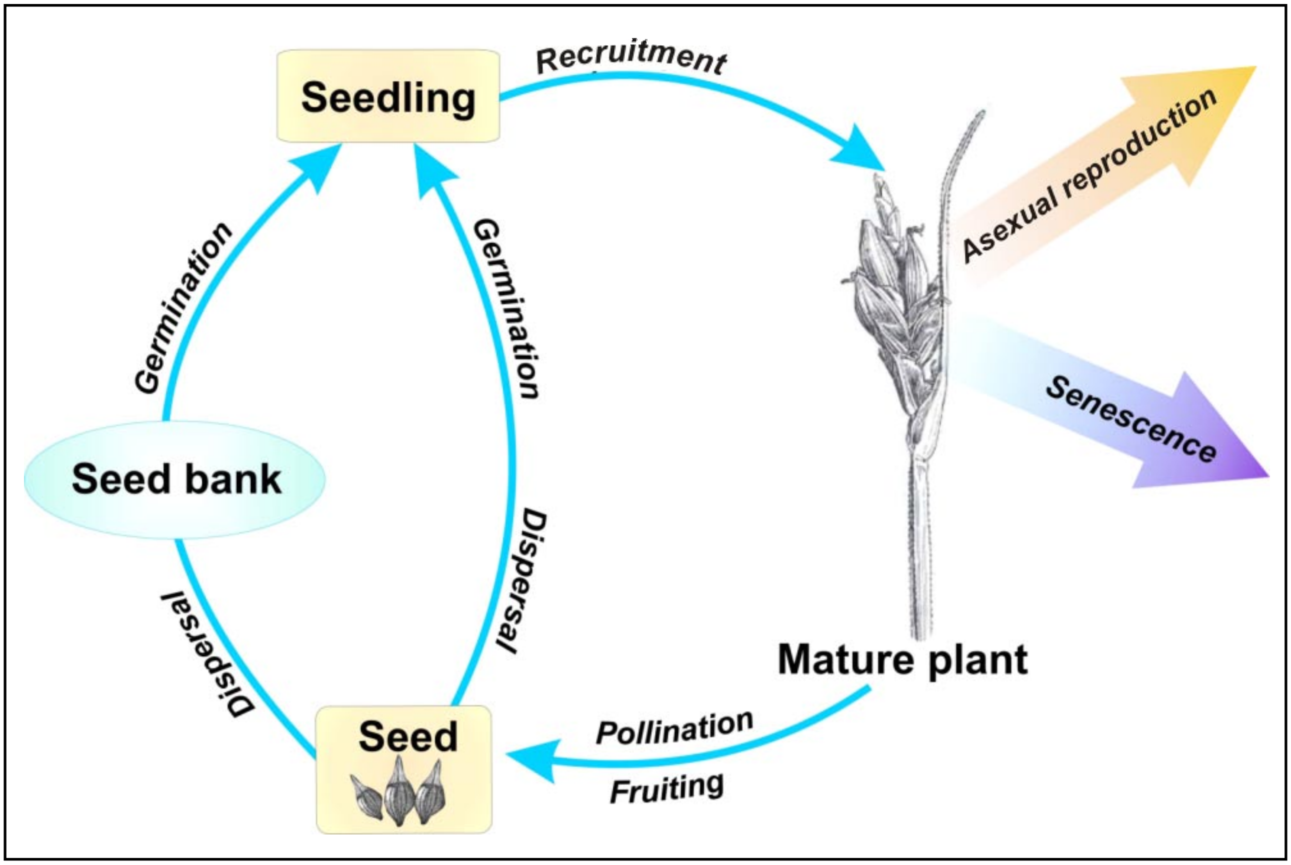

Figure 5. Generalized life cycle diagram for *Carex leptalea*.

soil seed bank (Schütz 1998, Schütz and Rave 1999, Schütz 2002). The relative importance of seed bank processes in the establishment dynamics of *C. leptalea* is unknown.

Genetic characteristics and concerns

Little work on the genetics of *Carex leptalea* has been conducted. Chromosome numbers of 50 and 52 (2n) have been reported for the species (Ball and Reznicek 2004). Wahl (1940) noted a haploid chromosome count of 26 for the species. Published analyses of clonal sedges from outside of the region suggest that many *Carex* species show little genetic differentiation even among populations from widely separated areas, and that overall genetic variability is similar among species (McClintock and Waterway 1993, Vellend and Waterway 1999). Whether these results would apply to *C. leptalea*, however, is unknown.

Waterway (1991) conducted a comparative study of clonal diversity and genetic variation in nine *Carex* species found commonly in subarctic fens, and she found that species with relatively broad ecological amplitudes had a larger percentage of unique genotypes per site as well as higher levels of heterozygicity and polymorphism. In addition, she found that species with long-spreading rhizomes were more polymorphic than caespitose species or those with only short-spreading rhizomes like *C. leptalea* (Waterway 1991).

There are no data to evaluate the genetic structure *Carex leptalea* for Region 2 populations. Since the main regional distributional centers for *C. leptalea* - central Colorado, western Wyoming, and the Black Hills - are apparently isolated from each other and from populations outside of the region, genetic crossing between populations may be rare. Fine-scale genetic exchange is certainly possible, however, within an area like the Black Hills, which supports a number of occurrences. No collections of *C. leptalea* germplasm have been made, and it is impossible to say what the underlying genetic structure of *C. leptalea* populations is in the region.

Hybridization

Hybridization has been widely reported in the genus *Carex* (Cayouette and Catling 1992). Most verified crosses have been between closely related species within the same section; however, intersectional hybrids have been described. It appears that the majority of crosses produce infertile offspring, but some hybrids are known to produce partially fertile seeds (Cayouette and Catling 1992, Ball and Reznicek 2004). We found no specific reference to hybrids involving *C. leptalea*, and since no other sedge species in the section Leptocephalae co-occur with *C. leptalea* in Region 2, the formation of hybrids would appear highly unlikely. A possible exception is the Tarryall Range in Colorado, where the only population of *C. tenuiflora* in Region 2 occurs.

Demography

No information on the demography of *Carex leptalea* occurrences is available. Quantitative data regarding age and life history stages and the nature of the transitions between them are generally difficult to obtain. What specific factors govern the transition of seedlings to mature plants, or between different age classes or life history stages in this species are unknown, but it is likely that some mortality due to herbivory, disease, or competition affects recruitment level (Harper 1977). Also unknown is the relative phenology and life span of *C. leptalea* shoots; however, work done on several other temperate *Carex* species may provide some insights into their dynamics. In a study of *C. rostrata* in a New York fen, Bernard (1976) found that most shoots emerged between mid-summer and early fall, and lasted, at most, 20 to 25 months before senescing. Notably, only 17 percent of the shoots he followed survived to produce seeds. Similar results have been reported from Canada for the same species (Gorham and Somers 1973). Whether similar patterns would be observed for *C. leptalea* is unknown.

As of now, no Population Viability Analysis (PVA) has been performed for *Carex leptalea*. In general, insufficient data are available to identify a minimum viable population size. In general, small occurrences are more susceptible to localized extinction due to environmental stochasticity (Pollard 1966). However, many sites supporting occurrences in the region are limited in their potential to support large numbers of individuals because of their small size (e.g., wetlands associated with small seeps). More information regarding plant growth rates and lifespan, rates of seed production and viability, and seed bank formation and expression would help to identify vulnerable stages in the life history of *C. leptalea*.

Community and ecosystem ecology

Hydrogeomorphic and geological settings

Wetlands in general, and those supporting *Carex leptalea* occurrences, occur in specific geomorphic and landscape settings. Many *C. leptalea* occurrences are in fens, which form only in sites with perennially stable water tables necessary for peat accumulation (Windell et al. 1986). Fens supporting *C. leptalea* in the western United States typically form in sites associated with closed basins or discrete springs controlled by bedrock fractures or contacts although information from herbarium and element occurrence records is often insufficient to say which setting best describes each occurrence. In addition to fens, the species has been reported from a large number of small wetlands associated with springs and seeps, particularly in the Black Hills. Many of these systems would *not* technically qualify as fens as they do not support significant peat accumulations. However, many may support histic (organic) epipedons.

Little Moose Lake on the Shoshone National Forest is an example of a fen formed in a closed basin setting (**Figure 6**). Wetland development in closed basins may proceed via terrestrialization, with gradual infilling of ponds by mineral and organic sediment deposition, coupled with the formation and expansion of floating or anchored peat mats, which create broad and expansive fens. In Region 2, these fen types are most common in glaciated terrain, where features such as kettle ponds or valley-spanning terminal moraines occur.

In contrast, the only known occurrence of *Carex leptalea* in Rocky Mountain National Park, Colorado is found in a fen formed in a slope setting (**Figure 7**) where converging groundwater flow paths create positive hydraulic head, resulting in the formation of springs. The cold and minerotrophic groundwater discharged to the surface retards organic matter decomposition and promotes the accumulation of peat. Fens formed in these settings can expand into adjacent forests via paludification, with accumulated peat slowing drainage and elevating water tables, promoting additional peat accumulation (Crum 1988, Chadde et al. 1998).

Springs are also common features in areas with complex physiography and bedrock geology. For example, because of its high topographic relief and

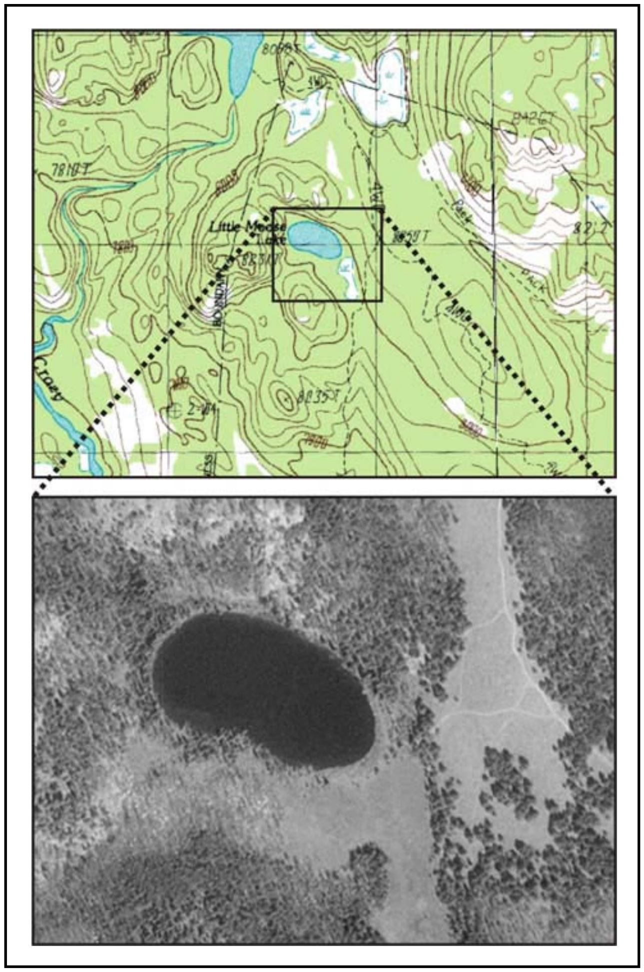

Figure 6. Topographic map and aerial photograph of Little Moose Lake, Shoshone National Forest, Wyoming, a fen supporting *Carex leptalea*.

complex geology, the Black Hills contains numerous springs and seeps (Hortness and Driscoll 1998, Driscoll et al. 2000), many of which support *Carex leptalea*.

The actual geological configuration of sites supporting wetlands may be complex. For example, the Swamp Lake fen on the Shoshone National Forest, which supports an occurrence of *Carex leptalea*, is on Quaternary glacial deposits. While the lake is underlain by impervious Precambrian granite, immediately to the south of Swamp Lake rise the Cathedral Cliffs, composed of three discrete layers including limestone, dolomite, and a cap of volcanic rock (**Figure 8**; Heidel and Laursen 2003). The limestone and dolomite formations contribute groundwater high in pH, and the wetland supports an extreme rich fen community, including rare species such as *C. livida* (livid sedge), *C. limosa* (mud sedge), *C. diandra* (lesser panicled sedge), and *Drosera anglica* (English sundew) (Fertig and Jones 1992, Heidel and Laursen 2003). In contrast, nearby fens in watersheds composed entirely of the granitic rock lack alkaline groundwater inputs, and instead of a rich fen, support poor and intermediate fens (Heidel and Laursen 2003, Mellmann-Brown 2004).

The stratigraphy and mineral composition of bedrock and quaternary deposits is an important variable influencing both the abundance and functional characteristics of wetlands at broad scales (Bohn et al. 2003). For example, the permeability and distribution of hydrologic flow paths, gross physiography, and groundwater chemistry often differ between areas composed of igneous or metamorphic rock versus sedimentary rocks, with significant implications for wetlands.

An additional factor of importance to wetlands is the areas Quaternary history. Glaciated landscapes typically contain a higher density of wetlands than adjacent un-glaciated terrain (Windell et al. 1986).

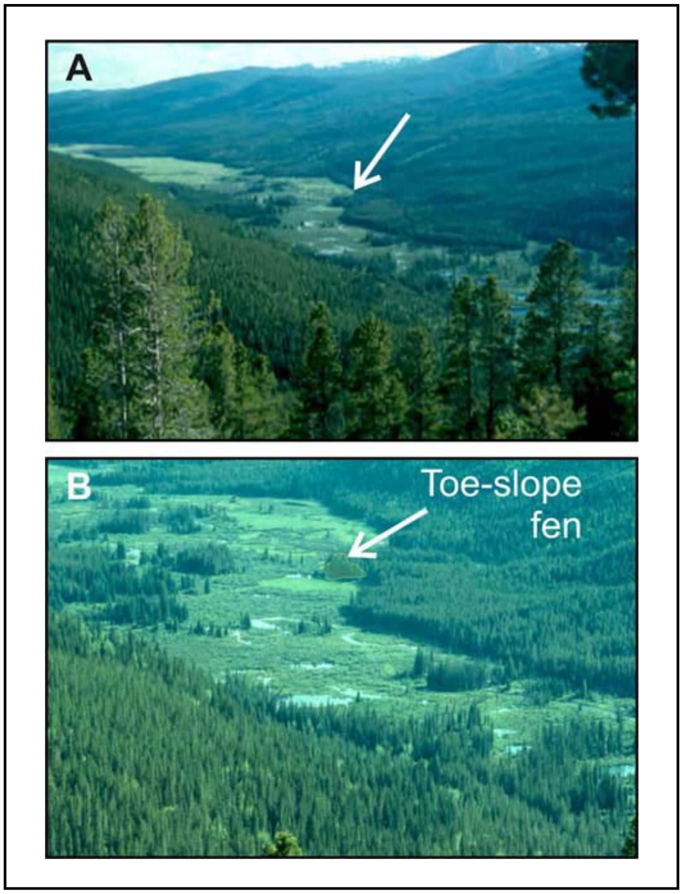

Figure 7. Landscape (A) and close-up (B) photographs of a forested fen supporting *Carex leptalea* in the Kawuneechee Valley, Rocky Mountain National Park, Colorado. The fen, indicated by arrows, is formed by the discharge of cold minerotrophic groundwater from adjacent valley slopes. Photographs by D. Cooper.

Landforms associated with glacial activities, such as kettle ponds, formed where stagnant ice blocks left behind by melting Pleistocene glaciers are buried in outwash or morainal material, are conducive to fen formation. In addition, terminal or lateral moraines can block drainages, producing landscapes of relatively low relief that retards the runoff of water (Cooper 1990). These factors are not relevant to unglaciated areas such as the Black Hills, which support the majority of Region 2 occurrences.

Differences in basin size, aspect, slope processes, and landform morphology can influence rates of peat accumulation and successional rates in larger basin and toe-slope wetlands. However, there is little known about drivers influencing the development of small, spring-fed wetlands supporting many *Carex leptalea* occurrences in the region (e.g., those in the Black Hills). More research is needed contrasting *C. leptalea* occurrences in small versus large fens and in sites lacking peat accumulations.

Substrate characteristics and microhabitats

Throughout its range, *Carex leptalea* typically, but not exclusively, occurs on peat substrates. The presence or absence of peat, and its thickness can be highly variable and is driven largely by variation in physiography, elevation, hydrologic regime, geomorphology, and wetland age (Belyea and Clymo 2001). For instance, peat thickness in fens formed in kettle ponds often varies with differences in aspect, elevation, and degree of minerotrophy (Sanderson and March 1996, Cooper and Arp 2002). Some Region 2 *C. leptalea* occurrences are in fens formed at the toe of hillslopes, where groundwater discharges to the surface, or at discrete hillslope or upwelling springs. The formation and accumulation of peat in these settings are strongly influenced by physiographic and hydrologic factors such as the hydraulic head at spring or seep locations and the stability of the groundwater flow. For example, in Yellowstone National Park, *C. leptalea* has been found in sites with between 0.9 and 2.4 m (3.0 and

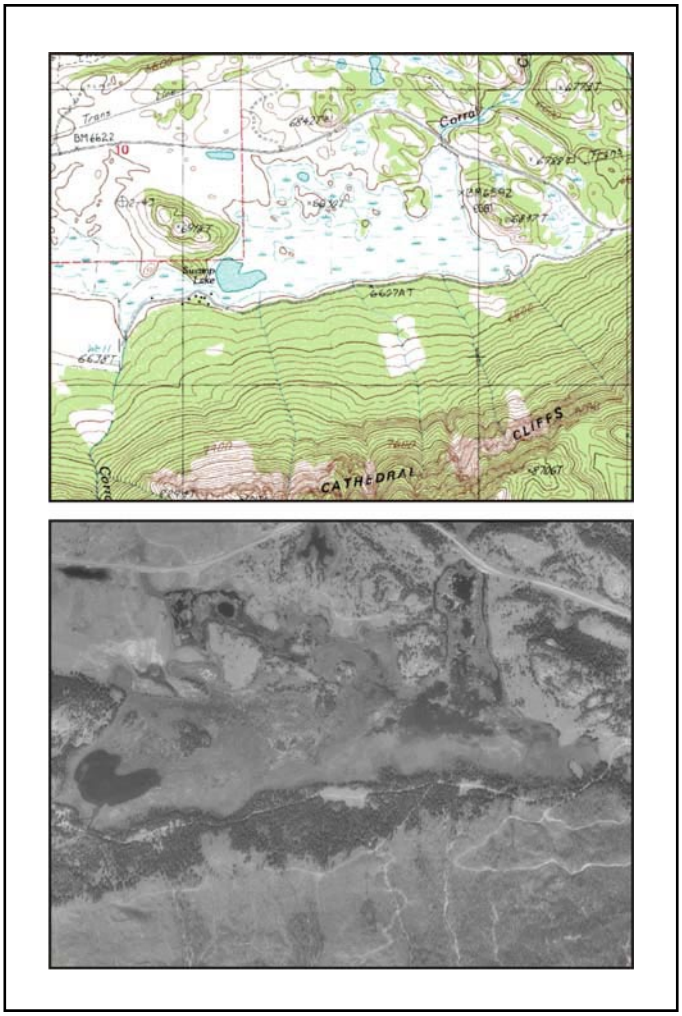

Figure 8. Topographic map and aerial photograph of Swamp Lake, Shoshone National Forest, Wyoming, an extremely rich fen supporting *Carex leptalea*.

7.9 ft.) of peat (Lemly and Cooper unpublished data). In contrast, Motzkin (1994) found *C. leptalea* in sites with organic sediments deposits only 0 to 15 cm (0 to 5.9 inches) deep in a New York rich fen.

In addition to moss or sedge peat deposits, *Carex leptalea* has been observed growing on decaying logs in forests (Mellmann-Brown personal communication 2004, Zacharkevics personal communication 2006). Many of these sites may support locally thick peat deposits derived largely from dead wood versus sedges. The importance of moss hummocks in providing habitat for *C. leptalea* has been noted at Swamp Lake, where Heidel and Laursen (2003) described *C. leptalea* from "muskeg zones", formed where moss hummocks meet the base of *Picea glauca* (white spruce) trees within the surrounding forest.

Hydrology

Water table depth is perhaps the single greatest factor influencing vegetation patterns in wetlands. Numerous studies have correlated vegetation patterns with such metrics as mean water table depth and intra and inter-annual hydrologic variability. Typically, most wetland species exhibit a unimodal distribution along water table gradients, but the range and maximum vary among species, and often within different populations of the same species (Tiner 1991, Mitsch and Gosselink 2000). In addition, temporal fluctuations in water table elevations between years can result in a high degree of turnover in species composition. This phenomenon is particularly important in wetland types with highly variable hydrologic regimes such as marshes (Bolen et al. 1989, Squires and van der Valk 1992), but it can also effect more hydrologically stable types like fens (Bayley and Mewhort 2004).

Hydrologic flow paths supporting wetlands can be complex, and they typically include surface water inputs as well as groundwater from both local and regional aquifers. For example, Swamp Lake on the Shoshone National Forest is fed by several water sources, including toe-slope seeps and springs, surface flows, subsurface flow from debris fans, and groundwater discharge from glacial deposits on the fen margins (Heidel and Laursen 2003).

As described earlier, several Region 2 *Carex leptalea* occurrences are found in fens formed in toe-slope locations. While these wetlands may occur on river floodplains (**Figure 9**), these fens function largely independently of the surface water in the stream (Woods et al. 2006).

Although there are no data specifically examining the hydrologic regime of *Carex leptalea* occurrences, anecdotal accounts and observations suggest that the species occurs in sites with relatively stable hydrologic regimes such as fens and perennial springs, but not in the wettest microsites such as floating peat mats, flarks, or pools. In an analysis of habitat relationships for 37 sedge species in Canada, Gignac et al. (2004) found that *C. leptalea* reached its maximum frequency of occurrence in plots that had a water table 0 and 20 cm (0 and 7.8 inches) below the ground surface. In contrast, Jones and Fertig (1999) observed *C. leptalea* on thick tussocks along the drier margins of fens in Wyoming.

Nutrients, water and peat chemistry

Although hydrologic regime is generally regarded as the principal gradient driving species' distribution and abundance in wetlands, vegetation patterns are also strongly related to peat and water chemistry. Gradients in pH and the concentration of nutrients such as nitrogen and phosphorus and mineral ions such as calcium (Ca^{2+}) and magnesium (Mg^{2+}) are commonly used to differentiate and classify peatlands (Crum 1988).

Concentrations of mineral ions and nutrients that fen plants require are principally supplied by groundwater inputs, with minor contributions from dry and wet atmospheric deposition and surface water inflows. Consequently, the geochemistry of bedrock and quaternary deposits in contributing watersheds are key controls of fen water pH, as well as nutrient and ion delivery (Glaser et al. 1981, Windell et al. 1986, Chee and Vitt 1989, Vitt and Chee 1990). Watersheds with limestone, dolomite, or shale bedrock produce water that is basic in reaction (pH 7.0 to 8.5) (Cooper 1996, Chapman et al. 2003, Heidel and Laursen 2003), while those composed of granitic or metamorphic rocks produce acidic waters (Cooper and Andrus 1994, Cooper et al. 2002).

In regards to fens, the terms poor and rich are typically are used to describe wetland fertility gradients, specifically nitrogen and phosphorus availability (Bragazza and Gerdol 2002), as well as species richness gradients. Gradients in pH and the concentration of mineral ions such as calcium (Ca^{2+}) are generally thought to co-vary with nutrient-availability gradients; some researchers suggest, however, that pH and nutrient gradients should be separated (Bridgham et al. 1996, Wheeler and Proctor 2000, Bragazza and Gerdol 2002). Within North American peatlands, most studies have found a close correlation between cation concentrations and pH, so either can be effectively used to characterize habitat. Several fen types occur in Region 2, including poor, transitional rich, rich, and extremely rich fens, each of which can support distinct

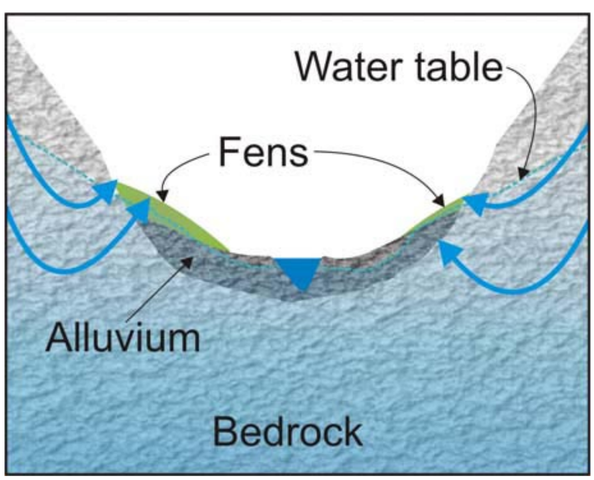

Figure 9. Schematic diagram illustrating the formation of toe-slope fens along the margins of a mountain valley.

plant species and vegetation types. Poor and transitional rich fens, which are only moderately influenced by minerotrophic groundwater, are common in Region 2. They are typically relatively species poor, have a bryophyte flora dominated by *Sphagnum* and other mosses, and have low pH and Ca^{2+} concentrations (Windell et al. 1986, Glaser 1987). Rich fens typically support a more diverse flora, including non-*Sphagnum* "brown mosses". Rich fen waters are less acidic and have higher Ca^{2+} concentrations, ranging from 10 to 30 mg/L (Crum 1988). Other than iron fens, extremely rich fens are the rarest type of fen in Region 2. These fens are typified by very high pH and Ca^{2+} concentrations and support a unique flora including the presence of calciphiles (Lesica 1986, Cooper 1996). Marl is often present due to the extremely high concentrations of Ca^{2+} and bicarbonate, and the formation of calcite (Fertig and Jones 1992, Johnson 2000). No similar classification scheme exists for small spring-fed wetlands, such as those in the Black Hills; however, the basic principals regarding pH, ion concentrations, and flora, particularly bryophytes, likely apply.

Few studies have examined the water chemistry of sites supporting *Carex leptalea*. Surveys of studies where pH measurements have been made suggest that the species only occurs in relatively mineral rich fens. *Carex leptalea* has been reported from transitional rich and rich fens, but apparently it does not occur in either true bogs, which do not occur in Region 2, or in poor fens (**Figure 10**; Motzkin 1994, Cooper and Jones 2004, Gignac et al. 2004). In an analysis of 37 sedge species in Canada, Gignac et al. (2004) included *C. leptalea* in group of species including *C. disperma* (softleaf sedge), *C. chordorrhiza* (creeping sedge), and *C. lasiocarpa* (woollyfruit sedge), which attained their maximum frequency of occurrence in sites with pH >6.

The affinity of *Carex leptalea* for more minerotrophic fens has been noted elsewhere. For example, Glaser et al. (1981) identified *C. leptalea* as an indicator of minerotrophic fens in Minnesota, along with species such as *Triglochin maritima* (seaside arrowgrass) and *C. chordorrhiza* (creeping sedge). Anderson et al. (1996) made similar conclusions for *C. leptalea* in Maine, as did Sjörs (1963) for northern Ontario. Occurrences in Idaho and Montana would also appear to be from transitional and rich fens (Bursik and Moseley 1992, Jankovsky-Jones 1997, Chadde et al. 1998, Cooper and Jones 2004).

An exception to this affinity to minerotrophic fens is the Swamp Lake site on the Shoshone National Forest, where the water is circum-neutral to basic, characteristic of an extremely rich fen (Heidel and Laursen 2003). Fertig and Jones (1992) measured pH values of 6.9 to 7.9 while pH measurements taken at calcareous springs at the site ranged from 8.0-8.4 (Heidel and Laursen 2003). Other extremely rich fens in the Rocky Mountains are not known to support *Carex leptalea* (Lesica 1986, Cooper 1996).

Nitrogen is typically the limiting nutrient for terrestrial plants, but in some environments, including

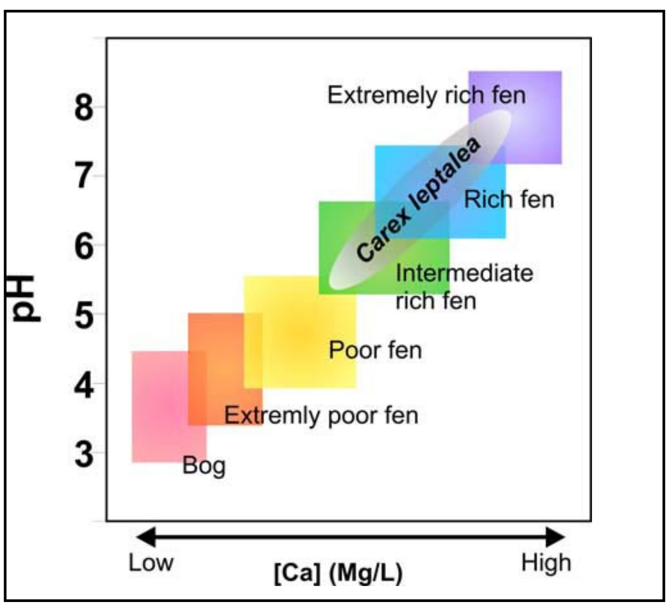

Figure 10. Diagram illustrating the approximate range of pH and Ca^{2+} values characterizing *Carex leptalea* occurrences.

some wetlands, phosphorus may be limiting (Mitsch and Gosselink 2000). For example, total net primary productivity (NPP) has been correlated with NO_{3-} and total phosphorus surface water concentrations (Beltman et al. 1996, Thormann and Bayley 1997). Biologically mediated oxidation-reduction reactions account for the principal fluxes of nitrogen in wetlands, such as nitrate reduction, N fixation, and denitrification (Beltman et al. 1996, Oien 2004). The bacteria responsible for these transformations differ depending on site-specific hydrologic and chemical characteristics. Anoxic sites typically have low total nitrogen, and due to low nitrifying bacteria activity, low NO_{3-}.

Sediment dynamics

No quantitative data are available on sediment dynamics in sites supporting *Carex leptalea*. In general, sediment flux rates into peatlands and springs are small. Because of the slow accumulation rates of organic matter in Region 2 fens, significant increases in mineral flux outside of the historic range of variability have the potential to negatively impact vegetation. Recent research suggests that much of the sediment input into basin fens is organic rather than mineral, and sediment delivery is limited primarily to fen margins (Cooper and Arp 2002). Organic input from trees and shrubs is also a key factor driving peat accumulation in forested fens that support many *C. leptalea* occurrences. No research has been directed towards the sediment dynamics of the spring-fed wetlands characteristic of the Black Hills.

Mass wasting events such as landslides may episodically contribute pulses of sediment to wetlands supporting *Carex leptalea*. Heidel and Laursen (2003) observed several debris flows entering the Swamp Lake wetland from adjacent cliff faces that were destabilized by fire and salvage logging activities. Based on the presence of ravines on the adjacent slopes, they also suggested that debris flows might have occurred in the past. Because the physiographic and geological settings of wetlands supporting *C. leptalea* occurrences are so variable, it is impossible to evaluate the importance of episodic events, such as debris flows.

Vegetation types and associated plant species

Wetlands support a distinct and diverse assemblage of plants species, and they are critically important to local and regional biodiversity (Brinson and Malvarez 2002, Leibowitz 2003). Although species diversity within individual plant communities is often low, strong hydrologic and chemical gradients, which are so critical in determining the fine-scale distribution of individual species, often create a number of communities, each supporting many different species. Species diversity among peatlands is highly variable, influenced by factors such as pH, nutrient status, local water table characteristics, and disturbance history. Diversity is typically lower in nutrient poor systems, such as bogs and poor fens, and in microsites characterized by extremely wet, acidic, or basic conditions. The small spring-fed wetlands of the Black Hills do not support great diversity, in large part because of their small size.

The vegetation types and plant species associated with *Carex leptalea* vary geographically and in relation to key underlying environmental gradients, such as pH and water table depth (**Table 3**). In upstate New York, Motzkin (1994) found *C. leptalea* in a community within a calcareous fen that had a sparse tree and shrub strata including *Pinus strobus* (eastern white pine), *Larix laricina* (tamarack), *Potentilla fruticosa* (shrubby cinquefoil), *Salix serissima* (autumn willow), and *Rhamnus alnifolia* (alderleaf buckthorn), and a low herbaceous stratum with *C. interior* (inland sedge), *C. flava* (yellow sedge), *Juncus dudleyi* (Dudley's rush), *J. nodosus* (knotted rush), and *Muhlenbergia glomerata* (spiked muhly) A similar community type has been documented from a sloping calcareous fen in Massachusetts (Picking and Veneman 2004) characterized by a sparse cover of *Larix laricina*, *Rhamnus alnifolia*, *C. interior*, *C. flava*, *C. hystericina* (bottlebrush sedge), *Parnassia glauca* (fen grass of Parnassus), *Solidago patula* (roundleaf goldenrod), *S. purshii* (bog goldenrod), *Thelypteris palustris* (eastern marsh fern), and *Equisetum fluviatile* (water horsetail).

Carex leptalea typically occurs in communities with some tree or shrub cover. The overstory associates vary with elevation and geographic region. For example, *Pinus strobus*, the dominant tree species in the New York fen analyzed by Motzkin (1994), does not occur in the Rocky Mountains, where different species including *Picea glauca*, *P. engelmannii* (Engelmann spruce), *P. engelmannii* (limber pine), and *Betula papyrifera* (paper birch) occur (Chadde et al. 1998, Cooper and Jones 2003, Cooper and Jones 2004). Although the composition of tree and shrub communities differs in these sites, gross physiognomy is often similar.

Overall site characteristics for communities supporting *Carex leptalea* are relatively similar, being moist, shady sites with seeps or springs, and containing species such as *Equisetum* spp., *C. disperma*, and *Picea* spp. Nearly all Black Hills National Forest occurrences appear to fit this general description (Zacharkevics personal communication 2006). Other common

Table 3. List of associated species reported from a sample of sites supporting *Carex leptalea*.

Reference	Study location	Associated species
Heidel and Laursen 2003	Shoshone National Forest, Wyoming	*Carex diandra*, *C. limosa*, *Drosera rotundifolia*, *Salix farriae*, *C. utriculata*, *C. simulata*, *Scirpus actus*, *Typha latifolia*, *Eleocharis quniqueflora*, *Drepanocladus aduncus*
Peinado et al. 1998	Alberta	*Abies balsamea*, *Betula papyrifera*, *Vaccinium angustifolia*, *Picea mariana*, *Viburnum edule*, *Thalictrum pubescens*, *Carex disperma*, *C. canescens*, *C. pauciflora*, *C. magellanica*, *Ribes lacustre*
Hansen and Hall 2002	Idaho	*Betula glandulosa*, *Salix bebbiana*, *S. lutea*, *S. serissima*, *Calamagrostis stricta*, *Carex aquatilis*, *C. simulata*, *C. interior*, *Juncus arcticus*
Jankovsky-Jones 1997	Idaho	*Picea engelmannii*, *Abies lasiocarpa*, *Calamagrostis canadensis*, *Carex scopulorum*, *C. utriculata*, *C. cusickii*, *C. leptalea*, *C. aquatilis*, *Eriophorum chamissonis*, *Betula glandulosa*, *Pedicularis groenlandica*, *Salix pedicellaris*, *Equisetum fluviatile*, *Sphagnum* spp.
Picking and Veneman 2004	Massachusetts	*Thelypteris palustris*, *Equisetum fluviatile*, *Senecio aureus*, *Juncus brachycephalus*, *Solidago purshii*, *Aster puniceus*, *Potentilla fruticosa*, *Parnassia glauca*
Glaser et al. 1990	Minnesota	*Scirpus hudsonianus*, *Cladium mariscoides*, *Parnassia palustris*, *Muhlenbergia glomerata*, *Scirpus cespitosus*, *Carex lasiocarpa*, *C. livida*, *Drosera anglica*, *D. rotundifolia*, *D. intermedia*, *Utricularia intermedia*
Wheeler et al. 1983	Minnesota	*Carex lasiocarpa*, *C. livida*, *C. limosa*, *C. leptalea*, *Drosera anglica*, *Cladium mariscoides*, *Eriophorum angustifolium*, *Menyanthes trifoliata*, *Rhynchospora alba*, *Drepanocladus revolvens*, *Campylium stellatum*, *Sphagnum subsecundum*
Cooper and Jones 2004	Montana	*Betula glandulosa*, *Pentaphylloides floribunda*, *Carex prairea*, *C. utriculata*, *C. buxbaumii*, *C. disperma*, *C. aquatilis*, *Juncus balticus*, *Hordeum brachyantherum Menyanthes trifoliata*, *Petasites sagittata*, *Scorpidium cossonii* (= *Drepanocladus revolvens*), *Tomenthypnum nitens*, *Campylium stellatum*, *Bryum pseudotriquetrum*, *Drepanocladus aduncus*, *Aulacomnium palustre*
Motzkin 1994	New York	*Carex interior*, *C. hystericina*, *C. flava*, *C. lacustris*, *C. stricta*, *Juncus nodosus*, *Drosera rotundifolia*, *Thelypteris palustris*, *Equisetum* spp., *Parnassia glauca*, *Solidago purshii*
Carleton and Maycock 1980	Ontario, Quebec	*Picea glauca*, *Vaccinium angustifolium*, *Linnaea borealis*, *Cornus canadensis*, *Ledum groenlandicum*, *Carex stricta*, *C. disperma*
Various survey accounts	Black Hills National Forest, South Dakota	*Populus tremuloides*, *Picea glauca*, *Equisetum palustre*, *Climacium* spp., *Cornus sericea*, *Corylus cornuta*, *Carex disperma*

vegetation associates reported from the Black Hills include *Cornus sericea* (redosier dogwood), *Corylus cornuta* (beaked hazelnut), *Betula papyrifera*, and *Populus tremuloides* (quaking aspen) (**Appendix**).

Occurrences in open, herbaceous-dominated fens occupy a different habitat. For example, the dominant species at Little Moose Lake on the Shoshone National Forest include *Carex limosa*, *Menyanthes trifoliata* (buckbean), *C. utriculata* (Northwest Territory sedge), *Salix planifolia* (diamondleaf willow), and *C. aquatilis* (water sedge), as well as the rare plants *Drosera anglica* and *C. diandra* (Heidel and Laursen 2003). Species reported from non-forested fens in Idaho include *Betula glandulosa* (resin birch), *Typha latifolia* (broadleaf cattail), *C. lasiocarpa* (woollyleaf sedge), *C. cusickii* (Cusick's sedge), *C. utriculata*, *C. aquatilis*, *Pedicularis groenlandica* (elephanthead lousewort), *Salix pedicellaris pedicellaris* (bog willow), *Equisetum fluviatile*, *Sphagnum teres*, and *Calliergon stramineum* (calliergon moss) (Jankovsky-Jones 1997).

The bryophytes found with *Carex leptalea* vary between sites. Intermediate rich fens may support *Sphagnum* mosses such as *S. teres*, while circumneutral to basic fens support "brown mosses" such as *Drepanocladus revolvens*, *Tomenthypnum nitens*, *Campylium stellatum*, *Bryum pseudotriquetrum*, *Drepanocladus aduncus*, and *Aulacomnium palustre* (Cooper and Jones 2004). In the Black Hills, mosses in the genus *Climacium* have been reported.

Carex leptalea is known to occur in many different community types. For example, Cooper and Jones (2004) included *C. leptalea* in their *Betula glandulosa* / *Carex* spp./"brown mosses" shrubby peatland vegetation type, occurring in rich and extreme rich fens. They also found it in their *Salix candida* / *C. utriculata* shrubby peatland vegetation type, *Eleocharis quinqueflora* - *Trichophorum caespitosum* /"brown mosses" herbaceous peatland vegetation type, and a *C. flava* / "brown mosses" herbaceous peatland vegetation type. Monitoring reports form the Black Hills provide little information regarding vegetation besides the frequent mention of mosses and a spruce overstory.

Competitors and relationship to habitat

There is little known about the relationship between *Carex leptalea* and possible competitors. Unlike many wetland sedges, *C. leptalea* occurs in both relatively unshaded and densely shaded sites. Gignac et al. (2004) noted that along with species like *C. disperma*, *C. leptalea* is tolerant of shade, occurring in sites with a mean shade of 37 percent. This suggests that competition for light may be less important than for other resources.

Parasites and disease

Only limited research has been conducted on the effects of pathogens or parasites on *Carex* species, and none involving *C. leptalea*. McIntire and Waterway (2002) document the incidence of a smut on sedges, including *C. limosa*, *C. rariflora*, and their hybrid in a Quebec peatland. Whether this smut or other parasites or pathogens affect *C. leptalea* in Region 2 is unknown. Although extant Region 2 *C. leptalea* populations are relatively isolated from one another, because the species likely once had a broader distribution and because many pathogens are generalist in nature, the possibility that some parasites or pathogens affect Region 2 occurrences cannot be eliminated.

Herbivores and relationship to habitat

No descriptions of herbivores feeding on *Carex leptalea* were encountered. While native ungulates may opportunistically feed upon the species, larger grazers, such as elk (*Cervus canadensis*) or cattle, generally avoid the wetland environments where *C. leptalea* occurs. Moose (*Alces alces*) are more likely to use wetlands, but there is no evidence that they feed on *C. leptalea*. In addition, moose are absent from the Black Hills, where the highest concentration of *C. leptalea* occurrences is found in the region. Because soils in sites supporting *C. leptalea* are typically saturated, burrowing or root-feeding herbivores, such as pocket gophers (*Thomomys* spp.), are unlikely to feed on the species. Impacts of trampling from large animals may be greater than the effects of herbivory.

Mycorrhizae

Although mycorrhizae are common on many plants, several families including the Brassicaceae, Juncaceae, and Amaranthaceae are considered non-mycorrhizal (Muthukumar et al. 2004). Historically, the Cyperaceae have also been considered non-mycorhizal, but research during the past few decades has identified several sedge species that have mycorrhizal associations. In their recent review of the topic, Muthukumar et al. (2004) identified 88 mycorrhizal sedge species, approximately 40 percent of the 221 species they evaluated. Most instances of mycorrhizal associates were arbuscular mycorrhizae (AM), but they did note instances of ectomycorrhizal associations as well. While they discussed the status of several *Carex* species, *C. leptalea* was not included. Whether *C. leptalea* forms mycorrhizal relationships, and if so, under what conditions, is unknown.

CONSERVATION

Threats

In addition to a species' rarity, the stability and resilience of ecosystems supporting known populations is important in assessing a species' conservation status. The degree to which a particular habitat characteristic (e.g., water table depth) responds to a disturbance can be characterized as an ecological stability while ecological resilience refers to the degree to which such a characteristic returns to its original state following a disturbance (Rejmankova et al. 1999). Both attributes should be considered when attempting to predict the potential ecological response of an individual species to different disturbance agents since the fate of any given species is typically intertwined with that of its ecological setting, particularly in species confined to small, discrete ecosystems.

Both stability and resilience should be evaluated in terms of a species' basic life history attributes and successional status. The implications of a particular disturbance agent on an early-seral, annual species will likely differ significantly from those on a late-seral, perennial species. Likewise, species capable of vegetative growth and reproduction may have different effect thresholds and recovery times following disturbance than species lacking the capability.

The following discussion outlines the basic types of disturbances likely to impact wetlands supporting *Carex leptalea*. Unfortunately, the data necessary for confident prediction of the response of any particular occurrence to a specific disturbance is unavailable. Therefore, the following discussion is based largely on a first-principles extrapolation from known case studies. Additionally, specific, impending threats to *C. leptalea* occurrences and more speculative estimates of potential future threats are differentiated.

Hydrologic alteration

Direct hydrologic alteration by ditching is one of the most common and long-lasting anthropogenic impacts to wetlands in Region 2. For example, ditches constructed in a fen prior to 1915 within what is now Rocky Mountain National Park were still effectively intercepting and diverting inflow to the fen nearly 75 years after ditch abandonment (**Figure 11**; Cooper et al. 1998). The resulting lower water tables facilitated the invasion of the fen by *Deschampsia caespitosa* (tufted hairgrass), a native grass common in seasonally dry, mineral soil sites. Similar changes may promote invasions by non-native species as well. Direct hydrologic alterations to discrete springs and seeps, the habitats characterizing *Carex leptalea* occurrences in the Black Hills, are less likely an issue.

The overall threat from future ditching or direct dewatering is presumably low for most *Carex leptalea* populations. However, where there are pre-existing water rights, these can take precedence over regulations or management directed at ecosystem or species conservation. This is true for a population of *C. leptalea* that is found in an area influenced by the Grand Ditch water diversion project in Grand County, Colorado on the western side of Rocky Mountain National Park (Chimner and Cooper 2003).

Because the wetlands supporting known *Carex leptalea* occurrences are fed principally by groundwater, a variety of actions outside of their immediate boundaries can alter their hydrology, sediment budgets, or water chemistry, with potentially significant ramifications for dependent wetland species. The water balance of individual wetlands varies as a function of the precipitation inputs, evaporation and transpiration (ET) losses, and the amount of water stored as groundwater (Mitsch and Gosselink 2000). Vegetation in surrounding uplands influences this balance through effects on transpiration and interception

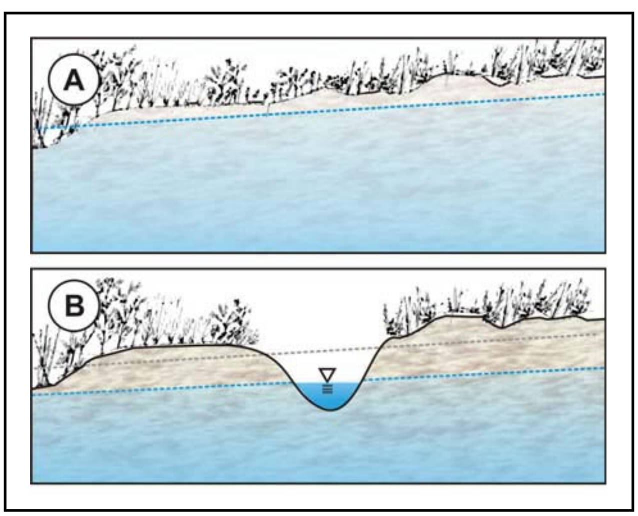

Figure 11. Schematic diagram illustrating water table in a hypothetical fen before (A) and after (B) ditching.

of rain or snow, which is susceptible to subsequent loss through evaporation or sublimation (Kauffman et al. 1997). Thus, any natural or anthropogenic process that significantly alters upland vegetation (e.g., fire or timber harvest) can impact nearby wetlands. These effects are most likely to result in major shifts in the hydrology in wetlands fed primarily by local aquifers, including the springs and seeps comprising much of the species' habitat in the Black Hills. Large fens may also receive groundwater inputs from larger aquifers, dampening the impacts of changes in hill-slope hydrologic process in the immediate surrounding watershed.

Timber harvest

The majority of *Carex leptalea* occurrences in Region 2 are in sites with moderate to high tree cover. The wetlands supporting these occurrences are often small features associated with springs and occur as discrete patches within broader upland forest vegetation associations. Consequently, direct mortality of *C. leptalea* plants is possible if harvest operations occur in sites supporting the species. The most likely impacts would be from direct ground disturbance from harvesting equipment and workers. In addition, increased light availability and temperatures following harvest may make sites less suitable for *C. leptalea*. In occurrences associated with larger fens, where forest harvest activities are less likely to occur, direct impacts to the species from timber harvest may be less of an issue.

Timber harvest may also indirectly affect some occurrences by changing hydrologic processes. Significant changes in watershed vegetation cover can alter surface runoff through its effects on evapotranspiration rates and snowpack accumulation patterns. For example, canopy removal in a subalpine watershed in Colorado increased precipitation reaching the forest floor by approximately 40 percent and, it increased peak snowpack water equivalent (SWE) by more than 35 percent (Stottlemyer and Troendle 1999, Stottlemyer and Troendle 2001). Logging, whether clearcutting or partial thinning, typically results in increased annual and peak streamflows in logged watersheds (Troendle and King 1987). However, the effects of increased water yield and surface inflows to peatlands are difficult to predict, and both positive and negative effects are possible.

Since the majority of snowmelt passes through subalpine watersheds not as surface flow, but rather as subsurface flow where soil processes can significantly alter meltwater chemistry (Stottlemyer and Troendle 1999), changes in snowpack accumulation and melt rates due to changes in upland vegetation cover can affect water chemistry in a variety of ways. For example, Stottlemyer and Troendle (1999) observed significant increases in the average snowpack Ca^{2+}, NO_3^-, and NH_4^+ content, and increased K^+, Ca^{2+}, SO_4^{2-}, NO^{3-}, and HCO^{3-} flux in shallow subsurface flows following logging treatments. The effects of these changes in the chemistry of surface and subsurface flows and the potential effects on wetland species like *Carex leptalea* are unknown.

Mineral sediment fluxes are typically low in the kinds of wetlands supporting *Carex leptalea*. Though both mineral and organic inputs to wetlands may change following tree harvest, what the short and long-term effects, if any, would be on *C. leptalea* occurrences, are unknown.

Fire

The indirect effects of fire on uplands adjacent to fens supporting *Carex leptalea* populations are likely similar to those of mechanical harvest, including increased water and sediment yield and changes in water chemistry. As with logging, the magnitude of these changes relative to pre-fire conditions should decrease over time as the density and cover of upland vegetation increase (Troendle and King 1985). Since fire has been a natural component of Rocky Mountain landscapes for millennia (Fall 1997), these indirect effects are unlikely to represent a significant threat to the future of *C. leptalea*.

In addition to the indirect effects of fire, direct effects on *Carex leptalea* populations include plant mortality. Since many *C. leptalea* occurrences are in communities with moderate to high levels of tree cover, fires may cause direct mortality of *C. leptalea* plants. In addition, changes in light and temperature regimes resulting from canopy removal may make sites unsuitable for surviving plants.

Roads and trails

Roads, and to a lesser degree, trail networks, can significantly affect local and watershed-scale hydrologic processes, thus indirectly affecting wetlands that support *Carex leptalea*. Roads, trails, and their engineering structures such as culverts and ditches can alter natural drainage patterns, reduce interception and infiltration rates by removing vegetation and increasing soil compaction, and alter the hydrologic response of basins to annual snowmelt runoff and isolated convective storms (Jones 2000, Forman and Sperling 2002). Increased overland flow typically results in a more rapid and extreme hydrologic response to precipitation events, potentially increasing erosion or sediment transport and deposition in affected sites. It is impossible to make specific predictions regarding the effects on habitats supporting *C. leptalea* since multiple variables could exacerbate or mitigate impacts. However, if changes to hydrologic or sediment regimes are great enough, *C. leptalea* occurrences could be negatively affected.

Road and trail networks can have a variety of additional effects on wetlands, including the introduction of pollutants and the alteration of water chemistry (e.g., conductivity, cation concentrations, pH) due to road dust, increased sediment deposition, and chemicals used in road maintenance (Wilcox 1986, Trombulak and Frissell 2000). Other variables that can either mitigate or exacerbate the effects of roads include road density, road slope and surface type, and the number, size, and design of engineering structures. Since these variables differ so greatly within and among national forests, formulating general statements regarding the threat to *Carex leptalea* from roads or trails is not possible. However, there are specific instances where the presence of roads has altered fen hydrology or sediment inflows. For example, Heidel and Laursen (2003) suggested that a highway bordering the Clay Butte Fen on the Shoshone National Forest, which supports an occurrence of *C. leptalea*, may impede groundwater flow into the basin.

Numerous instances of off-highway vehicle (OHV) trespass onto fens have been documented (Popovich personal communication 2004). Ruts caused by OHV access may function like small ditches, intercepting sheet flow on the surface of fens and altering fen hydrology. In addition, OHV use in or near wetlands may contribute pollutants from inefficient combustion and engine emissions (Havlick 2002). Anecdotal evidence suggests that "mud-bogging" is becoming more widespread as OHV use increases in many Region 2 forests (Popovich personal communication 2004). How much of a threat it poses to *Carex leptalea* populations is unknown. Presumably, since most *C. leptalea* occurrences are in sites supporting moderate to high tree cover, they are secure from these kinds of impacts.

Peat extraction

Because of its high porosity and water holding capacity, peat has long been used as a lawn and garden soil amendment, as well as for industrial applications (WEC 2004). Because sites providing the necessary hydrologic conditions needed for peat accumulation are rare in Region 2 and because peat formation rates are low, most of the peat sold commercially in the United States is imported from Canada. Peat production in Region 2 is small, and consequently, peat mining does not appear to represent a realized threat to known *Carex leptalea* populations in the region. Historically, peat mining was more widespread in the region, but its impact to *C. leptalea* was likely small, as most occurrences are associated with small, relatively discrete springs that support minor peat deposits.

Livestock and native ungulate grazing

We found no studies examining the effects of livestock grazing on *Carex leptalea*. Since livestock generally tend to avoid extremely wet sites, they may rarely utilize *C. leptalea*. However, the majority of occurrences in Region 2, particularly in the Black Hills, are associated with small springs and seeps, which may be accessed by livestock (Zacharkevics personal communication 2006). A review of the occurrence records for the species indicates occasional herbivory by livestock, but most accounts suggest that impacts due to trampling may be more important. The boggy substrates characteristic of both larger fen and small spring sites are relatively fragile and easily disturbed by even low levels of use. In addition, drought conditions resulting in reduced water tables can make larger wetlands more accessible and appealing to livestock, and the increased used can potentially cause significant impacts to wetland species in a relatively short time (Houston personal communication 2005).

Native ungulates, including deer, elk, and moose, can also significantly affect wetland flora, both directly (e.g., herbivory and trampling) and indirectly (e.g., nutrient enrichment via urine or fecal deposits). Similar to livestock, elk typically avoid extremely wet sites, and they presumably represent a minor threat to *Carex leptalea* populations. However, because most occurrences are confined to small discrete areas, even incidental trampling may significantly impact individual occurrences.

Recreational impacts

Where *Carex leptalea* occurrences are within short distance of existing trails or roads, they may be vulnerable to trampling effects from hikers, campers, or recreational fishers. However, we found no evidence that such use is negatively affecting the species. Sites supporting *C. leptalea* are generally unsuitable for road or trail construction since they are saturated year-round. In addition, work involving disturbance to such a wetland often requires a Clean Water Act Section 404 permit, making wetland impacts undesirable in transportation planning.

There are no documented impacts from winter recreation such as cross-county skiing, snowshoeing, or snowmobiling on *Carex leptalea* populations. However, compaction of accumulated snow can cause later spring melt and altered peat temperature profiles in wetlands, effectively reducing the length of the growing season for plants (Cooper and Arp 2002). However, there is no evidence to suggest that such impacts have affected known occurrences.

Exotic species

Exotic species are widely recognized as one of the principle threats to native ecological systems (Mack et al. 2000, Crooks 2002). However, there is little evidence that *Carex leptalea* is threatened by exotic species in Region 2. Exotic plants such as Canada thistle (*Cirsium arvense*) can invade wetlands, but the particular microsites that support *C. leptalea* appear to be too wet to support the most common exotics. Several records from the Black Hills mention the presence of exotic species in the immediate vicinity of *C. leptalea*, including Canada thistle, bull thistle (*Cirsium vulgare*), and gypsyflower (*Cynoglossum officinale*), but none of these reports indicates the presence of exotics in the specific microsites supporting *C. leptalea* (**Appendix**).

Atmospheric deposition of pollutants

Atmospheric nitrogen deposition of pollutants has been shown to cause a wide variety of ecological responses (Fenn et al. 2003), but few studies have focused specifically on fens. Li and Vitt (1997) examined the response of the bryophytes *Sphagnum fuscum* and *Tomenthypnum nitens* to nitrogen deposition in bogs and fens in western Canada. Both of these species occur in Region 2 fens. They found that the response of individual species varied, but that in general, moss productivity increased. However, productivity of *Betula pumila* and *Ledum groenlandicum*, two shrub species also examined, was unchanged (Li and Vitt 1997). There are no data from which to evaluate specific effects on *Carex leptalea*. However, the effects of nitrogen deposition could increase production of certain plant species and increase competition with *C. leptalea*.

Climate change

Because of their strong dependence on watershed-scale hydrologic processes, wetlands may be especially sensitive to major shifts in temperature or precipitation. The fidelity of *Carex leptalea* to wet sites such as springs and seeps suggests that the warmer regional temperatures predicted under some global climate change scenarios (U.S. Environmental Protection Agency 1998, Wagner 2003) may have adverse effects on the species. While an increase in precipitation, called for by some models, may ameliorate the negative hydrologic effects of warmer temperatures, it may still negatively affect the viability of *C. leptalea* populations by shifting the balance between it and competing species (Moore 2002). Moore (2002) found that the production of graminoids and forbs increased in response to increasing water table elevations, as might occur under some climate change scenarios. This higher productivity could result in greater competition between *C. leptalea* and associated vegetation.

Ultimately, the most important climatic factor influencing the future of wetlands in Region 2 is likely to be the spatial and temporal patterns of precipitation (Moore 2002). Since *Carex leptalea* populations in portions of Region 2, such as Colorado, are widely separated from one another, the fate of the species in parts of region is tied to that of the specific sites in which it presently occurs. Significant shifts in climate could reduce the viability of occurrences as a whole by altering their basic hydrologic functioning, thereby reducing the suitability of sites for *C. leptalea*. Because most occurrences are associated with sites supporting partial or complete tree cover, indirect effects of climate change on fire regimes may also impact the species.

Cumulative effects

It is often difficult to demonstrate the effects of individual factors on a species' performance; it is even more challenging to evaluate the cumulative effects of multiple stressors. However, cumulative effects must be considered when discussing threats from management activities (Reid 1993, Bedford 1999). Many individual ecological stressors act synergistically, and mitigating for each individually may fail to achieve effective protection. Since the wetlands supporting *Carex leptalea* occurrences depend on their watershed for hydrologic functioning, the watershed is the appropriate scale for evaluating potential management impacts on the species.

Conservation Status of Carex leptalea in USFS Region 2

Multiple factors need to be examined when assessing the conservation status of a species. These include its rarity, its degree of habitat specialization, its sensitivity to natural and anthropogenic stressors, and known population trends. *Carex leptalea* was designated a sensitive species in Region 2 principally because of perceived rarity. Within the region, the species has been found from a limited number of sites in the states of Wyoming, Colorado, and South Dakota. The greatest number of occurrences, approximately 41, has been found in the Black Hills region of South Dakota. Many of these occurrences were discovered after the species was placed on the Region 2 sensitive species list in 2003 (USDA Forest Service 2003). The discovery of new occurrences in the Black Hills following its initial listing has led to the removal of the species from the most recent sensitive species list for Region 2. The recent discoveries also suggest that there may be additional, unknown occurrences, at least in the Black Hills area.

There are insufficient data from which to confidently evaluate population trends for *Carex leptalea* on a regional basis because many occurrences have only been visited once and the quality and rigor of population estimates are variable. Consequently, this assessment is based largely on general knowledge of the species' life history, its habitats, and known threats to wetlands supporting the species in the region. There is no specific evidence to suggest that populations are declining in Region 2, but there is insufficient information to place a high degree of confidence in this assessment.

Despite its broad geographic distribution, *Carex leptalea* appears to occur in relatively similar ecological settings throughout its range. The species is most commonly associated with small fens, seeps and springs, typically under partial or complete tree cover. Most occurrences are small in size and may therefore be relatively vulnerable to localized disturbance such as trampling by livestock. Other possible direct impacts to sites include fire or logging. Because occurrences of *C. leptalea* depend on the maintenance of stable and wet hydrologic regimes, individual occurrences may also be vulnerable to indirect or cumulative effects on hydrology.

Although it has a distinctive morphology, *Carex leptalea*, like most sedges, is easily overlooked in botanical surveys, particularly if plants are not fruiting. Since no systematic surveys of suitable habitats in Region 2 have been conducted, additional undocumented occurrences could be found. As a consequence, fens, springs, and seeps should be carefully evaluated for the presence of *C. leptalea* prior to significant shifts in management.

Management of Carex leptalea in USFS Region 2

Carex leptalea occurs in a small range of wetland types, habitats that often support populations of other rare species and are functionally unique. Consequently, a goal of future research should include broad-scale assessments of the distribution and abundance of suitable habitats. Multiple techniques could be used, including the use of remotely sensed data (e.g., hyperspectral imagery, color aerial photographs) to identify and map wetlands. GIS (Geographic Information System) analyses of existing data sets such as the National Wetlands Inventory in relation to the key climatic, hydrologic, and geological drivers of wetland formation, structure, and function could be undertaken.

Since few data regarding population size are available, comprehensive demographic surveys of known populations should be conducted to better evaluate the status of *Carex leptalea* populations and to provide baseline data essential for effective monitoring. Known populations should be regularly visited, and surveys should be conducted to identify potential population trends.

Also important is the collection of basic hydrologic and sediment data at individual wetlands. These data can be extremely valuable in developing realistic models describing vegetation dynamics and for understanding and evaluating the effects of management activities on *Carex leptalea*. The installation of even a few groundwater monitoring wells, easily accomplished by a single individual in an afternoon, can yield invaluable data regarding the hydrologic functioning of sites.

There is little information available regarding the restoration of fens and springs. What little research that has been conducted in Region 2 suggests that effective restoration of vegetation is contingent upon restoration of appropriate hydrologic regimes (Cooper et al. 1998, Cooper and MacDonald 2000). This typically requires removing obstacles or diversions in the groundwater flow systems that historically supported the wetland. There have also been no studies evaluating propagation and revegetation techniques for *Carex* *leptalea*. However, a variety of approaches have been developed for other sedges, and these could possibly be successfully modified for *C. leptalea*.

Implications and potential conservation elements

The relative rarity of *Carex leptalea* in Region 2 is, in part, a function of its specialized habitat. Occurrences show a strong fidelity for particular wetland types, including springs and fens, both of which comprise only a small portion of Region 2 landscapes. Ensuring the viability of the habitat of the species is, in general, the best approach to conserving *C. leptalea*. Although we found no data suggesting that major changes in abundance are occurring, data on the distribution and abundance of the species are incomplete, thus reducing our ability to confidently assess the status and population trends of the species.

The majority of occurrences of *Carex leptalea* in the region, particularly in the Black Hills, are associated with discrete springs although the species is known from larger fens as well. Both habitats share similar hydrologic regimes dominated by perennial groundwater inflows. As with many obligate wetland species, *C. leptalea* occurs along a relatively narrow range of hydrologic conditions. Any changes that alter the hydrologic functioning of wetlands supporting the species may therefore pose a threat.

In fens, direct hydrologic alterations, such as ditching, have the greatest potential to negatively impact the species. Many fens in the region were ditched in the past and continue to exhibit impaired hydrologic function. These sites should be identified, as the basic functioning of many systems can be relatively easily restored (Cooper et al. 1998). In addition to direct hydrologic impacts, many management practices can indirectly alter fen hydrologic regimes and thereby negatively affect the viability of occurrences. Since the hydrologic regime represents the single greatest influence on wetland ecology, actions with the potential to alter water and sediment flux to wetlands ought to be critically evaluated early in project planning, and effects should be monitored following implementation. Indirect hydrologic changes are the most likely impact from management in spring habitats.

Tools and practices

Species and habitat inventory

Because few data regarding population size are available, comprehensive demographic surveys of known occurrences need to be conducted to better evaluate the current status of occurrences and to provide baseline data essential for effective monitoring. Known occurrences need to be periodically revisited, and follow-up surveys need to be conducted in order to identify potential trends. Since many botanical surveys involve one or maybe a few visits to a given site, unusually wet or dry conditions present at the time of sampling may obscure vegetation patterns. Also, since seasonal and inter-annual variation in water table levels can influence plant abundance and cover, rare species such as *Carex leptalea* may be overlooked if wetlands are not surveyed during appropriate conditions. This is less likely to be the case in small, spring-fed occurrences, where vascular plant diversity is typically low.

Additional information gaps regarding *Carex leptalea* include the role of seed banks in the population dynamics of the species and the relative importance, frequency, and prerequisite conditions necessary for sexual establishment. Such information is essential not only for understanding extant occurrences, but also for developing approaches for restoring heavily degraded systems. If conducted in conjunction with studies of hydrology and vegetation patterns, these kinds of inquiries could significantly advance our understanding not just of *C. leptalea*, but of the systems that the species inhabits

Although the range of habitats occupied by *Carex leptalea* is narrow, more information regarding specific habitat characteristics of known occurrences is needed. Such information could be part of habitat monitoring efforts. For example, while some of the larger fens in the region have been the focus of research, there is little known about the small, spring-fed wetlands supporting the majority of occurrences of *C. leptalea*. The installation of shallow groundwater wells would provide useful information regarding the specific characteristics of hydrologic regimes supporting the species. Other issues that ought to be considered as part of habitat monitoring include livestock usage and exotic species. Although anecdotal accounts suggest that these factors are not threats to the majority of occurrences, they may be important at some sites.

Population and habitat monitoring

The development and implementation of quantitative population monitoring protocols would improve our knowledge of the population dynamics of *Carex leptalea*. Plot-based approaches are most desirable since these most reliably facilitate the evaluation of long-term trends in abundance. However, even qualitative approaches such as presence/absence surveys may be of value, providing an early indication of major changes. Population monitoring is most-profitably conducted in conjunction with habitat monitoring. For example, by monitoring water levels in wetlands supporting occurrences, observed changes in the abundance of *C. leptalea* can be more reliably tied to changes in hydrologic drivers.

Beneficial management actions

Managers can most effectively promote the continued persistence of *Carex leptalea* by striving to maintain the natural hydrologic regimes in wetlands that support the species. Management activities likely to directly or indirectly affect hydrologic regimes ought to be avoided where possible, and if these are unavoidable, best management practices aimed at mitigating harmful effects ought to be pursued. At a broader scale, establishment of special protected areas (e.g., Research Natural Areas) would help to assure the conservation of the species. Because maintenance of the hydrologic integrity of fens supporting the species is so important, another option that the USFS could take is to file for water rights on wetlands that support rare species such as *C. leptalea*. Collection and storage could also be pursued.

Information Needs

Water chemistry parameters of sites supporting *Carex leptalea* are poorly understood, particularly for occurrences in the Black Hills. Likewise, more data are needed regarding the range of hydrologic conditions that support the species. Basic hydrologic monitoring using small, portable flumes or shallow groundwater monitoring wells would provide invaluable information regarding hydrologic requirements of the species. Occurrences on the Black Hills are most deficient with regards to this kind of information. More comprehensive evaluations of soil characteristics in sites supporting the species should also be conducted. Of particular interest is whether soils are mineral or organic, and if the latter, to what depth peat has accumulated. For example, while most occurrence records from the Black Hills note “mossy” or “boggy” soils, indicating the presence of waterlogged, organic soils, no actual soil sampling has been conducted. Such information would be useful in understanding patterns of development, age, and relative stability. Basic hydrologic information is also needed for these occurrences.

A better understanding of the distribution of habitats is also needed. For example, Global Positioning System (GPS) mapping of springs, including presence/absence surveys for the species, could be conducted, greatly improving our understanding of habitat abundance and distribution and the actual percentage of springs occupied by the species. Because most occurrences are associated with high amounts of tree cover, remotely sensed data such as aerial photographs may be of relatively little utility.

Definitions

Achene – Small, dry fruit with a close-fitting wall surrounding a single seed (Hurd et al. 1998).

Androgynous – Having staminate flowers above the pistillate flowers in the same spike (Hurd et al. 1998).

Bog – A peatland deriving water and nutrients only from the atmosphere (Crum 1988).

Carr – A European term referring to peatlands dominated by shrubs such as alders or willows (Crum 1988).

Emarginate – With a broad, shallow notch or dentation (Hurd et al. 1998).

Fen – A peat-accumulating wetland that receives some drainage from surrounding mineral soil (Mitsch and Gosselink 2000).

Flark – A linear pool or hollow transverse to water flow in a water track (Wright et al. 1992).

Hollow – A low area within a peatlands that is wetter than surrounding hummocks (Crum 1988).

Hummock – A raised area within a peatland often formed around the roots of trees or shrubs that is generally drier and more acidic than nearby hollows (Crum 1988).

G/S1 – Critically imperiled globally/state because of rarity (5 or fewer occurrences in the world/state; or 1,000 or fewer individuals), or because some factor of its biology makes it especially vulnerable to extinction (NatureServe 2004).

G/S2 – Imperiled globally/state because of rarity (6 to 20 occurrences, or 1,000 to 3,000 individuals), or because other factors demonstrably make it very vulnerable to extinction throughout its range (NatureServe 2004).

G/S3 – Vulnerable throughout its range or found locally in a restricted range (21 to 100 occurrences, or 3,000 to 10,000 individuals) (NatureServe 2004).

G/S4 – Apparently secure globally/state, but may be quite rare in parts of its range, especially at the periphery; usually more than 100 occurrences and 10,000 individuals (NatureServe 2004).

G/S5 – Demonstrably secure globally/state, but may be quite rare in parts of its range (NatureServe 2004).

Lectotype – A specimen chosen as the standard bearer of a species, subspecies, or other taxonomic group (Wikipedia 2006a).

Marl – An unconsolidated calcium carbonate deposit typically formed in freshwater lakes, but also deposited in very alkaline wetlands (Crum 1988).

Minerotrophic – Fed by groundwater that has been in contact with soil or bedrock and is therefore richer in nutrients than rainwater (Crum 1988).

Mycorrhiza – A commonly mutualistic and intimate association between the roots of a plant and a fungus (Begon et al. 1996).

Obligate wetland species – Plant requiring saturated soils (Mitsch and Gosselink 2000).

Peat – An accumulation of undecomposed dead plant matter that forms plant production exceeds decomposition, typically in areas where oxygen levels are low due to prolonged inundation (Crum 1988).

Peatland – A general term referring to wetlands with a peat substrate; includes fens and bogs (Crum 1988).

Perigynium – (Plural: perigynia) an inflated saclike structure enclosing the ovary (achene) in the genus *Carex* (Hurd et al. 1998).

Poor fen – A weakly minerotrophic fen fed by waters that are weakly mineralized, generally with an acidic pH (about 3.5-5.0)(Crum 1988).

pH – a measure of the activity of hydrogen ions (H+) in a solution and, therefore, its acidity or alkalinity; the pH value is a number without units, usually between 0 and 14, that indicates whether a solution is acidic (pH 7)(Wikipedia 2006b).

Rhizome – A usually prostrate stem, rooting at the nodes (Hurd et al. 1998).

Rich fen – A strongly minerotrophic fen fed by waters rich in minerals, generally with a circumneutral pH (Crum 1988).

Sensitive species – Species identified by the Regional Forester for which population viability is a concern as evidenced by significant current or predicted downward trends in population numbers or density and significant current or predicted downward trends in habitat capability that would reduce a species' existing distribution (USDA Forest Service 2006).

SNR – Species not assigned a NatureServe subnational rank (NatureServe 2004).

SX – NatureServe subnational rank denoting that the species is believed to be extirpated from state or province (NatureServe 2004).

Water table – The top of water-saturated ground; the surface at which the fluid pressure in the pores of a porous medium is exactly equal to atmospheric pressure (Wright et al. 1992).

Water track – A path of concentrated water flow from a mineral source (Wright et al. 1992).

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APPENDIX

Occurrence records for Carex leptalea

Occurrence records for USDA Forest Service Region 2; also included are records for Yellowstone National Park, which is not part of Region 2. Record sources include the Rocky Mountain Herbarium (RMH), University of Colorado Herbarium (CU), the Colorado Natural Heritage Program (CNHP), Wyoming Natural Diversity Database (WYNDD), South Dakota Natural Heritage Program (SDNHP), and unpublished survey results from the Black Hill National Forest (BHNF) and Yellowstone National Park (Lemly). Note that multiple records exist for many occurrences, e.g., both herbarium and Element Occurrence (EO) records for the same site. Records lacking site descriptions are marked with 'NI' (No Information) in the comments field. Black Hills National Forest survey data from 2005 are not included.

Source	State	County	Accession/EOR/ID #	Elevation (m)	Ownership/management	Date of collection/ last observation	Comments
CNHP	Colorado	Grand	PMCYP037E0*003*CO	2,848	Rocky Mountain National Park	07/07/1994	Field survey of 7 July 1994 by D.J. Cooper.
CNHP	Colorado	Clear Creek	PMCYP037E0*002*CO	3,125	Arapaho National Forest, Never Summer Wilderness	09/18/1992	Field survey to Upper Creek for Bakerville/ Loveland bike path route evaluation by M. Reid; EO rank AB.
CNHP	Colorado	El Paso	PMCYP037E0*001*CO	2,400	Pike National Forest, Mount Evans Wilderness	06/23/1956	Specimen (COLLECTION #4713) AT Colorado College Herbarium; EOR rank H; C.W.T. Penland.
WYNDD	Wyoming	Park	PMCYP037E0*3*WY	2,012	Shoshone National Forest	08/13/1980	Northern Absaroka Mountains, Clarks Fork Valley, Crandall Creek.; R.D. Dorn
WYNDD	Wyoming	Park	PMCYP037E0*4*WY	2,012	Shoshone National Forest, Swamp Lake Special Botanical Area	08/18/1992	Semi-open edge of wet *Picea glauca* swamp forest and mossy stream bank. Often found on mossy soils overlying the exposed roots of spruce trees.; Northern Absaroka Mountains, Clarks Fork Valley, 2 locations: (1) Swamp Lake wetland on the north side of the Cathedral Cliffs and south of WY Highway 296, ca 34 air miles northwest of Cody; (2) 1 mile east of Lodgepole Creek in back of Pearson's cabins; (southwest of Swamp Lake).; Fertig and Jones 1992 Swamp Lake report.
WYNDD	Wyoming	Park	PMCYP037E0*8*WY	2,471	Shoshone National Forest, Absaroka-Beartooth Wilderness	08/31/1996	Slightly drier microsites on moist, moss-rich, open hummocks of *Pinus contorta* and *Picea engelmannii* with understory of *Betula glandulosa*, *Salix planifolia*, and *Ledum glandulosum*.; Beartooth Range, pair of unnamed ponds ca 0.7 miles northeast of Lily Lake, ca 0.2 miles west of Lake Creek, ca 1.8 miles north of US Highway 212. (Found primarily on the south side of the east pond along the forest edge); Fertig 1997 Shoshone National Forest report.

Appendix (cont.).

Source	State	County	Accession/EOR/ID #	Elevation (m)	Ownership/management	Date of collection/ last observation	Comments
WYNDD	Wyoming	Park	PMCYP037E0*9*WY	2,451	Shoshone National Forest	08/27/1996	Mossy hummocks at edge of semi-open *Picea engelmannii*/*Pinus contorta* swamp forest. Hummocks with *Picea* and *Pinus* species canopy and understory of *Betula glandulosa*, *Ledum glandulosum*, *Salix planifolia*, and *S. farriae* on mesic, moss-rich organic black soil.; Beartooth Range, east end of Little Moose Lake, ca 2.5 air miles north of US Highway 212, ca 1.5 miles south of the Montana state line; W. Fertig.
WYNDD	Wyoming	Albany	PMCYP037E0*14*WY	2,800	Medicine Bow National Forest	09/07/2002	Narrow outer zone at headwaters of a large, open peatland, on the north side, in places with hummocky moss cover and short shrubs; east slope of Medicine Bow Mountains, on Sheep Mountain at headwaters of Fence Creek. From the Wildlife Habitat Area parking lot on southwest side of mountain, travel ca. 2.5 miles to where the trail meets the two-track on the summit. Continue north along the headwaters of Fence Creek; B. Heidel.
WYNDD	Wyoming	Crook	PMCYP037E0*15*WY	1,340	Black Hills National Forest	09/05/2002	Ponderosa pine/paper birch/beaked hazelnut community on shady, northern, inundated-saturated bottom slopes.; Black Hills, Bearlodge Mountains, East Creek and southwest of Pine Creek Spring. [Pine Creek Spring (Sec 24): From Hwy 24 take FS Road 830 north past 830.4I (ca 0.5 miles north of turn to 830.4M), park halfway along straight portion of road running north-northeast. Site is to the east in the draw. East Creek (Sec 23): From Hwy 24 drive north on FS road 830, turn west at sign for East Creek, past gate, and drive to end of road. Population is north of road in the East Creek drainage.]; Black Hills National Forest Botany Database.

Appendix (cont.).

Source	State	County	Accession/EOR/ID #	Elevation (m)	Ownership/management	Date of collection/ last observation	Comments
WYNDD	Wyoming	Crook	PMCYP037E0*16*WY	1,506	Black Hills National Forest	08/04/2002	Ponderosa pine- paper birch/beaked hazelnut community on a north facing, open, moist bottom slope; Black Hills, Bearlodge Mountains, North Redwater Creek. Travel west on FS Road 843, turn left on FS Road 833, park in second right turn. Population is just south of road and west of 833; Black Hills National Forest Botany database.
RMH	Wyoming	Park	na	2,012	Shoshone National Forest	06/24/1989	Hummocks in marly wetlands; B.E. Nelson.
RMH	Wyoming	Park	0	2,012	Shoshone National Forest	08/22/1984	In open calcareous fen; E.F. Evert.
RMH	Wyoming	Teton	260408	2,073	Grand Teton National Park	06/10/1958	Shady and boggy area; J. Wetherell.
RMH	Wyoming	Park	329096	1,982	Shoshone National Forest	08/13/1980	Mossy floor of spruce forest with *Habenaria* and *Pyrola*; R. Dorn.
RMH	Wyoming	Park	357400	2,049	Shoshone National Forest	08/11/1982	In spruce-pine swamp forest; E.F. Evert.
RMH	Wyoming	Teton	401608	1,829	Shoshone National Forest	07/29/1964	Wet site; W.M. Johnson.
CU	Colorado	Grand	454273	2,848	Rocky Mountain National Park	07/07/1994	In sloping, spring-fed fen on the west side of the river; D.J. Cooper #2224.
CU	Colorado	Clear Creek	454912	3,125	Arapaho National Forest, Never Summer Wilderness	09/18/1992	On mossy hummocks saturated by seepage from north-facing slope, with *Salix planifolia*, *Carex aquatilis*, *C. dioica* ssp. *gynocrates*, and *Paludella squarrosa*; N. Lederer #4403.
CU	Colorado	Jackson	475064	2,744	Routt National Forest	06/29/2000	Scarce on Sphagnum hummocks in wet fen with *Salix planifolia* and *Betula glandulosa*; N. Lederer #00-49.
RMH	Wyoming	Park	544822	2,073	Shoshone National Forest	06/24/1989	Mossy stream bank; R. Dorn.
RMH	Wyoming	Park	579436	2,009	Shoshone National Forest	08/18/1992	Edge of *Picea glauca* swamp forest and open *Carex rostrata* marsh; soils moist to water-logged, with leaf and needle debris; W. Fertig
RMH	Wyoming	Teton	616567	2,134	Grand Teton National Park	07/16/1995	Boggy area at forest edge with *Cardamine breweri*, *Ribes lacustre*, *Potentilla fruticosa*, and *Angelica arguta*; S. Markow.
RMH	Wyoming	Park	645391	2,439	Shoshone National Forest	08/27/1996	Mossy hummocks at edge of semi-open *Picea engelmannii-Pinus contorta* swamp forest; with *Betula glandulosa* and *Ledum glandulosum*.; W. Fertig, S. Mellman-Brown.

Appendix (cont.).

Source	State	County	Accession/EOR/ID #	Elevation (m)	Ownership/management	Date of collection/ last observation	Comments
Lemly	Wyoming	Park	na	2,012	Yellowstone National Park	2004	Floating Island Lake; *Salix wolfii* / Mixed graminoids; peat depth of 240+ cm.
Lemly	Wyoming	Park	na	2,012	Yellowstone National Park	2004	Floating Island Lake; *Picea glauca* / *Carex disperma*; peat depth of 240+ cm.
Lemly	Wyoming	Park	na	2,012	Yellowstone National Park	2004	Floating Island Lake; *Picea glauca* / *Alnus incana* / *Carex disperma*; peat depth of 240+ cm.
Lemly	Wyoming	Park	na	1,963	Yellowstone National Park	2004	Elk Creek Lower Fen; *Picea glauca* / *Alnus incana* / *Carex disperma*; peat depth of 90 cm.
Lemly	Wyoming	Park	na	1,963	Yellowstone National Park	2004	Elk Creek Lower Fen; *Picea glauca* / *Equisetum arvense*; peat depth of 90 cm.
Lemly	Wyoming	Park	na	1,963	Yellowstone National Park	2004	Elk Creek Upper Fen; *Picea englemannii* / *Equisetum arvense*; peat depth of 60 cm.
BHNF	South Dakota	Lawrence	Survey ID 04CL01A	1,841	Black Hills National Forest	06/10/2004	Mossy, west-northwest-facing slope with several seeps/springs dominated by *Picea glauca*. Plants occur in wet clumps at the margins of flowing seeps in boggy areas. Sometime they occur in clumps among moss covered *P. glauca* roots; 101-500 individuals; no significant use of site evident; *Cirsium arvense* and *Cynoglossum officinale* scattered throughout site.
BHNF	South Dakota	Pennington	Survey ID 04CL02A	1,902	Black Hills National Forest	06/17/2004	Mossy spruce dominated north-facing slope with flowing spring. Moist to saturated. Downed spruce trees abundant on slope. An old beaver dam occurs up this seep. Species also occurs in the flatter more boggy areas above the dam; approx. 125 individuals; population area: 10-50 m; grazing occurs in drainage bottom, but no cattle impacts observed at time of visit.
BHNF	South Dakota	Pennington	Survey ID 04CL03A	1,896	Black Hills National Forest	06/17/2004	Boggy seep area on lower *Picea glauca* dominated slope. Several *Carex* species present in area, grazing occurs in area, cattle seen at bottom of drainage at time of survey and vegetation in some of the wetter areas of bottom damaged from over trampling, not cattle damage to site itself; limestone geological formation; 11-50 individuals; population area 5-10 m.

Appendix (cont.).

Source	State	County	Accession/EOR/ID #	Elevation (m)	Ownership/management	Date of collection/ last observation	Comments
BHNF	South Dakota	Lawrence	Survey ID 04CL04A	1,433	Black Hills National Forest	06/21/2004	Very mossy, northeast facing wet-mesic slope with seeps and a thick cover of *Equisetum*. Plants occur at margins of gently flowing seeps and on thick soft springy mats of moss up the slope; often scattered with patches of other *Carex* species; 101-500 individuals; plants scattered all over mossy-boggy areas, margins of flowing seeps, etc.
BHNF	South Dakota	Pennington	Survey ID 04CL05A	1,847	Black Hills National Forest	07/07/2004	Wide, flat mossy, moist, spruce-dominated area just on the south side of North Fork Castle Creek. Boggy in spots with some seeping water; *Equisetum* dominates much of the area; ground is often lumpy with soft mats of moss covering much of the area; grazing present in area, but no damage observed on the south side of the creek where plants occurs; some trampled areas in the creek bottom and trails on the north side; 501-1000 individuals.
BHNF	South Dakota	Pennington	Survey ID 04CL06A	1,829	Black Hills National Forest	07/07/2004	Northeast facing spruce-dominated slope with occasional pine and aspen; plants occur in rich mossy area in vicinity of flowing seep; some grazing observed in area; scattered *Cirsium arvense* found in area; 11-50 individuals.
BHNF	South Dakota	Crook	Survey ID 04CL07A	1,372	Black Hills National Forest	08/26/2004	Plants occur along the margins of a gently flowing spring in lush birch/hazelnut dominated side drainage; origin of spring above plants is boggy with thick moss, liverworts, and thick patches of lady fern; water becomes channelized where plants occur; areas on slope in bottom with considerable leaf litter; very rich and interesting microhabitat; dry, fairly open pine flats above; grazing observed in pine flats above but not in the seep area supporting plants; 1-10 plants; is a very fragile area that could easily be damaged by over trampling.

Appendix (cont.).

Source	State	County	Accession/EOR/ID #	Elevation (m)	Ownership/management	Date of collection/ last observation	Comments
BHNF	South Dakota	Custer	Survey ID 04BM01	1,753	Black Hills National Forest, Black Elk Wilderness	10/04/2004	Spruce-dominated bottom with scattered pine and birch; gently flowing stream; plants in mossy areas usually right along creek margins; occasional mossy seeps along the creek that plants extend up to, but most occur right along the creek; Upper Iron Creek; 101-500 individuals; scattered *Cirsium arvense* in drainage.
BHNF	South Dakota	Pennington	Survey ID 04BM03	1,841	Black Hills National Forest	10/06/2004	Spruce-dominated bottom with mossy, boggy, hummocky areas; *Climacium* moss present; *Salix* sp. scattered consistently through the bottom; grazing present in area; some cropped grass/sedge and trampling, but not very severe; 51-100 individuals; population area 50-100 m.
BHNF	South Dakota	Custer	Survey ID 04BM04	1,829	Black Hills National Forest, Black Elk Wilderness	10/07/2004	Mossy spruce dominated drainage bottom with *Corylus cornuta* shrub layer and lots of down trees; *Carex leptalea* occurs along the creek margins and in hummocky wet areas in the vicinity; Grizzly Creek tributary; one fairly dense *Cirsium vulgare* patch in bottom.
BHNF	South Dakota	Pennington	Survey ID 03CL50A	1,902	Black Hills National Forest	07/22/2003	North Fork Castle Creek Botanical Area; plant found on spongy, mossy undulating ground with partial shade provided by spruce, which is the dominant overstory plant; 1-10 individuals; population area 5-10 m; cows present on the creek about 60 m southeast of the site in a meadow.
BHNF	South Dakota	Lawrence	Survey ID 03CP10C	1,683	Black Hills National Forest	07/24/2003	Wet, boggy, shallow draw on a northerly-facing spruce dominated slope; *Equisetum palustre* abundant; no flowing water at the time of the visit; surface is hummocky, like in other seepage/bog areas encountered; plants mostly shaded; adjacent to campground.

Appendix (cont.).

Source	State	County	Accession/EOR/ID #	Elevation (m)	Ownership/management	Date of collection/ last observation	Comments
BHNF	South Dakota	Pennington	Survey ID 03CL50B	1,890	Black Hills National Forest	07/22/2003	North Fork Castle Creek Botanical Area; plants occur Along the margins of moist seep areas; overstory dominated by *Picea glauca* with sparse patches of *Populus tremuloides*; plants mostly occur on thick mats of moss that are raised slightly above the water level; *Cornus sericea* shrubs often occur in the vicinity of plants; cattle seen in vicinity of the site, but not in direct location of plants; 161 individuals.
BHNF	South Dakota	Pennington	Survey ID 03CL50D	1,921	Black Hills National Forest	07/23/2003	North Fork Castle Creek Botanical Area; found along a slow moving stream on mossy, moist, hummocky ground; also seen along seeping areas on the southern slope above the stream; *Carex leptalea* found along margins of marshy sections near the stream; spruce overstory; 101-500 individuals.
BHNF	South Dakota	Pennington	Survey ID 03CL50E	1,963	Black Hills National Forest	07/23/2003	North Fork Castle Creek Botanical Area; side of a small botanical area dominated by spruce; somewhat open although plants are in at least partial shade and mostly on hummocks and root boles of downed trees; understory dominated by *Glyceria*, *Carex disperma*, and *Equisetum palustre*.
BHNF	South Dakota	Pennington	Survey ID 03CL50C	1,918	Black Hills National Forest	07/23/2003	North Fork Castle Creek Botanical Area; plants occur in moist areas at the margins of a seep; plants are often on the outer edges of the seep or on hummocks raised slightly above the water level; overstory dominated by *Picea glauca* and *Populus tremuloides*; grazing occurs in near site, but no evidence of cattle in site area; 131 individuals.
BHNF	South Dakota	Custer	Survey ID 03CA27A	1,707	Black Hills National Forest	10/02/2003	Sunday Gulch; moist to saturated seep area that occur on the lower southwest-facing slope above Sunday Gulch; dominant overstory is *Picea glauca*; 51-100 individuals; population area 50-100 m.

Appendix (cont.).

Source	State	County	Accession/EOR/ID #	Elevation (m)	Ownership/management	Date of collection/ last observation	Comments
BHNF	South Dakota	Custer	Survey ID 03CL70A	1,768	Black Hills National Forest	09/03/2003	Needles; moist mossy area under a canopy of *Picea glauca*; ground is quite "lumpy" and hummocky where plants occur; site occurs in the vicinity of the pending Needles timber sale, marked trees on edge of site area; 1-10 individuals.
BHNF	South Dakota	Pennington	Survey ID 03CL10A	1,921	Black Hills National Forest	08/04/2003	Lyons Spring; mossy seep area next to a small creek; partially shaded by spruce cover; heavy grazing observed near and directly in the site, with substantial stream-side damage; *Cynoglossum officinale* sparsely in the vicinity of the plants; 101-500 individuals.
BHNF	South Dakota	Pennington	Survey ID 03CL60A	1,524	Black Hills National Forest	10/06/2003	Battle Creek side drainage near Mount Rushmore; plants mostly on a moist to saturated flat bench area with seeps on a west southwest-facing slope above; dominant overstory is *Picea glauca* with some *Betula papyrifera* and *Populus tremuloides*; 101-500 individuals.
BHNF	South Dakota	Pennington	Survey ID 03CL30A	1,905	Black Hills National Forest	07/28/2003	Flag Mountain; area is moist with lots of moss cover, plants often found on hummocky patches with partial shade from spruce cover; cattle damage to vegetation in area, some grazing directly to *Carex leptalea*; 101-500 individuals.
BHNF	South Dakota	Pennington	03B870	1,439	Black Hills National Forest	06/30/2003	Beaver Park; 11-51 clumps; overstory: *Pinus ponderosa*, *Betula papyrifera*, *Picea glauca*, and *Populus tremuloides*; midslope; aspect 140 deg.; 4 percent slope.
BHNF	South Dakota	Pennington	031450M	1,644	Black Hills National Forest	09/23/2003	Iron Mountain; in depression (seep) on west bank of Nelson Creek, high moss fern, and liverwort cover; *Pinus ponderosa*, *Picea glauca*, and *Betula payrifera* overstory; aspect: 335°.; 0-10 percent slope; 11-51 clumps.
BHNF	South Dakota	Meade	03B870C	1,439	Black Hills National Forest	06/30/2003	*Pinus ponderosa*, *Betula papyrifera*, *Picea glauca*, and *Populus tremuloides* overstory; on rocky shore of creek in Forbes Gulch; 11-51 clumps.

Appendix (cont.).

Source	State	County	Accession/EOR/ID #	Elevation (m)	Ownership/management	Date of collection/ last observation	Comments
BHNF	South Dakota	Pennington	031390I	1,540	Black Hills National Forest	09/21/2003	Found in open areas with SCCY, PIGL and BEPA in understory; on flat SW bank of Willow Creek, growing in moss.
BHNF	South Dakota	Pennington	031450G	1,610	Black Hills National Forest	09/23/2003	Iron Mountain project; along Nelson Creek; moss dominated understory with *Picea glauca* and *Betula papyrifera* overstory; 3 percent slope; aspect: 295º.
BHNF	South Dakota	Pennington	031590C	1,533	Black Hills National Forest	09/24/2004	Iron Mountain project; in small seep/depression on the west side of creek; *Picea glauca* dominant in overstory and midstory; wet area with small area of standing water; 0 percent slope.
BHNF	South Dakota	Lawrence	03BOMUA	1,555	Black Hills National Forest	10/28/2003	None.
BHNF	South Dakota	Lawrence	03BM80A	1,512	Black Hills National Forest	09/18/2003	Very wet mossy area in the drainage bottom with hummocky lumps and exposed spruce roots; overstory dominated by *Picea glauca*; no noxious weeds or evidence of cattle in area; 1-10 individuals.
BHNF	Wyoming	Crook	02L550G	1,357	Black Hills National Forest	09/05/2002	Hanging into water; 0-10 percent slope; aspect: 60°; 1-10 clumps.
BHNF	Wyoming	Crook	02L670G	1,311	Black Hills National Forest	08/30/2002	Occurs on banks along east creek; flowing water present; large diversity of *Carex* spp.; two clumps.
BHNF	Wyoming	Crook	02A460D	1,509	Black Hills National Forest	08/04/2002	One plant; *Pinus ponderosa*, *Betula papyrifera*, and *Quercus macrocarpa* overstory
BHNF	South Dakota	Pennington	00B160A	1,585	Black Hills National Forest, Black Elk Wilderness	07/26/2000	*Picea glauca* community; shaded and flat.
BHNF	South Dakota	Pennington	00B200A	1,768	Black Hills National Forest, Black Elk Wilderness	07/17/2000	Below upper Iron Creek at confluence with dry tributary; *Picea glauca*, moss community.
BHNF	South Dakota	Pennington	00B200B	1,753	Black Hills National Forest, Black Elk Wilderness	07/18/2000	*Picea glauca / Betula papyrifera* community; shaded.
BHNF	South Dakota	Custer	99M120A	1,530	Black Hills National Forest	08/21/1999	Uses of site include grazing and logging; weeds like CIAR4 and EUES found upslope; 40 percent slope; shaded; one clump.
BHNF	South Dakota	Pennington	99S7A0A	1,854	Black Hills National Forest	08/16/1999	Delicate sedge was found in very shaded, cool, moist environment; some cattle grazing evident, but not severe; 10 percent slope; 4-6 tufts.

Appendix (concluded).

Source	State	County	Accession/EOR/ID #	Elevation (m)	Ownership/management	Date of collection/ last observation	Comments
BHNF	South Dakota	Pennington	99D5A0A	1,774	Black Hills National Forest	08/14/1999	Confined to saturated soils in narrow PIGL drainages; three tufts.
BHNF	South Dakota	Pennington	99D5A0B	1,811	Black Hills National Forest	08/14/1999	Confined to saturated soils in narrow PIGL drainages; three tufts.
BHNF	South Dakota	Pennington	93U170C	1,463	Black Hills National Forest	07/20/1993	1 percent slope; *Picea glauca* and *Betula papyrifera* overstory; numerous clumps.
BHNF	South Dakota	Pennington	93U140C	1,585	Black Hills National Forest	08/17/1993	Partial shade; 0 percent slope; *Picea glauca* overstory; numerous clumps.
BHNF	South Dakota	Lawrence	9000120A	1,433	Black Hills National Forest	07/12/1990	Forbes Gulch/Beaver Park project area; localized colony on mossy hummock in spring-head wetland with *Carex disperma* and *C. interior*.
BHNF	South Dakota	Lawrence	890140A	1,692	Black Hills National Forest	?/?/1989	Locally common in wet moss with *Carex disperma*; densly shaded by tall *Picea glauca*.
SDNHP	South Dakota	Lawrence	PMCYP037E0*001*SD		Black Hills National Forest	07/27/1983	NI
SDNHP	South Dakota	Custer	PMCYP037E0*002*SD		Black Hills National Forest	06/25/1924	NI
SDNHP	South Dakota	Pennington	PMCYP037E0*003*SD		Black Hills National Forest	07/29/1983	NI
SDNHP	South Dakota	Lawrence	PMCYP037E0*004*SD		Black Hills National Forest	06/28/1989	NI
SDNHP	South Dakota	Meade	PMCYP037E0*005*SD		Black Hills National Forest	07/12/1990	NI
SDNHP	South Dakota	Pennington	PMCYP037E0*006*SD		Black Hills National Forest	07/20/1993	NI
SDNHP	South Dakota	Pennington	PMCYP037E0*007*SD		Black Hills National Forest	8/17/19937	NI
SDNHP	South Dakota	Custer	PMCYP037E0*008*SD		Black Hills National Forest, Black Elk Wilderness	07/17/2000	NI
SDNHP	South Dakota	Pennington	PMCYP037E0*009*SD		Black Hills National Forest, Black Elk Wilderness	07/26/2000	NI
SDNHP	South Dakota	Pennington	PMCYP037E0*010*SD		Black Hills National Forest	08/08/1998	NI
SDNHP	South Dakota	Pennington	PMCYP037E0*011*SD		Black Hills National Forest	08/14/1999	NI
SDNHP	South Dakota	Pennington	PMCYP037E0*012*SD		Black Hills National Forest	09/08/1999	NI
SDNHP	South Dakota	Pennington	PMCYP037E0*013*SD		Black Hills National Forest	08/14/1999	NI
SDNHP	South Dakota	Pennington	PMCYP037E0*015*SD		Black Hills National Forest	08/16/1999	NI