Carex alopecoidea Tuckerman (foxtail 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 alopecoidea (foxtail sedge). Photograph by Black Hills National Forest Staff at *C. alopecoidea* site CAAL8-18 on August 2, 2004 (USDA Forest Service 2004). Used with permission.

SUMMARY OF KEY COMPONENTS FOR CONSERVATION OF *CAREX ALOPECOIDEA*

Status

Carex alopecoidea (foxtail sedge) is endemic to North America, occurring in five Canadian provinces and in 21 states within the United States. Documented occurrences are distributed throughout the northeastern United States extending westward to the Rocky Mountains and southward to Tennessee. Within the USDA Forest Service (USFS) Rocky Mountain Region (Region 2), *C. alopecoidea* occurs in wetlands on the Black Hills National Forest in western South Dakota and eastern Wyoming. *Carex alopecoidea* is not found on National Forest System lands in any other states within Region 2. Occurrences on the Black Hills National Forest in Region 2 are on the western periphery of the species' range. Historical *C. alopecoidea* populations in Maine and Tennessee have possibly been extirpated; the species is presumed extirpated in the District of Columbia.

Carex alopecoidea is neither listed nor a candidate for listing under the Endangered Species Act. The species is designated as a sensitive species on National Forest System lands in Region 2. The Global Heritage rank for the species is G5 (common, widespread, and abundant). The Wyoming Natural Diversity Database and the South Dakota Natural Heritage Program rank *C. alopecoidea* as imperiled (S2). This rank is applied to species that are generally known from six to 20 occurrences within a jurisdiction and are considered to be at high risk of extinction due to very restricted range, steep declines, or other factors.

Primary Threats

The loss of occurrences or alteration of the hydrology of the riparian habitats where it occurs composes the main viability concern for this taxon. Possible threats identified during monitoring on the Black Hills National Forest include impacts from grazing by cattle and other large herbivores, presence of invasive species, and proximity of occurrences to private land. While no specific threats associated with occurrences in proximity to private lands were identified in the monitoring reports, increased recreational traffic and potential invasive species encroachment are both of concern.

Most montane riparian areas are subject to a range of general threats that often occur in these habitats (e.g., surface mining, impacts from recreational use such as trampling or soil disturbance from hikers, road building, four-wheel drive vehicle and off-road vehicle use, and fire). No surface mining, recreational, or road construction impacts were identified during monitoring efforts, but impacts should be considered if these uses are present in proximity to occurrences. Other threats that may affect *Carex alopecoidea* include environmental factors such as global warming and nitrogen deposition.

Primary Conservation Elements, Management Implications and Considerations

Knowledge concerning optimal habitat quality and ecology of *Carex alopecoidea* is limited. Hydrology and function of these habitats have not been investigated. Occurrences in Region 2 are vulnerable to changes to hydrologic regime. Maintenance of existing hydrology for *C. alopecoidea* and its habitat within Region 2 will benefit the species.

Minimal information is available regarding factors limiting the growth of *Carex alopecoidea* to determine conservation elements. To improve management of *C. alopecoidea*, additional research is needed. Priorities for research include:

- Monitor existing occurrences and inventory for additional occurrences; land use history and current management practices are important data to be recorded for each occurrence

- Investigate the hydrology of the area where the species occurs

- Investigate the species' response to disturbance
- Determine threats to the species persistence
- Develop and implement a monitoring program to identify population trends
- Investigate the habitat requirements of this species and its interactions with the surrounding plant community

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INTRODUCTION

This assessment is one of many being produced to support the Species Conservation Project for USDA Forest Service (USFS) Rocky Mountain Region (Region 2). *Carex alopecoidea* (foxtail sedge) is the focus of an assessment because of its limited distribution within Region 2 and the limited knowledge concerning its distribution, habitat, population trends, and threats on National Forest System lands. The species is designated as a sensitive species on National Forest System lands within Region 2 (USDA Forest Service 2003a). Within the National Forest System, a sensitive species is a plant or animal whose population viability is identified as a concern by a Regional Forester because of significant current or predicted downward trends in abundance or significant current or predicted downward trends in habitat capability that would reduce its distribution (FSM 2670.5[19]). A sensitive species may require special consideration in management, so knowledge of its biology and ecology is critical. This assessment addresses the biology of *C. alopecoidea* throughout its range in Region 2. This introduction defines the goal of the assessment, outlines its scope, and describes the process used in its production.

Goal

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

Scope

This assessment examines the biology, ecology, conservation status, and management of *Carex alopecoidea* with specific reference to the geographic and ecological characteristics of Region 2. Although some of the literature on the species may originate from field investigations outside the region, this document places that literature in the ecological and social context of the central Rocky Mountains. Similarly, this assessment is concerned with reproductive behavior, population dynamics, and other characteristics of *C. alopecoidea* in the context of the current environment.

Peer-reviewed literature for rare plant species is often limited, and this is the case for *Carex alopecoidea* (Scoggan 1978-1979, Radford et al. 1980, Great Plains Flora Association 1986, Mohlenbrock 1999, Johnston 2001). In addition to standard taxonomic descriptions for the species, other journal articles were found that address recent systematic studies of the genus *Carex* (Manhart 1990, Reznicek 1990, 2001, Roalson et al. 2001, Darrouzet-Nardi 2003). Although no information was found for *C. alopecoidea* specifically, these articles discuss the kinds of molecular studies that might clarify the affinities of *C. alopecoidea* within the *Carex* genus.

Element occurrence records (EORs) for *Carex alopecoidea* were obtained from Natural Heritage Programs in Wyoming and South Dakota. Unpublished field survey results from the Black Hills National Forest collected from 2002 to 2004 were also acquired. These data were important in providing geographic distribution information on Black Hills National Forest land as well as general site information at each of the occurrences. These data required special attention because of the diversity of persons and methods used in their collection.

Peer-reviewed articles on *Carex* life history and population biology were used to infer life history stages of *C. alopecoidea* (Bartlett and Noble 1985, Bernard 1990). Articles on the evolution, speciation, seed dispersal, and ecology of the genus *Carex* were also reviewed (Callaghan 1976, Handel 1978, Reznicek and Catling 1986, Alexeev 1988, Bernard 1990, Cayouette and Catling 1992, Miller 1999, Vellend 2000).

Treatment of Uncertainty

Science represents a rigorous, systematic approach to obtaining knowledge. Competing ideas regarding how the world works are measured against observations. However, because our descriptions of the world are always incomplete and observations limited, science focuses on approaches for dealing with uncertainty. In this assessment, the strength of evidence for particular ideas is noted, and alternative explanations described when appropriate.

Overall, knowledge of *Carex alopecoidea* is sparse and incomplete. The information presented is based on herbarium labels, information synthesized from EORs obtained from the Wyoming Natural Diversity Database (WYNND) and the South Dakota Natural Heritage Program (SDNHP), field surveys conducted by the Black Hills National Forest, and anecdotal observations. The authors utilized personal communications with botanists who have experience with the species and information regarding other members of the genus *Carex* to draw inferences where possible.

Publication of Assessment on the World Wide Web

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

Peer Review

Assessments developed for the Species Conservation Project are 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 on this or related taxa. Peer review was designed to improve the quality of communication and to increase the rigor of the assessment.

MANAGEMENT STATUS AND NATURAL HISTORY

Management Status

Carex alopecoidea is endemic to North America, occurring in five Canadian provinces and in 22 states within the United States. Documented occurrences are distributed throughout the northeastern United States extending westward to the Rocky Mountains and southward to Tennessee. **Figure 1** illustrates the distribution of the species in North America and its conservation status in the states or provinces where it occurs.

The current NatureServe (2006) global rank for *Carex alopecoidea* is G5 (common, widespread, and abundant, although it may be rare in parts of its range). The Wyoming Natural Diversity Database (WYNDD) and the South Dakota Natural Heritage Program (SDNHP) rank *C. alopecoidea* as S2 (species that are generally known from 6 to 20 occurrences within a jurisdiction and are considered to be at high risk of extinction due to very restricted range, steep declines, or other factors) (NatureServe 2006). Historically-known populations of this sedge in Maine and Tennessee have possibly been extirpated, and the species is presumed extirpated in the District of Columbia. *Carex alopecoidea* is infrequent enough in at least five of the 22 states and one of five provinces where it occurs to be considered critically imperiled. It is also ranked imperiled or vulnerable in six states and three provinces (**Figure 1**). *Carex alopecoidea* is listed as threatened in Massachusetts and Connecticut.

Within Region 2, *Carex alopecoidea* occurs in the Black Hills region of eastern Wyoming and western South Dakota (**Figure 2**). Eighteen of the 21 known occurrences in Wyoming and South Dakota are found within the Black Hills National Forest. In Wyoming, all known occurrences are located on National Forest System lands in Crook County. Seven of the ten documented locations in South Dakota occur on the Black Hills National Forest in Lawrence County. In eastern South Dakota, one occurrence is located on South Dakota state park land within the Pickerrel Lake Recreation Area in Day County, and two are located in Brookings County one on public land owned by the City of Brookings and one on private lands. **Figure 2** shows the distribution of this species in Region 2.

Existing Regulatory Mechanisms, Management Plans, and Conservation Strategies

Carex alopecoidea is neither listed nor a candidate for listing under the Endangered Species Act. USFS Region 2, however, has designated it as a sensitive species based on the findings of a 2002 evaluation (Bacon 2002, Burkhart and Crook 2002, Handley et al. 2002, USDA Forest Service 2003a). It was determined that *C. alopecoidea* warrants sensitive species status because it occupies a very narrow ecological amplitude on the western edge of its range on the Black Hills National Forest and because the riparian habitats it occupies may be vulnerable to management actions (Burkhart and Crook 2002). Because *C. alopecoidea* is

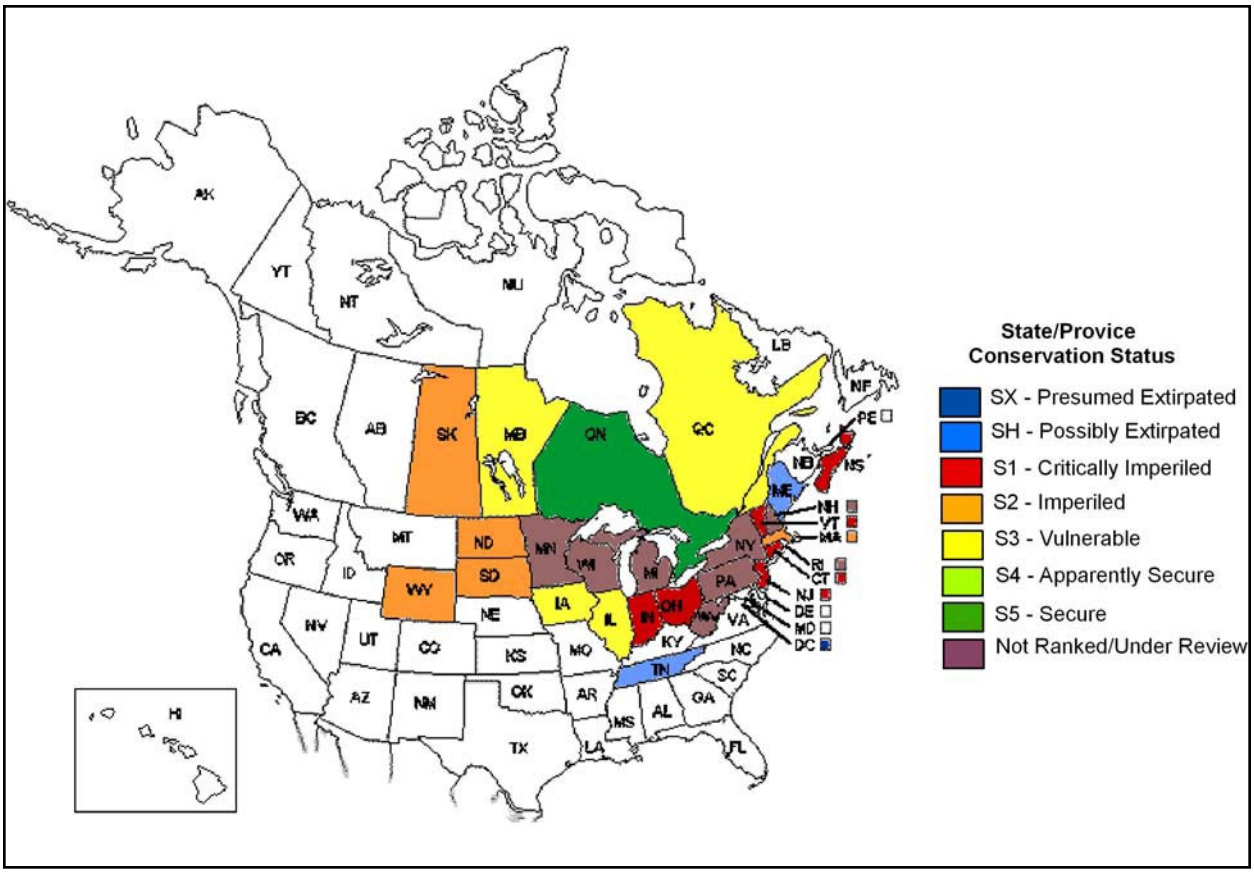

Figure 1. Map of the distribution of *Carex alopecoidea* in North America and conservation status of *C. alopecoidea* in the states or provinces where it occurs (NatureServe Explorer 2006).

designated sensitive in Region 2, the Regional Forester is directed to maintain viable populations (USFS Document R2 Supplement 2600-2005-1). Management of occurrences on National Forest System lands is conducted according to the standards and guidelines of the Revised Black Hills National Forest Management Plan (USDA Forest Service 1997) as amended by the 2001 Phase I Amendment (USDA Forest Service 2001) and the 2003 Phase II Amendment (USDA Forest Service 2005a).

One occurrence of *Carex alopecoidea* is located in the Upper Sand Creek Botanical Area, and one occurrence is located in the Dugout Gulch Botanical Area. Both of these areas are within the Black Hills National Forest and were designated as botanical areas in 1997 (USDA Forest Service 1997). Under this designation, the areas are to be managed in such a way that the drainages and surrounding uplands and the botanical features for which the areas were established are not impaired (USDA Forest Service 1997). Designated botanical areas are withdrawn from mineral entry and protected from off-road motorized use; travel is restricted to designated roads and trails, and timber harvest and firewood gathering are restricted (USDA Forest Service 1997). Fire suppression and the use of prescribed fire may be allowed if they will protect the values for which the botanical area was set aside (USDA Forest Service 1997).

Carex alopecoidea is designated as an obligate wetland species within U.S. Fish and Wildlife Service Wetland Region 4, which includes South Dakota and Wyoming (Reed 1997). An obligate wetland species is a plant that naturally and almost always occurs (estimated probability 99 percent) in wetlands. Several federal regulations and polices provide protection of the wetland habitats in which *C. alopecoidea* occurs. The primary national law that regulates wetlands is Section 404 of the Clean Water Act, which requires parties who wish to discharge dredged or fill material into the navigable waters of the United States to obtain a permit from the U.S. Army Corps of Engineers. Regulatory agencies and the courts have interpreted “navigable waters” to include wetlands. The basic premise of the program is that no discharge of dredged or fill material may be permitted if a practicable alternative exists that is less damaging to the aquatic environment. The program

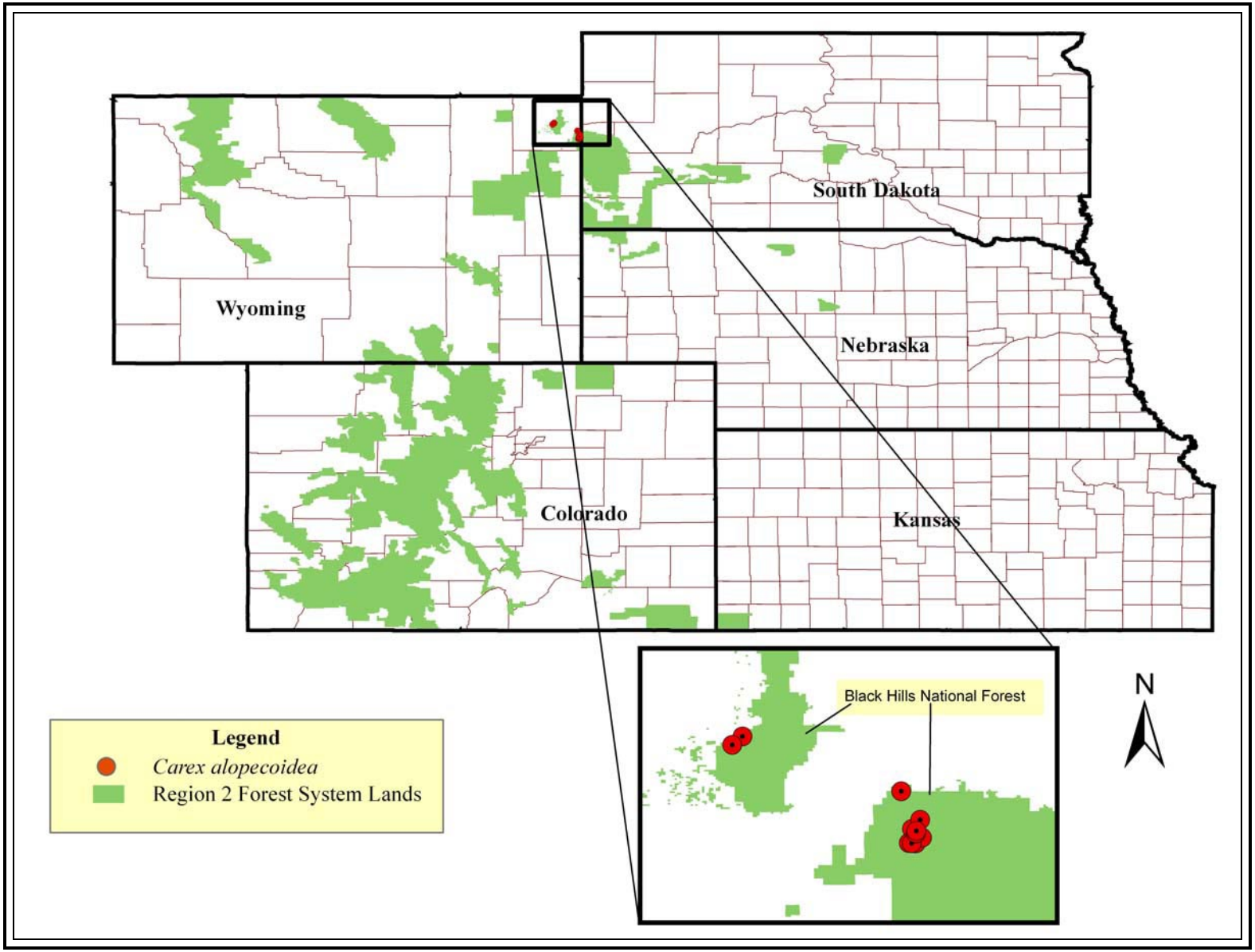

Figure 2. Distribution of *r* occurrences on USDA Forest Service lands in Region 2.

requires all steps to be taken to avoid or minimize wetland disturbance and requires compensation for any remaining unavoidable impacts.

The Watershed Conservation Practices Handbook (Forest Service Handbook 2509.25-99-1) also offers protection of the wetland habitats where *Carex alopecoidea* occurs by providing direction for the protection of soil, aquatic, and riparian systems on National Forest System lands. The objectives of the policy are to maintain long-term ground cover, soil structure, water budgets, and flow patterns of wetlands to sustain their ecological function. The practices address five areas: hydrologic function, riparian areas, sediment control, soil productivity, and water purity.

Carex alopecoidea has no other legal protection that would prevent the destruction of habitat or individuals within Region 2. As of this writing, a conservation strategy has not been written for this species at a national or regional level by the USFS or any other federal agency. The above standards and guidelines provide tools for the conservation of *C. alopecoidea* and the wetland habitats in which it occurs. Protection of the wetland habitats in which this species occurs is the key to its protection.

Biology and Ecology

Classification and description

The cosmopolitan Cyperaceae plant family has 122 genera and perhaps as many as 5,000 species (Darrouzet-Nardi 2003). About 2,000 (40 percent), of all Cyperaceae species are in the genus *Carex* (sedges). The distribution of *Carex* is worldwide, with about 25 percent of all species occurring in China, 21 percent in North America, 11 percent in Europe, 10 percent in Japan, 4 percent in New Zealand, and 19 percent elsewhere. Sedges are prevalent in temperate and cold regions, are perennial herbs (rarely flowering in the first year), and are usually found in wet places (Mabberley 1997). They are best known for their important role in wetlands, where they contribute to soil stability, water filtration, water purification, and water retention.

Manhart (1990) indicated that despite being the largest genus in most temperate floras, *Carex* has been included in few chemosystematic investigations. In Manhart's review of chemosystematic methods, it was suggested that enzyme electrophoresis and, in some cases, flavonoid comparisons were appropriate techniques to use for *Carex* systematic research. It was argued that these chemicals could help with phylogenetic alignments of problematic *Carex* taxa as well as with higher taxonomic categories within the Cyperaceae. Since few *Carex* species have been examined, the selection of which *Carex* species to analyze in order to obtain maximum chemosystematic information is a real issue. Currently, evolutionary trends identified by Reznicek (1990, 2001), Roalson et al. (2001), and Darrouzet-Nardi (2003) provide the best available guidelines to use for the selection of *Carex* species in phylogenetic investigations. There are no data available for *C. alopecoidea*. Until additional molecular or chemosystematic information is available, *Carex* taxonomists will continue to rely on traditional morphological affinities and on the above-mentioned guidelines to assign lineages.

Taxonomic description

Like other member of the Cyperaceae, members of the genus *Carex* usually have solid, triangular stems and 3-ranked leaves with closed sheaths. *Carex* species are monoecious or occasionally dioecious and androgynous or gynaecandrous. All species of *Carex* have rhizomes to some degree, some long and trailing and others short and inconspicuous (Ball and Reznicek 2002). The flowers have no perianth and have 1 to 3 stamens that are surrounded by a sac-like structure called a perigynium (Ball and Reznicek 2002). The genus *Kobresia* and others outside of Region 2 also have a perigynium; however, the *Kobresia* has open, unsealed margins that merely wrap around the achene (Cronquist et al. 1994). Within this perigynium is a solitary, lens-shaped or triangular achene or nutlet (Jones and Luchsinger 1979). The perigynium is an important structure that is often used as a diagnostic character in taxonomic keys (Great Plains Flora Association 1986). The nomenclature and classification for *C. alopecoidea* have remained stable. There are no synonyms, and it is considered a good species, evident by its stable position within various *Carex* treatments. The taxonomic nomenclature of *C. alopecoidea* is summarized in **Table 1** (Roalson et al. 2001, Standley 2002, USDA Natural Resources Conservation Service 2006). There are several, all similar, taxonomic descriptions available for this sedge in regional floras (Scoggan 1978-1979, Radford et al. 1980, Great Plains Flora Association 1986, Mohlenbrock 1999, Johnston 2001, Standley 2002). Included here is a composite of the descriptions for *C. alopecoidea* from these references.

Carex alopecoidea is a caespitose perennial 4 to 10 dm (15.8 to 39.4 in.) tall, with short, black, rhizomatous roots (Mohlenbrock 1999, Standley 2002). The leaf sheath has a leaf blade attached to it, with basal

Table 1. Classification of *Carex alopecoidea* Tuckerman.

Carex alopecoidea Tuckerman
Family: Cyperaceae
Tribe: Cariceae
Genus: *Carex*
Subgenus: *Carex*
Species: *Carex alopecoidea* Tuckerman
Citation: Enumeratio Methodica Caricum Quarundam 18. 1843.
Synonyms: none
Vernacular Names: foxtail sedge, northern foxtail sedge, tawny sedge
Type: Isotype: No. 25100 New York Botanical Garden. Collected D. Cooley, Washington or Michigan. Amer. J. Sci. Arts 8:350 1849. Type: 1843.

sheaths clothed with persistent linear fibers. The leaves are usually 3 to 8 mm (0.12 to 0.31 inches) wide, but they can range from 2 to 10 mm (0.08 to 0.39 inches). The sheaths are tight, not cross-rugulose ventrally, and purple to red-dotted (Fertig 2001, Standley 2002).

The *Carex alopecoidea* inflorescence is 2 to 4 cm (0.8 to 1.6 inches) long, densely spicate, elongated, and cylindric with eight to 12 branches. The bract below the lowest spike is setaceous (bristle-like) and shorter than the inflorescence. The terminal spike is androgynous, the lateral spikes are either androgynous or pistillate with 10 to 30 pistillate flowers. The pistillate scale is short-awned (<2 mm [0.08 inches]), acuminate to cuspidate, and light in color. The perigynia are narrowly winged or wingless, 3.0 to 4.5 mm (0.12 to 0.18 inches) long and 1.5 to 2.0 mm (0.06 to 0.08 inches) wide. *Carex alopecoidea* perigynia are brownish-yellow in color; plano-convex, ovate-ovoid or lanceolate in shape; and spongy or corky at the base (**Figure 3**). The body of the perigynia is sometimes three to five-veined or veinless dorsally and typically veinless ventrally. The stipe is tapered and serrulate up to 2 mm (0.079 inches) long. The achenes are lenticular and have two stigmas (Fertig 2001, Standley 2002).

Similar species

Sedges can be difficult to identify in the field. Mature reproductive and rooting structures are necessary for accurate identification. Therefore, the following discussion of separating similar species depends upon the quality and maturity of the material in question. *Carex alopecoidea* specimens from Brookings County in eastern South Dakota (**Table 2**) were first misidentified as *C. gravida*. *Carex gravida* has winged perigynia that abruptly contract to a beak, and the leaves have a whitish sheath with green mottling. *Carex alopecoidea* can be differentiated by the longer, tapering beak, and the purple to red mottling on the leaf sheaths. Another look alike is *C. vulpinoidea*. The flowering heads of *C. alopecoidea* are typically 2 to 4 cm (0.8 to 1.6 inches) long, and the awns of the flowering scales are 2 mm (0.06 inches) or less in length. *Carex vulpinoidea* has a considerably longer inflorescence (3 to 10 cm [1.2 to 3.9 inches]), and the awns on the flowering scales are 3 mm (0.12 inches) or more in length. Additionally, some confusion has occurred with *C. hoodii*, which has awnless scales and a denser, head-like inflorescence than is typical of *C. alopecoidea* (Dorn 2001, Fertig 2001, Standley 2002). *Carex conjuncta*, which grows in nearby Nebraska, differs primarily in the rough sheath fronts, while *C. alopecoidea* has smooth sheath fronts. Finally, *C. stipata* can sometimes have reduced inflorescences that resemble *C. alopecoidea*; however cross-wrinkled sheaths can be used to differentiate it from *C. alopecoidea*.

Distribution and abundance in Region 2

On National Forest System lands in Region 2, *Carex alopecoidea* occurs in wetlands of western South Dakota and in eastern Wyoming on the Black Hills National Forest (**Table 2**). The Black Hills are isolated mountains surrounded by the North American Prairie province (Takhtajan 1986) where floristic elements from different phytogeographic regions converge. For example, the Black Hills has plant species that are associated with the Great Plains, the Rocky Mountains, boreal forests of Canada, eastern deciduous forests of Appalachia, and the Atlantic floristic region (Takhtajan 1986). In the Black Hills, *C. alopecoidea* is at the westernmost edge of its distribution.

Occurrence of *Carex alopecoidea* on National Forest system lands administered by the Black Hills National Forest was confirmed in 2000 (Fertig 2000; Holst et. al 2001; Marriott and Faber-Landendoen 2000).

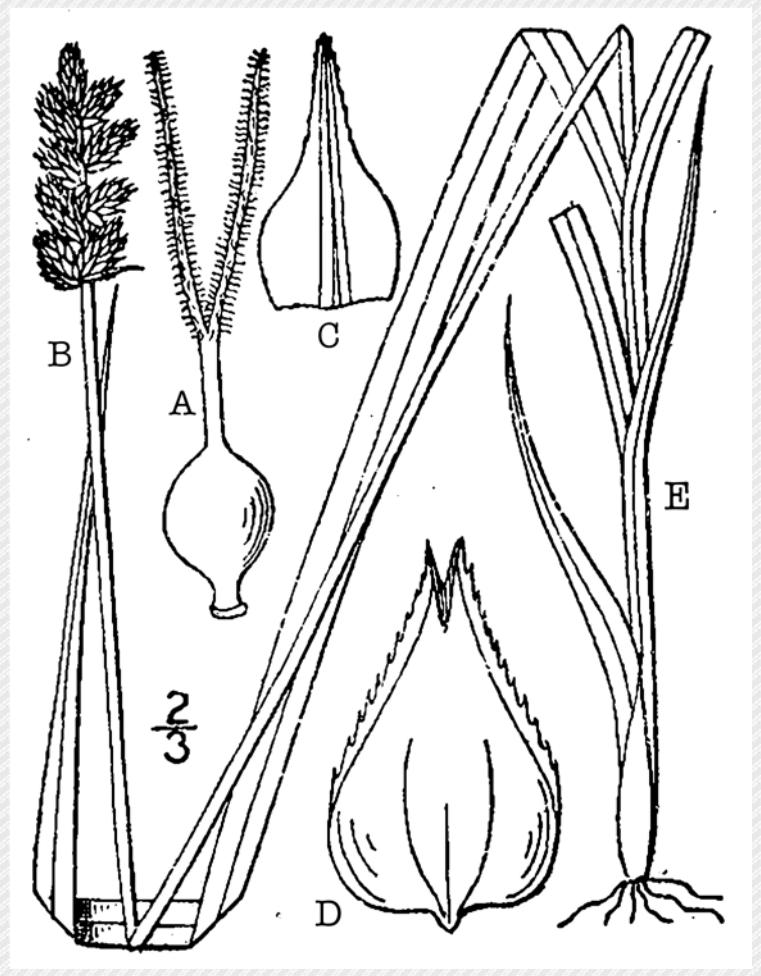

Figure 3a. Line drawing of *Carex alopecoidea* showing achene (A), spike (B), scales (C), perigynia (D), and habit (E). Drawing courtesy of the Kentucky Native Plant Society (Britton and Brown 1913).

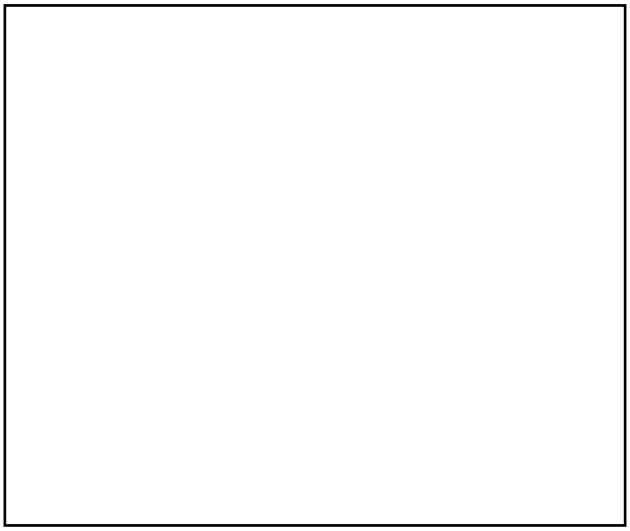

Figure 3b. Perigynia of *Carex alopecoidea* (Ball and Reznicek 2002). Used with permission.

Figure 3. Line drawings of *Carex alopecoidea*.

Table 2. Summary of abundance and habitat data for *Carex alopecoidea* taken from Wyoming and South Dakota Element Occurrence Records. N/A = Not Available. Sources: South Dakota Natural Heritage Program 2004, Wyoming Natural Diversity Database 2004.

EOR / State	County	Area (hectares)	Total # of Plants	Elevation	EOR Data Habitat Characteristics and Associated Species	Land Ownership
001 / WY	Crook	ca. 0.5	160	1,760 m. (5,774 ft.)	Approximately 9 subpopulations spanning over 2.5 miles in 6 confluent valleys. Wet, open valley bottoms. Riparian with *Salix bebbiana*, *Corylus cornuta*, *Agrimonia striata*, *Agrostis stolonifera*, *Carex utriculata*, *C. pellita*, and *S. microcarpa*. Excellent or good estimated viability.	Spearfish/Nemo Ranger District USFS, BHNF
002 / WY	Crook	< .01	10	1,450 m. (4,757 ft.)	Bottom of shaded drainage about 30 meters from creeklet. Ten stems in about 1 sq. meter of habitat. Riparian: in birch/hazelnut forest with *Adenocaulon bicolor*, *Actaea rubra*, and *Rubus parviflorus*. Density estimate of reproductive stalks: 10 per sq. m. Good estimated viability.	Spearfish/Nemo Ranger District USFS, BHNF Upper Sand Creek Botanical Area
003 / WY	Crook	N/A	N/A	1,500 m. (4,921 ft.)	Adjacent to spring in *Betula* sp. woods. Viability not assessed.	Spearfish/Nemo Ranger District USFS, BHNF
004 / WY	Crook	N/A	N/A	1,450 m. (4,757 ft.)	2 subpopulations in about 1/2 mile. Small opening in mesic sedge-grass meadow near banks of small creek. Possibly fair estimated viability.	Spearfish/Nemo Ranger District USFS, BHNF Dugout Gulch Botanical Area
005 / WY	Crook	ca. 0.5	50-100	1,800 m. (5,906 ft.)	Riparian: On pond margins in slight shade with *Salix* sp., *Typha* sp., and *Carex* sp. Population is intermittently scattered along 1.8 miles of Spottedtail Gulch. Viability not assessed.	Spearfish/Nemo Ranger District USFS, BHNF Bearlodge Ranger District
006 / WY	Crook	< .01	11	1,650 m. (5,413 ft.)	Riparian meadow in open light on moist soil with *Salix bebbiana*, *Trifolium repens*, *T. pratense*, *Monarda fistulosa*, *Mentha arvense*, *Taraxacum officinale*, *Verbascum thapsus*, *Achillea millefolium*, *Cirsium* sp., *Cerastium* sp., and *Ribes* sp.	Bearlodge Ranger District USFS, BHNF
007 / WY	Crook	Widespread across ca 0.7 mile of Gulch	734 Count is probably larger as many individuals without the reproductive structure	1,800 m. (5,906 ft.)	widespread across ca 0.7 mile of Pole Cabin Gulch and becomes infrequent as the population extends up a second drainage to 0.2 miles northeast of Pole Cabin Spring. Riparian meadows with dry to moist soils: with *Crataegus* sp., *Corylus* sp., and *Salix* sp.	Bearlodge Ranger District USFS, BHNF
008 / WY	Crook	< .01	37	1,600 m. (5,249 ft.)	Wet meadow near a spring with *Salix bebbiana*, *Prunus* sp., and *Carex* sp.	Bearlodge Ranger District USFS, BHNF

Table 2 (concluded).

EOR / State	County	Area (hectares)	Total # of Plants	Elevation	EOR Data Habitat Characteristics and Associated Species	Land Ownership
009 / WY	Crook	<.01	813	1,480 m. (4,856 ft.)	Riparian: *Salix bebbiana*, *Crataegus chrysocarpa*, *Pinus ponderosa*, *Cynoglosum officinale*, *Rudbeckia laciniata*, *Cirsium arvense*, *Phleum pratense*, and *Urtica dioica*.	Bearlodge Ranger District USFS, BHNF
010 /WY	Crook	< .01	4	1,400 m. (4,600 ft.)	Birch/hazelnut and shrub community in moist bottom. Viability not assessed.	Bearlodge Ranger District USFS, BHNF
011 /WY	Crook	< .01	5-10	1,370 m. (4,500 ft.)	Grass/sedge riparian community.	Bearlodge Ranger District USFS, BHNF
001 / SD	Lawrence	< .01	ca. 150	1,865 m. (6,119 ft.)	Riparian: *Betula* sp., *Corylus* sp., *Populus tremuloides*, and *Pinus ponderosa.*	Northern Hills Ranger District Cement Ridge Allotment USFS, BHNF
002 / SD	Lawrence	< .01	8	1,890 m. (6,201 ft.)	Riparian: *Salix bebbiana* and *Pteridium aquilinum.*	Northern Hills Ranger District Cement Ridge Allotment USFS, BHNF
003 / SD	Lawrence	< .01	40	1,840 m. (6,037 ft.)	Riparian: *Typha* spp. A broad drainage between large ridges.	Northern Hills Ranger District Cement Ridge Allotment USFS, BHNF
004 / SD	Lawrence	< .01	N/A	1,910 m. (6,266 ft.)	Riparian. An unnamed drainage with *Populus tremuloides* and *Salix bebbiana.*	Northern Hills Ranger District Cement Ridge Allotment USFS, BHNF
005 / SD	Lawrence	< .01	47	1,860 m. (6,102 ft.)	Riparian. Shallow drainage between low ridges.	Northern Hills Ranger District Cement Ridge Allotment USFS, BHNF
006 / SD	Lawrence	< .01	50	1,850 m. (6,070 ft.)	Riparian: Wet, open meadow near beaver ponds.	Northern Hills Ranger District Cement Ridge Allotment USFS, BHNF
007 / SD	Brookings	< .01	N/A -Common	1,570 m. (5,151 ft.)	Riparian. Low margin of oxbow along Big Sioux River.	Private: Conservation Park
008 / SD	Brookings	< .01	N/A	1,585 m. (5,200 ft.)	Riparian. Along Big Sioux River at Brookings.	Public: City of Brookings
009 / SD	Day	< .01	N/A	1,855 m. (6,086 ft.)	Wetland meadow at margin of a shallow marsh with *Sparganium eurycarpum*, *Carex retrorsa*, and *Ranunculus pensylvanicus.*	State Pickerrel Lake Recreation Area
SD_BHNF CAAL8-20	Lawrence	0.8	233	1,761 m (5,780 ft.)	Pettigrew Gulch. Grass/sedge dominated drainage. There is a small stream flowing down the center of the drainage, with little overstory cover for most of the area.	Northern Hills Ranger District Cement Ridge Allotment USFS, BHNF

As of March 2006, there are 18 known occurrences (EORs) reported on the Black Hills National Forest in Wyoming and South Dakota. All EORs encompass one or more observations or subpopulations represented by points, lines, or polygons (WYNDD 2006). Baseline data were gathered from 14 known subpopulations in 2001 including estimates of linear extent, number of subpopulation patches, as well as other data. Additional quick reconnaissance surveys were conducted in 2002 in similar habitats on the Bearlodge and Northern Hills Ranger Districts. As a result of these surveys, four new EORs were identified in the northwestern Black Hills and the Bearlodge Mountains (including 15 additional observations). Similar reconnaissance project specific surveys conducted in 2003 resulted in discovery and reporting of two additional EORs (USFS 2004).

Based on the surveys conducted by personnel from the Black Hills National Forest, *Carex alopecoidea* is currently known to occur along low gradient perennial streams in the upper headwater areas of two drainages in the northwestern Black Hills and the main portion of the Bearlodge Mountains. Individuals are located in the transitional areas between saturated soil conditions and the adjacent mesic upland areas (USDA Forest Service 2005b). Many of the occurrences are associated with old beaver dams (Crook personal communication 2005).

Due to differences in techniques and personnel, abundance estimates between the Black Hills National Forest, the WYNDD, and the SDNHP differ in totals. Unfortunately, different collectors have used different methods to count individual sedges on the EOR forms. Indeed, counting individual perennial sedges can be a difficult task. Some collectors designate clusters or distinct clumps of sedges as one individual. Others count and report the number of flowering spikes. Most collectors recognize that both individual and inflorescence counts are difficult. The latter are restrictive because reproductive spikes are visible only at certain times of the year. In addition, vegetative sedges can easily be confused with other sedge species that co-occur in the same area.

Based upon monitoring data obtained by Black Hills National Forest botanists, a conservative 2004 estimate of total number of individuals occurring on the Black Hills National Forest is approximately 4357 individuals (USDA Forest Service 2004). Abundance estimates recorded on EOR forms from Wyoming range from 813 plants distributed over 2.5 square miles (EOR WY*009) to 10 plants in 1 square meter (EOR WY*002). The SDNHP EOR records estimate approximately 275 individuals on the Black Hills National Forest and in Brookings County. A conservative and unverified total number of plants occurring throughout Region 2 is approximately 5000 individuals.

Population trend

There are very few data that can be used to draw conclusions concerning the trend for individual populations of *Carex alopecoidea*. Past census counts focused on counting clumps that were reproductive; this resulted in conservative estimates due to the omission of vegetative individuals. The inherent problems with determining populations of graminoid species, particularly those that are capable of asexual reproduction, present a challenge to accurately identify increases or decreases in populations. Another problem is the designation of what a population is versus a subpopulation. The heritage programs (WYNDD and SDNHP) tend to combine occurrences in close proximity and track the combined subpopulations. The Black Hills National Forest gathered data on four occurrences that are considered subpopulations by WYNDD and the SDNHP.

Abundance data were obtained from these four subpopulations in 2003 and 2004. The four locations showed a change in numbers of individual fruiting clumps between 2003 and 2004. The following counts represent several subpopulations of four occurrences listed in **Table 2**. The Pettigrew Gulch occurrence (CAAL8-20) had 327 plants counted in 2003 and 233 plants were counted in 2004. The Pole Cabin population (WY*007) had 734 plants counted in 2003 and 1,003 plants were counted in 2004. The Beaver Creek occurrences (WY*009) had 349 plants counted in 2003 and 576 plants were counted in 2004, and an additional subpopulation at WY*009 had 813 plants counted in 2003 and 895 plants were counted in 2004 (USDA Forest Service 2003b, USDA Forest Service 2004, USDA Forest Service 2005b). Only one of the above four locations (CAAL8-20) showed a decrease in numbers. The recorded field data all report that 2003 was a drought year. It is probable that the numbers would have increased with the additional moisture in 2004. The decrease in the Pettigrew Gulch population may have been due to sampling error as the field notes reported that the survey time ran out and was incomplete. This data should be viewed with caution. These subpopulations may not have been counted consistently both years; for example, the boundary of the area of census was inexact and no vegetative individuals were counted. Continued monitoring of these sites may provide additional information to provide a basis for determining population trend.

Habitat

The primary habitat for *Carex alopecoidea* throughout its range is riparian wetlands. *Carex alopecoidea* is an obligate wetland species in South Dakota and Wyoming (Reed 1997). It is associated with perennial flowing water and can be found above the saturated edge of the water line, especially on and along the edges of abandoned beaver ponds (Crook personal communication 2005). A few observations suggest that *C. alopecoidea* can also occur in areas that may be hydrologically connected to perennial water features but are not inundated during the growing season (South Dakota Natural Heritage Program 2004, Wyoming Natural Diversity Database 2004). The majority of known occurrences on the Black Hills National Forest are documented along the upper headwaters of drainages associated with low gradient perennial streams (USDA Forest Service 2005b). Elevation of occurrences ranges from 1,370 m (4,500 ft.) in the Cub Creek drainage of the Black Hills (Wyoming) to 1,970 m (6,500 ft.) near a tributary of Beaver Spring Creek (South Dakota). **Table 2** presents general habitat information obtained from EORs and herbarium labels.

The Black Hills National Forest has recorded site characteristics of the known *Carex alopecoidea* occurrences on the forest. These descriptions suggest that *C. alopecoidea* can be associated with many different wetland, riparian, and upland plants. **Table 3** lists plant species commonly associated with *C. alopecoidea* as reported on EORS and Black Hills National Forest rare plant survey/monitoring form. However, certain characteristics and associated dominants are consistently observed. The majority of the occurrences are adjacent to *Pinus ponderosa* (ponderosa pine) and *Populus tremuloides* (aspen) woodland vegetation types. Within these areas, *C. alopecoidea* is typically found in a riparian wetland dominated by scattered individuals of *Salix bebbiana* (Bebb willow), *Crataegus chrysocarpa* (fireberry hawthorn), *Corylus cornuta* (beaked hazelnut), and *Betula papyrifera* (paper birch). The densities of the riparian tree and shrub species that are listed as associates are not known. These woody plants grow in association with *Carex alopecoidea* and may sometimes provide partial shade (South Dakota Natural Heritage Program 2004, Wyoming Natural Diversity Database 2004). Sometimes *C. alopecoidea* is associated with a grass-sedge dominated wet meadow community, characterized by *Agrostis stolonifera* (creeping bentgrass), *C. rostrata* (beaked sedge), and *Scirpus microcarpus* (panicled bulrush). **Figure 4** includes a photograph of one of the habitats on the Black Hills National Forest. This figure illustrates a typical bottomland wet meadow habitat with a relatively open canopy.

Table 3. Plant species associated with *Carex alopecoidea* (SDNHP 2004, WYNDD 2004). Those preceded by an asterisk are introduced species. Numbers in parentheses after a species are the number of EORs that list the taxon. Species in brackets were associated with *C. alopecoidea* occurrences in eastern South Dakota. The abbreviation sp. indicates specific species not known.

Scientific Name	Common Name	Family
**Achillea millefolium*	common yarrow	Asteraceae
Actaea rubra	red baneberry	Ranunculaceae
Adenocaulon bicolor	American trailplant	Asteraceae
Agrimonia striata	roadside agrimony	Rosaceae
Agrostis stolonifera	creeping bentgrass	Poaceae
Betula papyrifera (2)	paper birch	Betulaceae
Carex sp. (2)	sedge spp.	Cyperaceae
Carex retrorsa	knotsheath sedge	Cyperaceae
Carex utriculata	Northwest Territory sedge	Cyperaceae
Carex pellita	woolly sedge	Cyperaceae
Cerastium sp.	chickweed spp.	Caryophyllaceae
Cirsium sp.	thistle sp.	Asteraceae
**Cirsium arvense* (2)	Canada thistle	Asteraceae
Cirsium vulgare	Musk thistle	Asteraceae
Corylus sp. (2)	hazelnut spp.	Betulaceae
Corylus cornuta	beaked hazelnut	Betulaceae

Table 3 (concluded).

Scientific Name	Common Name	Family
Crataegus sp.	hawthorn spp.	Rosaceae
Crataegus chrysocarpa	fireberry hawthorn	Rosaceae
**Cynoglossum officinale*	gypsyflower	Boraginaceae
Mentha arvensis	wild mint	Lamiaceae
Monarda fistulosa	wild bergamot	Lamiaceae
**Phleum pratense*	timothy	Poaceae
Pinus ponderosa (2)	ponderosa pine	Pinaceae
Populus tremuloides	aspen	Salicaceae
Pteridium aquilinum	bracken fern	Dennstaedtiaceae
[*Ranunculus pensylvanicus*]	Pennsylvania buttercup	Ranunculaceae
Ribes sp.	currant spp.	Grossulariaceae
Rubus parviflorus	thimbleberry	Rosaceae
Rudbeckia laciniata	cutleaf coneflower	Asteraceae
Salix sp.	willow spp.	Salicaceae
Salix bebbiana (5)	Bebb willow	Salicaceae
Scirpus microcarpus	panicled bulrush	Cyperaceae
[*Sparganium eurycarpum*]	bur-reed	Sparganiaceae
**Tanacetum vulgare*	common tansy	Asteraceae
**Taraxacum officinale*	common dandelion	Asteraceae
**Trifolium repens*	white clover	Fabaceae
**Trifolium pratense*	red clover	Fabaceae
Typha sp.	cattail spp.	Typhaceae
Urtica dioica	stinging nettle	Urticaceae
**Verbascum thapsus*	common mullein	Scrophulariaceae

Figure 4. Typical habitat for *Carex alopecoidea* in the Black Hills National Forest. Photograph by Reed Crook, Black Hills National Forest 2001 (used with permission).

In regard to soils, there is probably a mix of alluvial sediments in wetland soils, with different soil particle sizes from different kinds of parent materials. Other than an unknown threshold amount of water, there may also be a particular soil pH range, soil texture, or soil nutrient condition that favors *Carex alopecoidea*. On the Black Hills National Forest rare plant survey/monitoring forms, observers consistently record limestone as the parent substrate. The particular chemistry of the soils where *C. alopecoidea* occurs on the forest locations is not known. Topographic and stream relief patterns that favor stream channeling, and thereby restrict wetland margins, can also reduce the amount of available habitat for this sedge. Therefore, more level areas are probably important habitats for this species.

While water availability and soil development on level terrain help to define *Carex alopecoidea* habitat, other factors, such as temperature regimes and pH, may also be important. The possibility that *C. alopecoidea* habitats are defined by factors such as level terrain, adequate soil water, adequate pH range, or appropriate temperatures are speculation. No field data have yet been collected to support any one of these possibilities over another.

Reproductive biology and autecology

The morphological description of *Carex alopecoidea* shows that this species has short rhizomes (Mohlenbrock 1999, Standley 2002). *Carex* species that produce short rhizomes tend to form stationary clumps restricted to one place. However, these caespitose clumps sometimes move slowly along the ground, dying at one end and forming new shoots at the growing end. The dwarf rhizome *Carex* species often have a higher rate of flowering, higher shoot production, lower competitive ability, and shorter life span (Bernard 1990). Additional field research that emphasizes careful extraction of the rooting structures may show the presence of long rhizomes for *C. alopecoidea*. Vegetative reproduction of *C. alopecoidea* likely occurs to some degree, but the dwarf rhizomes present on the caespitose clumps are not likely to produce large numbers of ramets.

In regard to pollination, *Carex alopecoidea*, like most sedges, is wind-pollinated (anemophily). The *C. alopecoidea* inflorescence is androgynous, with staminate flowers borne above the pistillate ones. This morphology is well suited to wind pollination. It is not known if *C. alopecoidea* is self-pollinated (staminate flowers sometimes disperse pollen before the pistillate flowers become receptive), cross-pollinated, or apomictic (seed formation without fertilization).

A review article on *Carex* hybridization indicated that numerous *Carex* hybrids have been reported, but most of these hybrids are sterile (Cayouette and Catling 1992). Anemophily could facilitate hybridization with other closely related *Carex*, but this situation is rare. The occurrence of numerous *Carex* hybrids in the northeastern United States was explained by Cayouette and Catling (1992) as a consequence of relatively recent glaciation and a high degree of overlapping flowering phenologies among sedges in this region. *Carex alopecoidea* has not been tested for hybridization potential and is not on the list of *Carex* hybrids known from North America (Cayouette and Catling 1992).

Carex seeds may be dispersed by wind, water (at times of flooding), or herbivores (Handel 1978). Vellend et al. (2000) indicated that ants are especially successful at dispersing *Carex* species seeds that occur in forest understories; however *C. alopecoidea* in Region 2 is generally associated with open wetland canopies. If herbivores dislodge *Carex* shoots, tillers, ramets, or rhizomes to produce genets, these vegetative propagules, as well as seeds, could disperse downstream during a flood. Once a seed is dispersed, Vellend et al. (2000) indicated it has a better chance of germination if it falls on soil instead of leaf litter. These are dispersal means that have been documented for other *Carex* species, but none of these possibilities has yet been identified as the actual seed dispersal means for *C. alopecoidea*.

Mycorrhizal fungi are a means by which plants can better utilize nutrients. The Cyperaceae family is generally considered to be non-mycorrhizal, but a recent review by Miller et al. (1999) has suggested that vesicular-arbuscular mychorrizae may be more widespread among sedges than previously realized. These researchers examined 23 *Carex* species in Illinois (*C. alopecoidea* was not studied), and they found that 16 of these sedges were mycorrhizal. Of special note in this study was that all seven of the non-mycorrhizal sedges had a similar and distinctive root hair that could be an anatomical trait associated with non-mycotrophy. It is not known if *C. alopecoidea* has this trait. Taxonomic relationships did not correlate with mycorrhizal and non-mycorrhizal status.

Demography

There have been no demographic studies for *Carex alopecoidea*, but demographic studies for other

Carex species have indicated the key importance of vegetative reproduction in maintaining or increasing the size of sedge populations (Bartlett and Noble 1985, Bernard 1990). Some *Carex* clones can live vegetatively for hundreds of years under special circumstances (Reznicek and Catling. 1986). It has been estimated that *Carex* species with the dwarf rhizome morphology may live up to 20 years (Bernard 1990). At present, the long-term survival of the Black Hills occurrences of *C. alopecoidea* is uncertain. Since it is a perennial plant that has survived for years (how many is unknown), it may continue to survive, but we do not know for how long. It is difficult to identify a *Carex* seedling (versus other monocots) in the field; therefore, without established monitoring plots, the effectiveness of reproduction by seed is unknown. It may also be that its vegetative reproductive abilities are limited.

No lifecycle diagram has been developed specifically for *Carex alopecoidea*. It is possible to describe a generalized life cycle for a typical *Carex* species since most species in this genus have a similar graminoid growth form and reproduce by rhizomes or by other asexual means to form clones (Bernard 1990). The life history of *Carex* is conveniently divided into three parts. The first and longest-lived stage is the vegetative phase with a root system. The next stage is the vegetative reproduction phase with aboveground genets and belowground rhizomes. The last stage is the sexual reproductive or flowering stage (Bernard 1990), a stage that may take years to initiate. A simple lifecycle diagram for a *Carex* species is presented in **Figure 5**.

It is important to note that *Carex alopecoidea* is a clump forming, caespitose sedge. Therefore, the contribution to vegetative growth from the short dwarf rhizomes is minimal and may not markedly increase the number of ramets.

Community ecology

No studies of the community ecology and interspecific relationships of *Carex alopecoidea* have been conducted. Native herbivory may be considered a possible community interaction. Possible native herbivores include deer, elk, or small mammals and may function in seed dispersal. Observations have been made of elk bedding down on *C. alopecoidea* sites. It is not known how this activity may affect *C. alopecoidea*. There have been no studies investigating parasites or diseases that may affect *C. alopecoidea*. Nor have there been any investigations of symbiotic or mutualistic interactions.

Nine of the associated plant species listed in **Table 3** are introduced species. Exotics are difficult to extirpate once they have become established, especially musk thistle (*Cirsium vulgare*) and Canada thistle (*C. arvense*) (Sheley and Petroff 1999). Purple loosestrife (*Lythrum salicaria*) is considered one of the most invasive species of North American wetlands. Morrison (2002) showed that the percent cover of *Carex alopecoidea* increased after removal of purple loosestrife in experimental plots in Milbrook, New York. A decrease in *C. alopecoidea* cover was observed in control plots where purple loosestrife was *not* removed. No purple loosestrife was observed in any of the Region 2 occurrence locations (Crook personal communication 2005). If this or some other noxious weed were to be introduced into a *C. alopecoidea* wetland, or if a noxious weed already present becomes more abundant, a decrease in the numbers of this sedge and an increase in shade may occur.

An envirogram is a useful tool for evaluating the relationships between the environment and a single species. It traces the environmental factors that affect a species from the most indirect (distal) interactions to factors that have a direct (proximal) effect (Andrewartha and Birch 1984). Traditionally, it is most often applied to animal/environment interactions. An example of an envirogram constructed for *Pinus lambertiana* (sugar pine) showed that the same principles used to construct one for animals could be equally applied to plants (Taylor 2000). The centrum is a key environmental component that in some way affects the survival of a species (Andrewartha and Birch 1984). An envirogram should be considered an analytical tool that pulls together all aspects of a plant's environment as a sequence of webs. Closest to the centrum components are Web 1 components, those factors that most affect a centrum. In turn, Web 2 components affect Web 1 components, Web 3 components affect Web 2 components, etc. Web 4 or Web "n" components are the most distant from the centrum. Therefore, Web 4 factors are often beyond the ecological and biological scope of a species.

Three envirograms were developed for *Carex alopecoidea*, and to aid in viewing, each centrum is color coded. The first (green) is for key abiotic or environmental resources including light, soil water, and nutrients (**Figure 6**). The second envirogram (yellow) is for life cycle components: growth and development, flowering/ fruiting, and seedling development (**Figure 7**). The third envirogram (blue) focuses on malentities (**Figure 8**). Malentities (the term used by Andrewartha and Birch (1984) for "negative perturbations") include

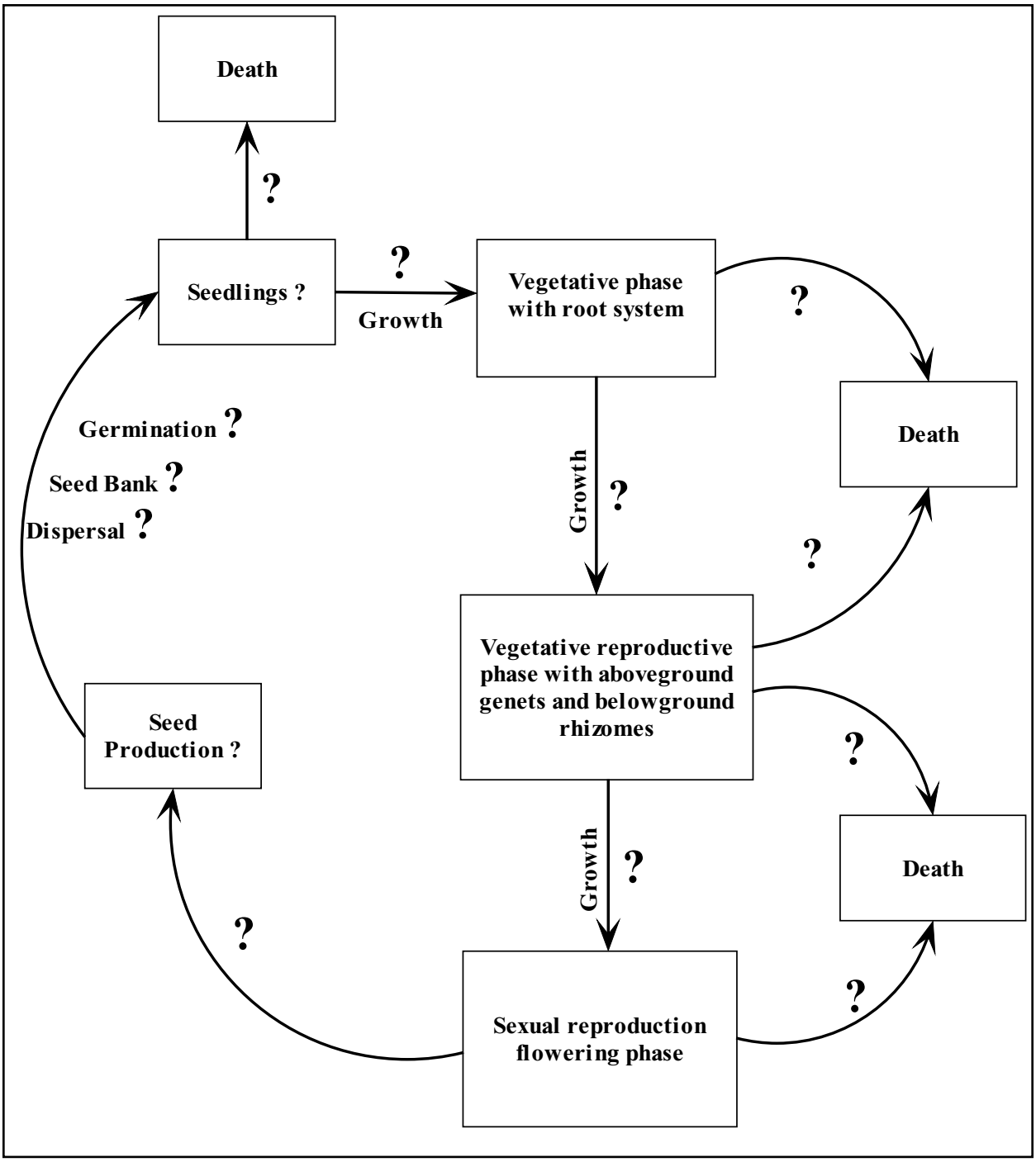

Figure 5. Generalized, simple life cycle diagram for *Carex*, a diagram that may also apply to *C. alopecoidea* Tuckerman. Question marks indicate uncertainties during a particular stage or the lack of information specific to *C. alopecoidea*.

such things as adverse human influences to a habitat, adverse weather, and atypical levels of herbivory. The construction of these web diagrams is a means to examine the entire range of environmental components associated with a plant species and to identify environmental components that are in need of research.

The resources centrum (**Figure 6**) for *Carex alopecoidea* is made up of three proximal factors: hydrology, light, and nutrients. Hydrology is affected by precipitation, soil porosity (permeability), soil water retention, and runoff. All of these are in turn affected by weather patterns, geology, and the addition of

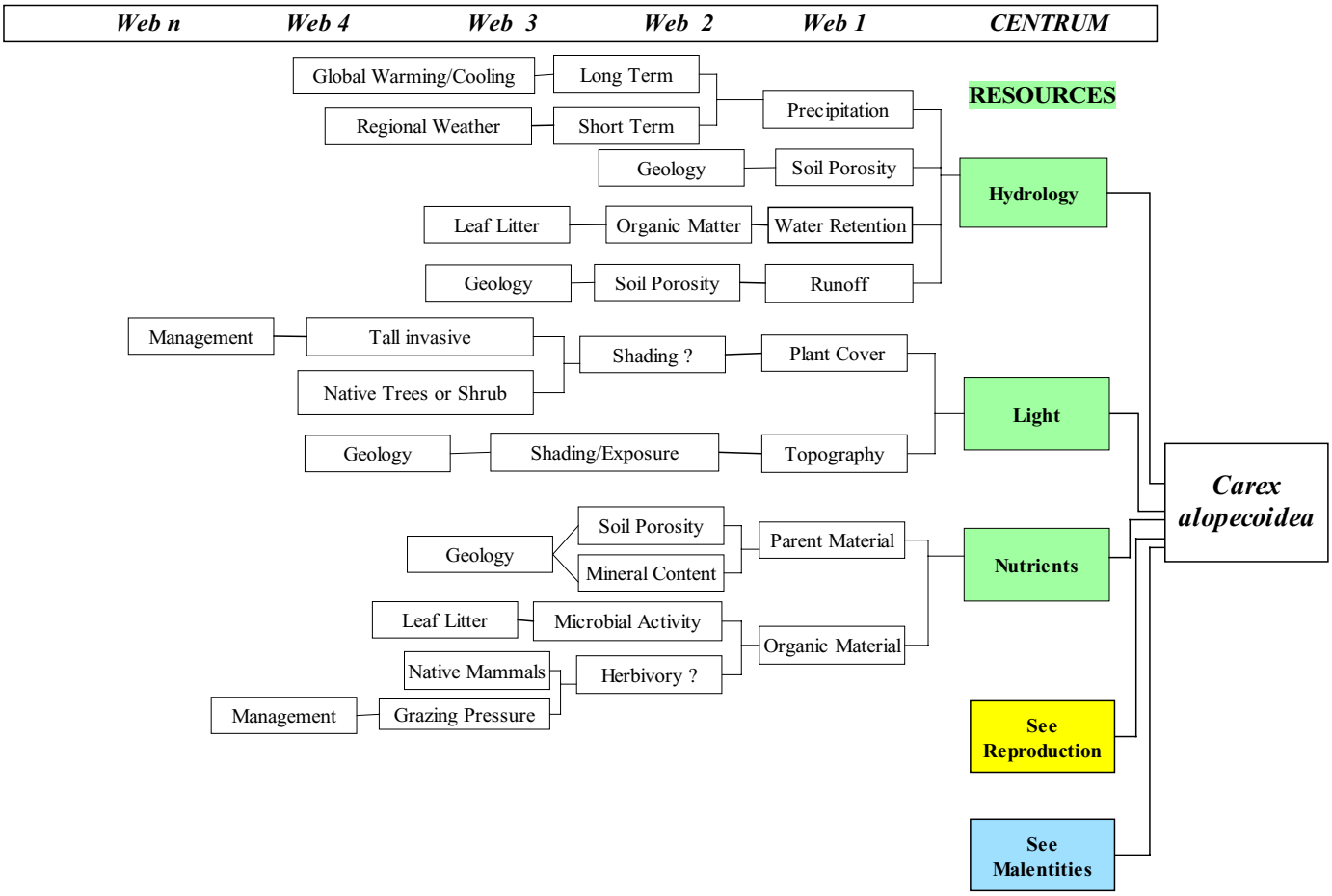

Figure 6. Envirogram for *Carex alopecoidea*, Resources centrum.

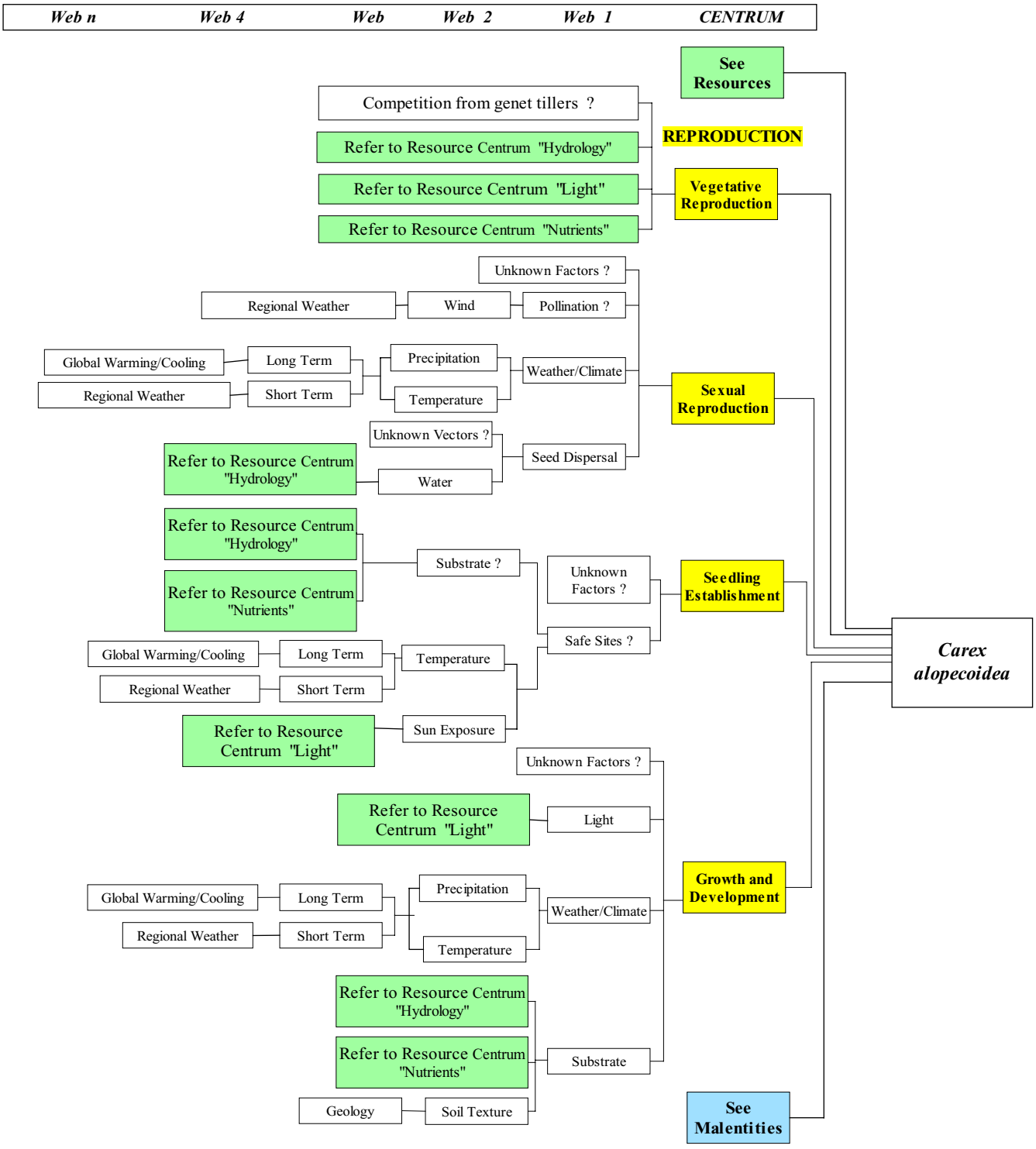

Figure 7. Envirogram for *Carex alopecoidea*, Reproduction centrum.

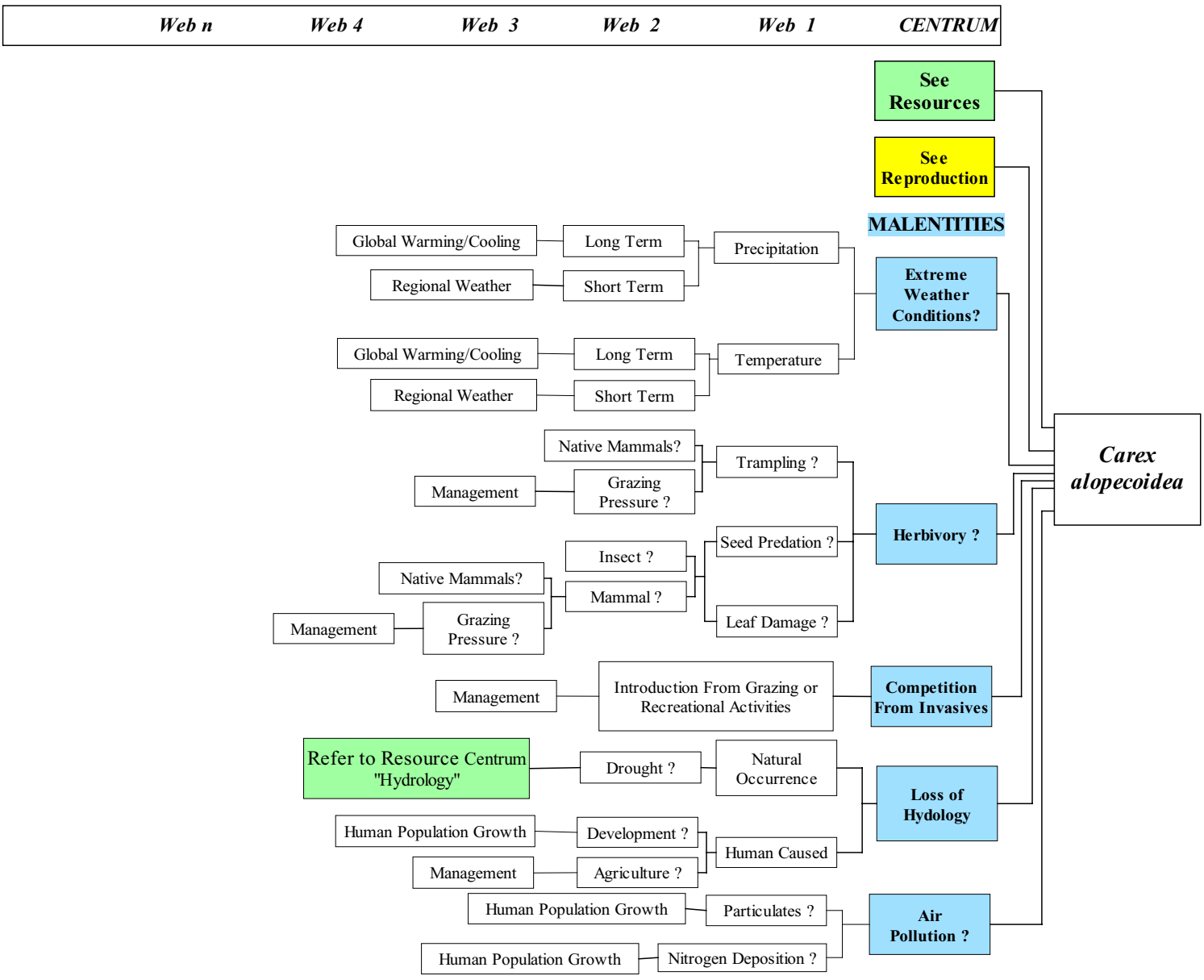

Figure 8. Envirogram for *Carex alopecoidea*, Malentities centrum.

organic matter in the substrate. Light can be affected by vegetation cover or topography, such as exposure, which is determined by the geologic structure of the area. Vegetation cover may also affect light through shading by native species such as trees or shrubs or from tall invasive species, which may shade individual clumps of *C. alopecoidea*. Nutrients may be affected by such things as substrate parent material and the addition of organic materials. If the health of the riparian habitats where this sedge occurs is maintained, water is not likely to be a limiting resource. Although water is the key to defining the habitat of *C. alopecoidea*, the many similar riparian areas without this sedge indicate that other factors, such as temperature regime and soil conditions, are also likely to be important in determining its survival.

The reproductive centrum (**Figure 7**) for *Carex alopecoidea* includes vegetative reproduction, sexual reproduction (flowering and fruiting), seedling establishment, growth and development. Longevity and the frequency and extent of asexual reproduction appear to be key points in the long-term survival of this sedge. If longevity of a clone is great, there is less need for frequent sexual reproduction to occur. Factors that affect vegetative reproduction include competition from other genet tillers and abiotic resources such as soil moisture, light, and nutrients (see resources centrum). Sexual reproduction can be affected by several factors including wind pollination, weather/climate, or seed dispersal mechanisms.

The malentities centrum (**Figure 8**) identified for *Carex alopecoidea* includes extreme weather conditions, herbivory, competition from invasives, and loss of hydrology. The potential loss of soil water or a change in the hydrology of an area, perhaps due to a drought or the development of roads or trails, represents a malentity for *C. alopecoidea*. A severe drought may adversely impact *C. alopecoidea* and its habitat. These malentities also interact, such as when a drought affects seed production. Grazing may impact individuals through trampling, seed loss, and leaf damage. Grazing animals or recreational use may introduce aggressive exotic plants, and these exotics could in turn impact *C. alopecoidea* populations through competition and/or shading. Herbivory, either through native mammals or livestock, may affect occurrences. Air pollution, including nitrogen deposition, particulate matter, and the development of greenhouse gases, may also negatively affect *C. alopecoidea* habitat. There may be possible impacts to this sedge associated with global warming. If the Earth were to warm, the sedge may require a corridor to higher elevations as habitat conditions change. Such a scenario would also require successful establishment into new areas by either asexual or sexual means.

CONSERVATION

Threats

Threats to *Carex alopecoidea* are based on observation during monitoring (USDA Forest Service 2004), information recorded on EOR forms, and potential threats to montane riparian habitats. The loss of occurrences or alteration of the hydrology of the riparian habitats where they occur composes the main viability concern for this taxon. Possible threats identified in monitoring data include impacts from grazing by cattle and other large herbivores, presence of invasive species, and proximity of occurrences to private land. No threats associated with occurrences in proximity to private lands were specifically mentioned in the monitoring reports; however increased recreational traffic and possibility of encroachment of invasive species are likely.

Most montane riparian areas are subject to a range of general threats that often occur in these habitats; these include surface mining, impacts from recreational use such as trampling or soil disturbance from hikers, road building, four-wheel drive and off-road vehicle use, and fire. No surface mining, recreational, or road construction impacts were identified during monitoring, but impacts should be considered if these uses are present in proximity to occurrences. Other threats that may affect *Carex alopecoidea* include environmental factors such as global warming and nitrogen deposition. The following is a discussion of specific threats in order of likely impact to *C. alopecoidea*.

Altered hydrology

As stated throughout the document, the primary habitat for *Carex alopecoidea* throughout its range is riparian wetlands. These riparian habitats are variable, ranging from perennial flowing streams to above the saturated edge of the water line. The hydrology of the wetland communities where *C. alopecoidea* occurs, including depth to groundwater, duration, and seasonality of inundations, has not been fully evaluated.

Natural and anthropogenic disturbances to the watershed can cause changes in hydrologic regime that can negatively affect wetlands. For instance, logging, fire, and roads can cause increases in overland flow during rainstorms, which will have the net effect of

maximizing runoff and minimizing infiltration. While the increased runoff results in overall greater water yield, the stormwater is delivered relatively quickly through surface processes rather than through sustained subsurface flows, which are often critical to wetland hydrology. In addition to the direct effects of grazing discussed below, herbivory in and around wetlands can cause increased erosion, which can modify streambank geometry and cause an increase in overland flow (Dunne and Leopold 1978).

Grazing

All known sites on the Black Hills National Forest are grazed by cattle to some extent, but any impacts to *Carex alopecoidea* as a result of cattle grazing are uncertain. There are no data to quantify the intensity or timing of grazing at occurrences, but EORs and monitoring observations noted either heavy, light, or, some grazing. Cattle grazing may impact individuals through trampling, matting, trailing, seed loss, and leaf damage (Hoffman and Alexander 1987, Milchunas 2006). Herbivory by native mammals may also affect occurrences.

Comments noted in Plant Species of Interest Monitoring Forms (USDA Forest Service 2004) filled out for occurrences observed in 2002 and 2003 on the Black Hills National Forest included observations of trampling, matting from cattle bedding adjacent to riparian areas, presence of cattle trails, and some elk bedding. The Phase II Amendment to the Black Hills National Forest Land and Resource Management Plan: Standard 2505 (f) states: "Implement additional measures to assure avoidance of livestock use on *Carex alopecoidea*. Restrict livestock use of all or portions of 5 of the largest geographically spaced occurrences at site numbers: CAAL8-19, CAAL8-20, CAAL8-22, CAAL8-30, CAAL8-31" (USDA Forest Service 2004). Results of monitoring at these sites could provide valuable information to determine the extent of impacts from grazing.

Invasive species

Noxious weed infestations have been commonly found in riparian systems on the Black Hills National Forest due to the high level of activity that occurs within those sites and the high potential for weed seed transportation. Many noxious weeds are adapted to riparian areas and are quick to establish on sites where soil disturbance has occurred such as stream banks, blown-out beaver dams, livestock and wildlife bedding areas, and undeveloped recreation trails. Canada thistle is one of the most common weeds found in riparian areas within the analysis area (USDA Forest Service 2002).

Observations by Black Hills National Forest botanists indicate that invasive plant species occur in proximity to *Carex alopecoidea* occurrences (see Community Ecology section). Wetland invasive species can form monotypes, which can alter habitat structure, lower biodiversity, change nutrient cycling and productivity, and modify food webs (Zedler and Kircher 2004).

Fire

Little knowledge is available to determine the degree of threat posed by natural or prescribed fire. Since occurrences are located in wetland areas with minimal tree and shrub cover, there appears to be only a slight chance that a natural or prescribed fire would directly impact *Carex alopecoidea* or its habitat. The wetland habitat itself provides some degree of fire protection, at least for the roots and rhizomes of wetland plants (Cope 1992). However, as noted in the altered hydrology section, fires in upland areas have the potential to increase erosion.

Global warming and nitrogen deposition

Other potential threats to the species include global warming (including extreme weather condition shifts) and nitrogen deposition (derived from air pollution). Both of these threats have the potential to persist over a longer-term period.

Global warming has been identified as a potential threat to both forested and non-forested communities. In Wyoming, potential impacts to forested communities as a result of global warming include alteration of species composition, geographic range, health, and productivity (U.S. Environmental Protection Agency 1998). Global warming could cause severe drought or other modification of climate regimes, affecting survivorship or ability to reproduce. Unusually cold springs may delay reproduction and seed set.

Soils and vegetation in the Black Hills may be sensitive to nutrient enrichment from nitrogen deposition. In some parts of the country, nitrogen deposition has altered soil nutrient cycling and vegetation species composition; native plants that have evolved under nitrogen-poor conditions have been replaced by invasive species that are able to take advantage of increased nitrogen levels (National Park

Service 2006). Possible effects of nitrogen deposition on a terrestrial ecosystem include premature abscission of pine needles, alteration of mycorrhizal fungi, loss of lichen communities, enhancement of non-native species invasions, and alteration of fire cycles by increasing fuel loads (Fenn et al. 2003).

Conservation Status of Carex alopecoidea in Region 2

Carex alopecoidea occurrences on National Forest System lands in Region 2 are on the western periphery of the species' range. Since this species is possibly extirpated at two marginal locations elsewhere in its North American range (Maine and Tennessee) and presumed extirpated in the District of Columbia, monitoring of the Black Hills occurrences, another marginal range location, should be a priority. A conservative and unverified total number of plants occurring throughout Region 2 is approximately 5000 individuals. Of four locations on the Black Hills National Forest, only one showed a decrease in numbers from 2003 and 2004. However, this data should be viewed with caution since the subpopulations may not have been counted consistently both years (e.g., the boundary of the area of census was inexact, and no vegetative individuals were counted). Due to the minimal monitoring data, no inferences can be made concerning the temporal pattern of abundance at any spatial extent. Recent surveys on the Black Hills National Forest have identified 17 new subpopulations for this sedge (Crook personal communication 2005). Additional occurrences may exist elsewhere on the Black Hills National Forest within Region 2.

Knowledge concerning optimal habitat quality and ecology of *Carex alopecoidea* is limited. Hydrology and function of these habitats have not been investigated. As stated above in the Threats section, viability concerns are associated with the management of the wetland habitats in which the species occurs. All species occurrences on the Black Hills National Forest were associated with wetland habitat types. It is reasonable to suspect that *C. alopecoidea* could be easily affected by an alteration of hydrological regimes. No other information concerning the viability (seed production) of the occurrences is available. No accurate predictions about the ability of *C. alopecoidea* to survive abiotic or biotic perturbations can be made until more data are accumulated.

It is impossible to evaluate the effects of current management activities on *Carex alopecoidea* because detailed information concerning impacts from management activities in Region 2 is lacking.

Management of Carex alopecoidea in Region 2

Implications and potential conservation elements

Two occurrences of *Carex alopecoidea* on the Black Hills National Forest are located within designated botanical areas; one occurrence is in the Upper Sand Creek Botanical Area, and one is in the Dugout Gulch Botanical Area. A botanical area is to be managed in such a way that the drainage and the botanical features for which it was established are not impaired (USDA Forest Service 1997).

The Phase II Amendment to the Black Hills National Forest Land and Resource Management Plan provides specific livestock management conservation direction for known *Carex alopecoidea* sites (Standard 2505 (f); USDA Forest Service 2004). Results of monitoring at occurrence sites could provide valuable information to determine the extent of impacts from grazing.

No other specific management or conservation plan is in place for protection of this species on National Forest System lands. No other federal protected areas have been designated that include the conservation of this species or its habitat as an explicit goal.

Management activities may have direct or indirect impacts to individuals or populations of *Carex alopecoidea*. No experimental data are available on the response of this species to historic, ongoing, or proposed management actions. Activities potentially occurring on National Forest System lands that may pose a threat to individuals or populations of *C. alopecoidea* include grazing, competition from invasive species, and fire. Although currently not a threat, if recreation use, road building, or off-road vehicle use should occur within proximity of an occurrence, the risk they present to the species or its habitat should be evaluated. The consequences of management actions may include habitat fragmentation, soil compaction, erosion or siltation, lowering of the water table, trampling of individuals, or loss of fitness or niche.

Knowledge concerning the optimal habitat quality and ecology of *Carex alopecoidea* is limited.

Hydrology and function of these habitats have not been investigated. Occurrences in Region 2 are vulnerable to changes to hydrologic regime. Maintenance of existing hydrology for *C. alopecoidea* and its habitat within Region 2 will benefit the species.

Minimal information is available regarding factors limiting the growth of *Carex alopecoidea* to determine conservation elements. To improve management of *C. alopecoidea*, additional research is needed. Priorities for research include:

- Monitor existing occurrences and inventory for additional occurrences; land use history and current management practices are important data to be recorded for each occurrence.
- Investigate the hydrology where the species occurs.
- Investigate the species' response to disturbance.
- Determine threats to the species' persistence.
- Develop and implement a monitoring program to identify population trends.
- Investigate the habitat requirements of this species and its interactions with the surrounding plant community.

Tools and practices

Continued monitoring efforts at known locations and searching potential habitat for new occurrences would provide additional information concerning the distribution and abundance of *Carex alopecoidea*. The potential for new occurrences in similar habitats in other drainages is high (Crook 2001, Crook personal communication 2005). Areas with the highest potential for new occurrences include areas with beaver dams and low gradient perennial streams ranging in elevation from 1,370 to 1,970 m (4,500 to 6,500 ft.). Infrared and color aerial photography used in conjunction with topographic maps would help managers to identify potential survey areas. These potential survey areas can be verified by local botanists and USFS personnel that are familiar with the area.

Surveys for *Carex alopecoidea* should be conducted in July, August, or September, when the plant is flowering and fruiting. Surveyors should be able to recognize the key characters of this sedge and should search all appropriate riparian plant communities, including wetlands near beaver dams. Field training is necessary to standardize among survey crew members how to best count vegetative reproduction (increase in ramets), as well as look for new plants (genets).

The Black Hills National Forest has been monitoring five occurrences of *Carex alopecoidea* since 2003. The 2005 monitoring protocol (USDA Forest Service 2005b) involves assessing the status of these five core occurrences and address three questions:

1) Is the species present?
2) Is there evidence of contraction or expansion of occurrences?
3) Have invasive plant species invaded the site?

Methodology utilized from 2003 to 2005 includes the following:

- annually count individuals at five occurrence locations and record baseline data at a fifth site.
- conduct quick reconnaissance surveys for *Carex alopecoidea* in similar habitat on the Bearlodge and Northern Hills Ranger Districts; if new sites are found, gather GPS data to pinpoint the locations.
- document any weeds designated as noxious by South Dakota or Wyoming; document if the weeds are co-located with *Carex alopecoidea*, or at what distance the weed species is located away from the occurrence site if they are occupying the same ecological site.

Additional data currently being collected by the Black Hills National Forest include current use of site; habitat characteristics including light, topographic position, moisture, slope, and slope shape; and associated species. Guidelines for the 2006 monitoring of *Carex alopecoidea* are currently being developed (Burkhart personal communication 2006).

Monitoring of soil moisture, water temperature, and pH could provide important information for managers in addition to the data currently being collected. The use of permanent photo plots could provide valuable information to evaluate change

over time of a small population segment (specifically vegetative reproduction [increase in ramets] and identify for new plants [genets]). Techniques for photo monitoring are described in Elzinga et al. (1998) and Hall (2001).

Additional quantitative data that document the condition of the community where *Carex alopecoidea* occurs, such as plant composition, structure, and function, would provide useful information. Although expensive to obtain, such data could be used to infer if existing conditions are resulting in an increase or a decline in *C. alopecoidea* population sizes. This information may also provide "clues" as to possible limiting factors controlling the distribution of the species. Common variables to be measured include cover or density of associated plant species, demographic parameters of important species, soil surface conditions (including rock), and microhabitat observations including slope, aspect, and geologic substrate. Soil temperature information may provide valuable insight to seed germination requirements and possible safe sites. Periodic measurement in the same areas would provide a long-term ecological database (possible academic research) that could document the rates and types of changes that can occur in response to natural processes such as succession and disturbance (Elzinga et al. 1998). Measurement of hydrology sources, such as depth to groundwater, duration and seasonality of inundation, would provide information concerning parameters that sustain *C. alopecoidea* populations.

The mission of the Center for Plant Conservation is to conserve and restore the rare native plants of the United States. No plant material of *Carex alopecoidea* has been stored with the Center for Plant Conservation or participating institutions.

Information Needs

Current knowledge of *Carex alopecoidea* in Region 2 is limited, but it is expanding based on data collected by the Black Hills National Forest since 2003. Extensive localized efforts to identify new occurrences on the Black Hills National Forest. Four new EORs were identified in the northwestern Black Hills and the Bearlodge Mountains (including 15 additional observations). Similar reconnaissance project specific surveys conducted in 2003 resulted in discovery and reporting of two additional EORs (USFS 2004). Continued survey efforts to identify other occurrences will provide additional information concerning the distribution and abundance of the species and should assist in the formulation of disciplined conservation strategies for Region 2.

Recommendations for further study include (in order of greater to lesser priority):

- initiate intensive field surveys to not only find new occurrences but also to relocate and monitor known locations; this inventory would include herbarium searches for misidentified specimens that may increase the number of occurrences.

- quantify the hydrological situation (e.g., rainfall, depth to water, stream-flow amounts, soil saturation) of several key occurrence areas and attempt to correlate this information with other monitoring data.

- continue to document and monitor the impacts of grazing and exotic weed encroachment on several of the larger *Carex alopecoidea* occurrences.

- monitor populations over the long term with the goal of determining population trends in this marginal part of its range.

- initiate basic research on demographic questions (i.e., vital rates, recruitment, survival, reproductive age, lifespan, proportion of populations reproducing, seed viability, seed bank dynamics, longevity) through population viability studies.

DEFINITIONS

Achene: The most generalized type of dry, indehiscent fruit, lacking the specialized features which mark a caryopsis, nut, samara, or utricle (Cronquist et al. 1994).

Acuminate: Gradually and concavely tapering to a narrow tip or sharp point (Cronquist et al. 1994).

Androgynous spike: A spike with both staminate and pistillate flowers, the staminate above the pistillate (Cronquist et al. 1994).

Bract: A specialized leaf, from the axil of which a flower or flower stalk arises; more loosely, any more or less reduced or modified leaf associated with a flower or an inflorescence, but not a part of the flower itself (Cronquist et al. 1994).

Caespitose: Growing in dense, low tufts (Cronquist et al. 1994).

Cuspidate: Tipped with an abrupt, sharp, often rigid point (Cronquist et al. 1994).

Dioecious: Producing male and female flowers (or other reproductive structures) on separate individuals (Cronquist et al. 1994).

Genet: A genet is defined as a plant part from a single zygote that can itself propagate (Harper and White 1974)

Gynaecandrous spike: A spike with both staminate and pistillate flowers, the staminate below the pistillate (Cronquist et al. 1994).

Inflorescence: A flower cluster of a plant, or, more correctly, the arrangement of the flowers on the axis (Cronquist et al. 1994).

Lanceolate: Lance-shaped; as used in American botanical literature, much longer than wide, widest below the middle, and tapering to both ends (or rounded to the base); like ovate, but narrower (Cronquist et al. 1994).

Longevity: The average life span of the individuals of a population under a given set of conditions (Lincoln et al. 1982).

Monoecious: With unisexual flowers, both types borne on the same individual (Cronquist et al. 1994).

Perigynium: A special bract which encloses the achene of *Carex* (Cronquist et al. 1994).

Rhizome: A creeping underground stem (Cronquist et al. 1994).

Scale: Any small, thin or flat structure (Cronquist et al. 1994).

Serrulate: Diminutive of serrate (toothed along the margin with sharp, forward-pointing teeth) (Cronquist et al. 1994).

Setaceous: Bristle-like (Cronquist et al. 1994).

Sheath: An organ which partly or wholly surrounds another organ, as the sheath of a grass leaf, which surrounds the stem (Cronquist et al. 1994).

Spicate: Arranged in a spike (Cronquist et al. 1994).

Spike: A more or less elongate inflorescence of the racemose (indeterminate) type, with sessile or subsessile flowers (Cronquist et al. 1994).

Vesicular-arbuscular mychorrizae: The term applied to the combination between a plant and its symbiont.

Vital rates: The class-specific annual rates of survival, growth, and fecundity (Morris et al. 1999).

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