Sisyrinchium pallidum Cholewa & Henderson (pale blue-eyed grass): A Technical Conservation Assessment

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Lynn Moore[1] and Sandy Friedley[2]
[1]Windom Floristics
361 South Camino Del Rio #222
Durango, CO 81303
[2]Ecosphere Environmental Services
2257 Main Avenue
Durango, CO 81301

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AUTHORS' BIOGRAPHIES

Lynn Moore Botanist/Owner Windom Floristics — Lynn graduated from Fort Lewis College with a Bachelor of Science in Biology (1992) and continued her graduate work at the University of Wyoming, where she finished a Masters of Science degree in Botany (1998). Lynn has worked in the private sector independently contracting services in the Four Corners area since 1997. She has experience in threatened and endangered species surveys, noxious weed surveys, environmental assessments, wetland delineations, and floristic surveys. Lynn is currently working on the treatments of three families, the Geraniaceae, Fumariaceae, and the Papervaceae, for the Flora of the San Juan Basin project. She actively researches the flora of the San Juan Mountains and adjacent areas through funding provided by small grants for floristic studies.

Sandy Friedley Botanist/Ecosphere Environmental Services — Sandy graduated from the University of Colorado with Bachelor of Arts in Environmental Biology in 1975 and continued here graduate work at Western State College, where she received a Master of Arts degree in Environmental Biology in 1983. She worked for the San Juan National Forest in the evaluation and transfer of vegetation cover and management data into GIS/ARC-INFO coverages. She also assisted in the development of an identification guide for sensitive plant species for the San Juan National Forest, including researching plant distribution and habitat descriptors. Sandy has worked with Ecosphere since 1999, as a field coordinator and assistant project manager for environmental consulting services in areas of due diligence environmental site assessments, NEPA, biological assessments, wetlands delineations, storm water management, and regulatory compliance and permitting.

COVER PHOTO CREDIT

Sisyrinchium pallidum (pale blue-eyed grass). Photograph by Bill Jennings. Used with his permission.

SUMMARY OF KEY COMPONENTS FOR CONSERVATION OF *SISYRINCHIUM PALLIDUM*

Status

Sisyrinchium pallidum (pale blue-eyed grass) is considered a regional endemic of central Colorado and southeastern Wyoming. The global heritage status rank established by NatureServe for the species is G2G3 (between imperiled globally because of rarity [6 to 20 occurrences] and vulnerable throughout its range), and the national heritage status rank established by NatureServe is N2N3 (between imperiled and vulnerable to extirpation or extinction). In Colorado, *S. pallidum* is ranked S2 (imperiled in the state because of rarity [6 to 20 occurrences] or because of other factors demonstrably making it very vulnerable to extirpation from the state). In Wyoming, *S. pallidum* is ranked S2S3 (between imperiled and vulnerable in state because of rarity [6 to 100 occurrences] or because of other factors demonstrably making it very vulnerable to extirpation from the state).

There are 66 known occurrences of *Sisyrinchium pallidum* in USDA Forest Service Region 2. Based on the available Colorado Natural Heritage Program and Wyoming Natural Diversity Database element occurrence record data, it is estimated that 9,500 to 11,500 individuals are located in Colorado, and approximately 233,000 to 354,000 are located in Wyoming. Total rangewide abundance for *Sisyrinchium pallidum* is conservatively estimated to be approximately 200,000 to 350,000 individuals. This estimate may be over or under the actual population number by tens of thousands.

No federally protected areas that include the conservation of this species or its habitat as an explicit goal have been designated. *Sisyrinchium pallidum* has documented occurrences on lands managed for multiple uses on two national forests in Colorado: the Pike-San Isabel National Forest (three occurrences) and the Routt National Forest (one occurrence). There is one documented occurrence in Rocky Mountain National Park in Colorado and two occurrences on the Mortenson Lake National Wildlife Refuge in Wyoming. Five occurrences of *S. pallidum* are found on Bureau of Land Management land in Wyoming; ten occurrences are on lands managed by the State of Colorado, and four are on lands managed by the State of Wyoming. One occurrence is located in the High Creek Fen Preserve, a 2400-acre wetlands area south of Fairplay, Colorado, managed by The Nature Conservancy since 1991. The majority of the occurrences (forty) are located on private lands in both states.

Primary Threats

Sisyrinchium pallidum is vulnerable based on its limited global distribution and the fragility of the wetland habitats in which it occurs. Current and potential threats include road improvement, changes in irrigation practices, residential development, cattle grazing, peat mining, and recreational activities. Activities that drain wetlands (including ditching and water diversion projects) may threaten the species' habitat. Existing laws, regulations, and enforcement of the same do not adequately protect occurrences located on private or public lands. No specific management or conservation plan is in place for protection of this species on National Forest System lands.

Primary Conservation Elements, Management Implications, and Considerations

Sisyrinchium pallidum is a species of wetlands, fens, riparian corridors, and meadows. It generally occurs in areas with soils that are saturated throughout the growing season and typically inundated in the spring. Based upon the limited data available, this species appears to be viable in Region 2. Due to its habitat specificity, preservation of the wetland habitat in which this species occurs is a primary conservation element. A priority for research is to determine the health of the wetland habitat including hydrology, pH, function of the wetland habitat, and associated wetland species. Other tools for conservation include surveying for new occurrences; gathering current and accurate population census information on known occurrences; evaluating reproductive and ecological characteristics (e.g., pollination mechanisms, seed germination, seedling establishment, herbivory, flowering/fruiting, dispersal vectors); gathering information on demographics (e.g., life history stages, population structure, longevity, mortality); and determining impacts to population viability from management activities and natural disturbances.

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INTRODUCTION

This assessment is one of many being produced to support the Species Conservation Project for the Rocky Mountain Region (Region 2) of the USDA Forest Service (USFS). *Sisyrinchium pallidum* (pale blue-eyed grass) is the focus of an assessment because it is a species whose population viability is identified as a concern based on its limited global distribution. In order to assess the need for special management, knowledge of its biology and ecology is critical. This assessment addresses the biology of *Sisyrinchium pallidum* 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, conservation status, and management of certain species based on available scientific knowledge. The assessment goals limit the scope of the work to critical summaries of scientific knowledge, discussion of broad implications of that knowledge, and outlines of information needs. The assessment does not seek to develop specific management recommendations. Rather, it provides the ecological background upon which management must be based and focuses on the consequences of changes in the environment that result from management (i.e., management implications). Furthermore, this assessment cites management recommendations proposed elsewhere, and when these have been implemented, the assessment examines their success.

Scope

This assessment examines the biology, ecology, conservation status, and management of *Sisyrinchium pallidum* with specific reference to the geographic and ecological characteristics of the USFS Rocky Mountain Region. Similarly, this assessment is concerned with reproductive behavior, population dynamics, and other characteristics of *S. pallidum* in the context of the current environment. The evolutionary environment of the species is considered in conducting the synthesis, but placed in a current context.

In producing this assessment, the authors reviewed refereed literature, non-refereed publications, research reports, and data accumulated by resource management agencies. Requests were made from various agencies and individuals with expertise of the habitat or species; not all of the individuals responded to the request for information. The assessment emphasizes refereed literature because this is the accepted standard in science. There are a limited number of refereed publications available specific to *Sisyrinchium pallidum*. Cholewa and Henderson's (Cholewa and Henderson 1984, 2002) work on the genus *Sisyrinchium* was valuable in the preparation of this report. Some non-refereed literature is utilized in the assessments when information was unavailable elsewhere. Non-refereed publications include state natural heritage program reports and element occurrence records as well as status reports prepared for the U.S. Fish and Wildlife Service and The Nature Conservancy. Non-refereed publications and reports were regarded with greater skepticism. Unpublished data (e.g. state natural heritage program records) were important in estimating the geographic distribution and abundance. These data required special attention because of the diversity of persons and methods used in their collection. Data for this species assessment were obtained by secondary sources through state natural heritage programs including the Wyoming Natural Diversity Database (WYNDD), Colorado Natural Heritage Program (CNHP), herbarium specimen label data, scientific literature, and knowledgeable individuals. Fifty-three herbaria within Region 2 and surrounding states were contacted. Nine responded with pertinent data, including the Rocky Mountain Herbarium (RM, Laramie, WY), Stanley L. Welsh Herbarium (BRY, Provo, UT), Carter Herbarium (COCO, Colorado Springs, CO), University of Montana (MONTU, Missoula, MT), Kathryn Kalmbach Herbarium (KHD, Denver, CO), Chadron State College Herbarium (CSCN, Chadron, NB), R.L. McGregor Herbarium (KANU, Lawrence, KS), San Juan College Herbarium (SJNM, Farmington, NM), and University of Colorado Museum (COLO, Boulder, CO). Literature of closely related taxa was reviewed and inferences were drawn where reasonable and when a basis could be established for application to *S. pallidum*. The authors of this assessment present no empirical data.

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 our observations are limited, science focuses on approaches for dealing with uncertainty. A commonly accepted approach to

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

Publication of Assessment on the World Wide Web

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

Peer Review

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

MANAGEMENT STATUS AND NATURAL HISTORY

Management Status

Sisyrinchium pallidum is not designated a sensitive species on USFS lands in Region 2. It is listed as a Special Status Species on both the Colorado and Wyoming BLM State Director's Sensitive Species lists. The global heritage status rank established by NatureServe for the species is G2G3 (between imperiled globally because of rarity [6 to 20 occurrences] and vulnerable throughout its range), and the national heritage status rank established by NatureServe is N2N3 (between imperiled and vulnerable to extirpation or extinction). In Colorado, *S. pallidum* is ranked S2 (imperiled in state because of rarity [6 to 20 occurrences] or because of other factors demonstrably making it very vulnerable to extirpation from the state). In Wyoming, *S. pallidum* is ranked S2S3 (between imperiled and vulnerable in state because of rarity [6 to 100 occurrences] or because of other factors demonstrably making it very vulnerable to extirpation from the state).

Existing Regulatory Mechanisms, Management Plans, and Conservation Strategies

There are 66 known occurrences of *Sisyrinchium pallidum* in Region 2. It has documented occurrences on lands managed for multiple uses on two national forests in Colorado: the Pike-San Isabel National Forest (three occurrences) and the Routt National Forest (one occurrence). There is one documented occurrence in Rocky Mountain National Park in Colorado and two occurrences on the Mortenson Lake National Wildlife Refuge in Wyoming. Five occurrences of *S. pallidum* are also found on Bureau of Land Management (BLM) land in Wyoming; ten occurrences are on lands managed by the State of Colorado, and four are on lands managed by the State of Wyoming. One occurrence is located in the High Creek Fen Preserve, a 2,400-acre wetlands area south of Fairplay, Colorado that has been managed by The Nature Conservancy since 1991. The remaining 40 occurrences are located on private lands in Colorado and Wyoming.

No specific management or conservation plans are in place for protection of this species on National Forest System lands, where management is currently according to the standards and guidelines of the Pike-San Isabel National Forest, Comanche and Cimarron National Grasslands Land and Resource Management Plan (U.S. Department of Agriculture 1984) as amended and the Routt National Forest Revised Land and Resource Management Plan (U.S. Department of Agriculture 1997). All occurrences located on USFS lands are in areas managed for multiple uses. Although *Sisyrinchium pallidum* is not considered a sensitive species on either forest in which it occurs, the National Forest Management Act requires the USFS to sustain habitats that support healthy populations of existing native and desired non-native plant and animal species on the national forests and grasslands. Project-specific National Environmental Policy Act compliance does not require evaluation of project alternatives with respect to *S. pallidum* occurrences; however, compliance with the Clean Water Act would provide protection for the riparian habitats in which it occurs.

BLM Manual 6840 establishes Special Status Species policy for plant species and the habitats on which they depend. Management guidelines that apply to *Sisyrinchium pallidum* and all Special Status Species

on the BLM Wyoming Sensitive Species List are to avoid or minimize adverse impacts. Management on BLM lands is currently according to the Resource Management Plan for the Great Divide Resource Area (U.S. Bureau of Land Management 1998) and the Resource Management Plan for the Royal Gorge Resource Area (U.S. Bureau of Land Management 1996). All occurrences located on BLM lands are in areas managed for multiple uses. No specific management or conservation plan is in place for protection of this species on Colorado state lands or at the High Creek Fen managed by The Nature Conservancy.

Existing laws and regulations and management and enforcement of the same do not adequately protect occurrences located on private or public lands. As mentioned above, the species occurs in numerous locations on private land (40 occurrences in Colorado and Wyoming). Since 1991, The Nature Conservancy began acquiring land that now comprises High Creek Fen Preserve, a 2,400-acre wetlands area south of Fairplay, Colorado. Other populations on private lands remain unprotected and subject to landowner management, including grazing and irrigation administration.

Currently, the High Plains Partnership for Species at Risk (composed of public entities and private individuals, administered by the Western Governors Association) has joined to conserve the cultural and natural heritage of the High Plains from Montana to Texas, including *Sisyrinchium pallidum* and its habitat. Land acquisition through this program in conjunction with The Nature Conservancy may assist in preservation of the species.

Biology and Ecology

Systematics and general species descriptions

The genus *Sisyrinchium* belongs to the family Iridaceae, a group including showy ornamentals such as the bearded *Iris* and the early spring flowering species of *Crocus*. The Iridaceae family has a cosmopolitan distribution, consisting of approximately 60 genera and 1800 species worldwide (Goldblatt 1990). Native members of this family are relatively few in North America, represented by five genera in the United States (Zomlefer 1994). The genus *Sisyrinchium* consists of approximately 80 species in the New World, with the greater part of these located in Central and South America. There are reportedly 37 species present in North America, north of Mexico. There is one species in New Zealand and one in Great Britain (probably naturalized) (Cholewa and Henderson 2002). The focus of this assessment is a showy wetland plant of the Rocky Mountain west, *Sisyrinchium pallidum* Cholewa & Henderson.

The monocot family Iridaceae is considered monophyletic (Dahlgren et al. 1985, Goldblatt 1990, Souza-Chies et al. 1997). A combined molecular data set produced a phylogenetic tree where all subfamilies were resolved as monophyletic, except for the Nivenioideae (Reeves et al. 2001). *Sisyrinchium pallidum* is a member of the subfamily Iridoideae, assigned to the *Bermudiana* section of the *Sisyrinchieae* tribe. The combined data set produced similar monophyletic resolution for the *Sisyrinchieae* tribe (Reeves et al. 2001).

In the Rocky Mountain Region, this family is represented by three genera: *Iris*, *Olsynium* and *Sisyrinchium* (Cholewa and Henderson 2002). The most common members of the genus *Sisyrinchium* in the Rocky Mountain west are *S. montanum* Greene and *S. idahoense* var. *occidentale* Bicknell. Both of these species are known to co-occur with *S. pallidum*. *Sisyrinchium demissum* Greene occurs in the southwest with occurrences in Nevada, Arizona, New Mexico, Texas, Colorado, and Utah. A polyploidy race of *S. demissum* was found in northern Utah, discovered as previously misidentified *S. radicatum* E.P. Bicknell (Cholewa and Henderson 2002). *Sisyrinchium radicatum* is apparently restricted to the southwest corner of Utah and the southeast corner of Nevada. The authors did not find any evidence that *S. pallidum* occurs with *S. radicatum*. *Sisyrinchium pallidum* has not been reported to occur with *S. demissum* according to information on herbarium sheets or status reports concerning *S. pallidum*.

H.D. Harrington made the first definite collection of *Sisyrinchium pallidum* in 1959. Important characters for identification are not well preserved in this species; consequently unverified collections may have been made as early as 1913 and 1937 (Cholewa and Henderson 1984, Hartman 1992). It was not until 1984 that this species was formally described (Cholewa and Henderson 1984). **Table 1** summarizes the current classification of *S. pallidum*.

There are no synonyms associated with *Sisyrinchium pallidum*. Technical descriptions of *S. pallidum* are available in the 1984 biosystematics paper by Cholewa and Henderson (1984) and in the treatment of *Sisyrinchium* by Cholewa and Henderson in the Flora of North America (Cholewa and Henderson 2002). The following description is a synthesis of four sources of information: Cholewa and Henderson (1984,

Table 1. Classification of *Sisyrinchium pallidum*.

Sisyrinchium pallidum Cholewa & Henderson
Family: Iridaceae
Genus: *Sisyrinchium*
Species: *Sisyrinchium pallidum* Cholewa & Henderson
Synonyms: Cholewa, A.F. and D.M. Henderson. 1984. Biosystematics of *Sisyrinchium* section *Bermudiana* (Iridaceae) of the Rocky Mountains. Brittonia 36:342-363.
Synonyms: None
Vernacular Name: Pale blue-eyed grass
Type: United States, Colorado. Park Co.: Antero Reservoir, 16 km E of Antero Junction, 0.8 km from hwy 24 on headquarters road, 2,660 m elev., abundant in meadow along stream with *Pedicularis crenulata*, *Deschampsia cespitosa*, *Triglochin maritimum*, and *Juncus balticus*. 13 July 1979, *A.F. Cholewa 456* (Holotype: ID; ISOTYPES CAN, CS, MO, NY, RM) .

2002), Hartman (1992), and Fertig (2000). *Sisyrinchium pallidum* is a single-stemmed or tufted perennial herb, usually less than 30 cm tall. Leaves are smooth-margined, erect, and shorter and narrower than the stem. One to five flowers are borne in a terminal inflorescence subtended by two unequal, flattened, leaf-like bracts. The inner bract is often half as long as the outer bract and has a conspicuous membranous margin for its entire length. The petals and sepals are pale blue with a yellow base and 7.5 to 10 mm long. Fruits are brown capsules 3 to 5 mm long. **Figure 1** provides a photograph of *S. pallidum*, and **Figure 2** provides a representative line drawing of this species.

Sisyrinchium montanum and *S. idahoense* var. *occidentale* are known to co-occur with *S. pallidum*. As stated above, the authors did not find any evidence that *S. pallidum* occurs with *S. demissum*. However, *S. demissum* is documented in Colorado and could be confused with *S. pallidum*. *Sisyrinchium demissum* comes close to the range of *S. pallidum*, occurring in south-central Colorado, with one verified location in Weld County, Colorado (approximately 50 km from the closest population of *S. pallidum*). *Sisyrinchium demissum* can be distinguished from *S. pallidum* by its branching stems and dark blue flowers. *Sisyrinchium pallidum* has very pale blue flowers born on unbranched stems. The other two Colorado species, *S. montanum* and *S. idahoense* var. *occidentale*, also do not typically have branched stems. Nebraska populations of *S. montanum*, however, exhibit an unusually high proportion of branched stems. Due to the morphological

Figure 1. Photograph of *Sisyrinchium pallidum* (photograph by Bill Jennings 1999 — copyright by Bill Jennings and used with permission).

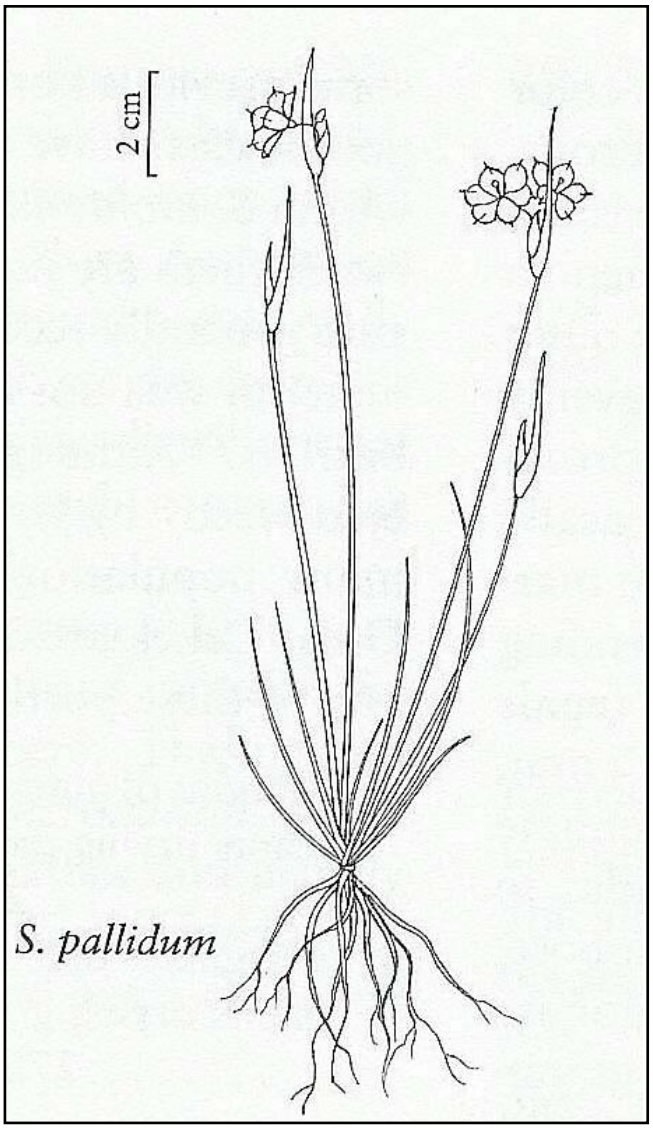

Figure 2. Representative line drawing of *Sisyrinchium pallidum* (Cholewa and Henderson 2002).

variation in Rocky Mountain members of *Sisyrinchium*, *S. montanum* and *S. idahoense* var. *occidentale* could be misidentified as *S. pallidum*. *Sisyrinchium montanum* has darker, blue-purple flowers, and the inner bracts lack the membranous margin found in *S. pallidum*. *Sisyrinchium idahoense* var. *occidentale* typically has shorter bracts than *S. pallidum* and dark blue flowers (Cholewa and Henderson 2002, Fertig 2000). Furthermore, the outer tepals of *S. pallidum* are slightly notched or rounded and may further enhance accurate identification. The best strategy for avoiding misidentifications in the field is to survey for individuals during the flowering season, June to July, when flower color is apparent.

Herbarium specimens can be difficult to identify if attention is not given to noting flower color before pressing or to arranging the spathes and flowers in such a way as to show the length of the bracts (Cholewa and Henderson 1984, 2002). Pressing plants in the field may help to preserve characters for later identification if care is taken in doing so. Other characters helpful in identification from dried specimens include length, width, and shape of apex of the corolla as well as awns, veins, and color. **Figure 3** shows comparative line drawings of *Sisyrinchium pallidum*, *S. montanum*, and *S. idahoense* var. *occidentale*. The outer bract of *S. pallidum* (**Figure 3A**) is typically 28 to 48 mm long. *Sisyrinchium idahoense* var. *occidentale* (**Figure 3B**) possesses a shorter outer bract that can measure up to 35 mm long, and *S. montanum* (**Figure 3C**) has the longest outer bract of the three species, measuring 36 to 76 mm long (Jennings 1990, Cholewa and Henderson 2002).

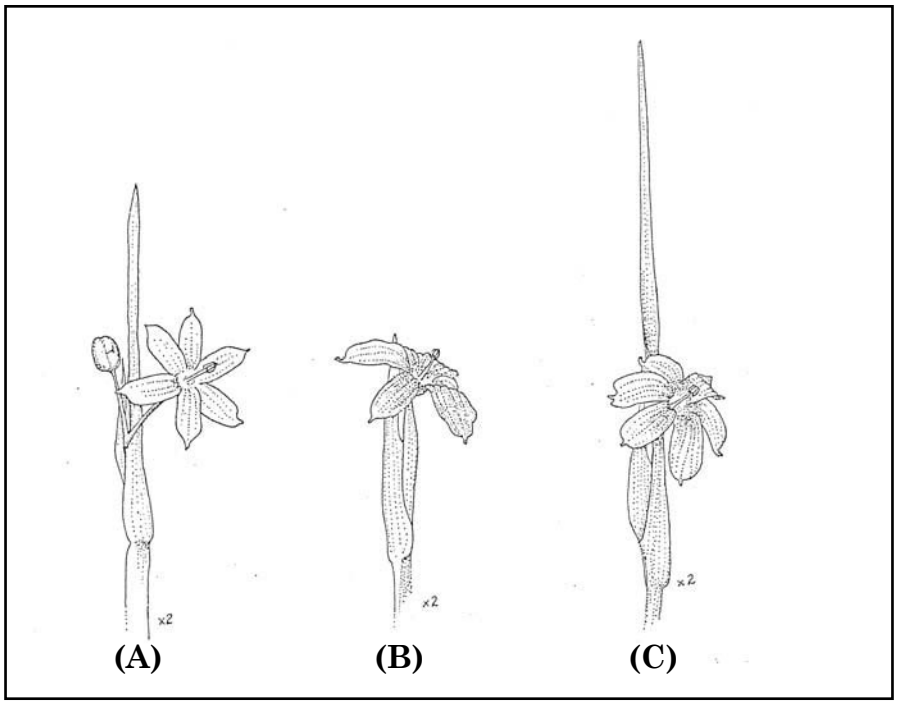

Figure 3. Comparative line drawings of *Sisyrinchium pallidum* (A), *Sisyrinchium idahoense* var. *occidentale* (B), and *Sisyrinchium montanum* (C) (Jennings 1990). Note the ratio of length of outer bract to inner bract. Drawing by Carolyn Crawford. Scale is 2x (copyright by Carolyn Crawford and used with permission).

Distribution and abundance

Historic and current global distribution of *Sisyrinchium pallidum* is restricted to the floristic region defined by Takhtajan (1986) as the Rocky Mountain Province of the Holarctic Kingdom. *Sisyrinchium pallidum* exhibits a discontinuous distribution, generally restricted to two geographic areas within Colorado and Wyoming. It is considered a regional endemic of central Colorado and southeast Wyoming. The majority of the known occurrences form two clusters of distribution. The two major groups of occurrences are approximately 250 km apart and are centered in the Laramie Basin, Albany County, Wyoming and in South Park, Park County, Colorado. Peripheral occurrences are located in suitable habitat radiating approximately 40 to 150 km away from the main population centers, documented in Carbon County, Wyoming and in Larimer, Chaffee, Saguache, and Jackson counties, Colorado. **Figure 4** shows the distribution of *S. pallidum* within the Pike-San Isabel National Forest and the Routt National Forest of USFS Region 2.

There are 66 known occurrences of *Sisyrinchium pallidum* in Region 2, 39 in Colorado (**Table 2**) and 27 in Wyoming (**Table 3**). *Sisyrinchium pallidum* has documented occurrences on a variety of land ownerships:

- Pike-San Isabel National Forest in Colorado (three occurrences)
- Routt National Forest in Colorado (one occurrence)
- Rocky Mountain National Park in Colorado (one occurrence)
- Mortenson Lake National Wildlife Refuge in Wyoming (two occurrences)
- Wyoming Bureau of Land Management (five occurrences)
- States of Colorado (ten occurrences) and Wyoming (four occurrences)
- The Nature Conservancy's High Creek Fen Preserve in Colorado (one occurrence)
- Private (24 occurrences in Colorado, 16 occurrences in Wyoming)

In Colorado, 15 of the 39 occurrences are on public land, and the remaining 24 occurrences are on private land. Land ownership information for 14 populations in Colorado is not available; it is assumed

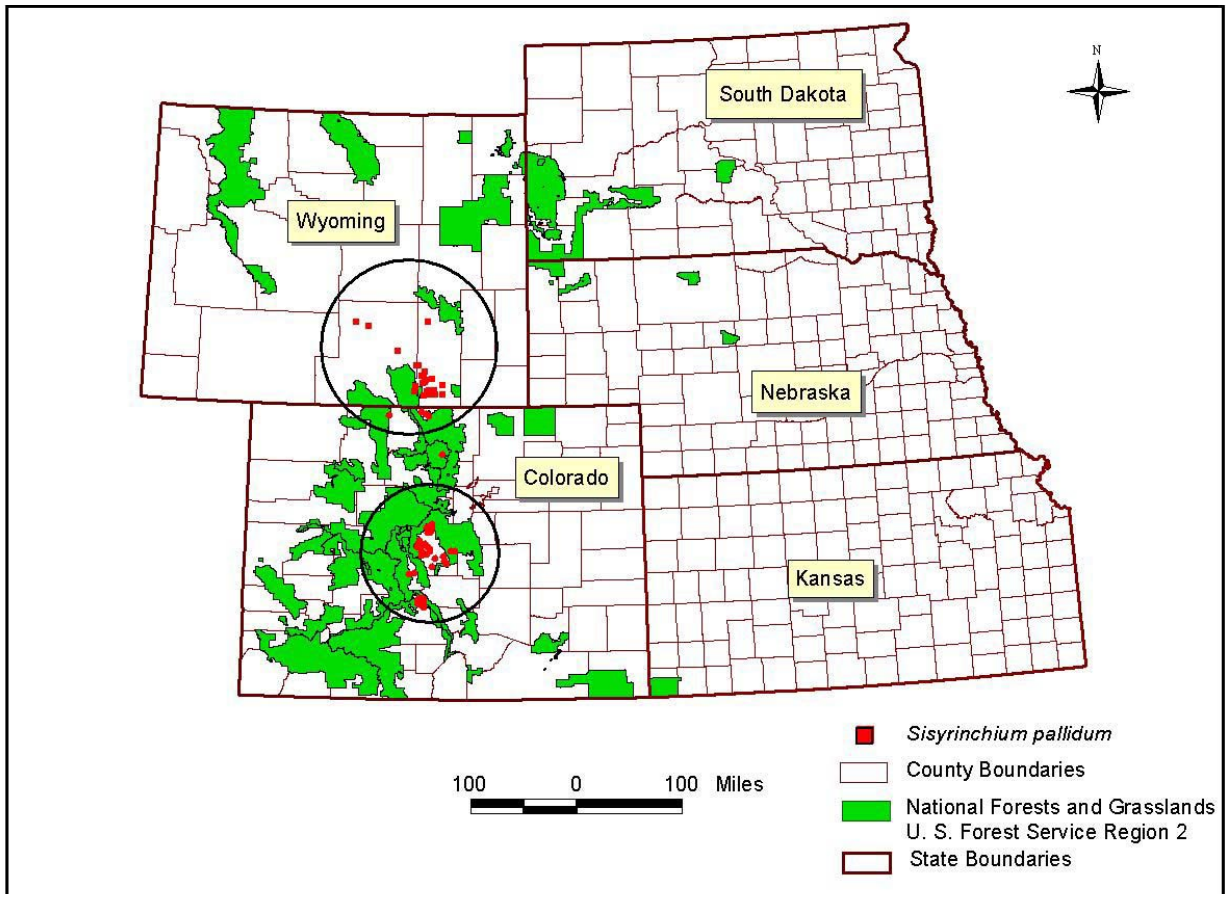

Figure 4. Distribution of *Sisyrinchium pallidum* in USDA Forest Service Region 2 — Colorado and Wyoming.

that these locations are on private land, but the specific information was not made available to the authors by the CNHP. These 14 locations are indicated as "unverified private" in **Table 2**. In Wyoming, 11 of the 27 occurrences are on public land, and the remaining 16 are located on private land. Two of the 16 occurrences in Wyoming are also assumed private, because the location data was not specific on the herbarium labels.

The 66 occurrences of *Sisyrinchium pallidum* are associated with several different watersheds or unique geographic areas:

In Colorado:

- South Park, South Platte River drainage (29 occurrences)
- Tarryall Mountains, South Platte River drainage (2 occurrences)
- East foothills of the Collegiate Range, Arkansas River drainage, (2 occurrences)
- North Park, North Platte River drainage (1 occurrence)
- Rocky Mountain National Park, South Platte River drainage (1 occurrence)
- San Luis Valley, Rio Grande River drainage (1 occurrence)
- Upper Laramie Basin, Laramie River drainage (3 occurrences)

In Wyoming:

- Laramie Basin, Laramie River drainage (23 occurrences)
- Medicine Bow River tributaries, Laramie River drainage (2 occurrences)
- Great Divide Basin (1 occurrence)
- Seminoe Reservoir, Laramie River drainage (1 occurrence)

Table 2. Summary of abundance data for Colorado occurrences of *Sisyrinchium pallidum* taken from Colorado Natural Heritage Program element occurrence records.

EOR	County	Area (hectare)	Number of occurrences	Total number of plants	Land ownership
034CO	Chaffee	Not recorded	1?	60	Unverified private
021CO	Jackson	Not recorded	1?	4	Routt National Forest
009CO	Larimer	0.05	1?	100's	State of Colorado/private
035CO	Larimer	Not recorded	1?	Not recorded	Unverified private
003CO	Larimer	Not recorded	1?	20 to 30	National Park Service: Rocky Mountain National Park
037CO	Larimer	Not recorded	1	300+	Private
036CO	Larimer	Not recorded	1	50	State of Colorado
005CO	Park	Not recorded	3	30 to 1,000+	State of Colorado: Tomahawk State Wildlife Area/private
025CO	Park	51	1?	Not recorded	State of Colorado /private
002CO	Park	Not recorded	2	50 to 250	Denver Water Department: leased to the state of Colorado
026CO	Park	Not recorded	1?	Not recorded	Unverified private
027CO	Park	Not recorded	1?	Not recorded	Unverified private
028CO	Park	Not recorded	1?	Not recorded	Unverified private
029CO	Park	Not recorded	1?	Not recorded	Unverified private
030CO	Park	Not recorded	1?	Not recorded	Unverified private
031CO	Park	Not recorded	2	Not recorded	Unverified private
032CO	Park	Not recorded	1?	Not recorded	Unverified private
033CO	Park	Not recorded	1?	Not recorded	Unverified private
040CO	Park	0.4	1	25 to 50	Unverified private
042CO	Park	Not recorded	3?	Not recorded	Unverified private
043CO	Park	Not recorded	1?	Not recorded	Unverified private
045CO	Park	Not recorded	1?	Not recorded	Unverified private
011CO	Park	Not recorded	1?	250	Pike-San Isabel National Forest
039CO	Park	0.04	2	4 to 10	Pike-San Isabel National Forest
041CO	Park	Not recorded	1?	Not recorded	Pike-San Isabel National Forest
001CO	Park	Not recorded	1?	1,000's	Private
006CO	Park	Not recorded	1?	200 to 500	Private
007CO	Park	Not recorded	1?	30	Private
008CO	Park	Not recorded	1?	50	Private
010CO	Park	0.4	1?	Not recorded	Private
012CO	Park	Not recorded	1?	30	Private
044CO	Park	0.8	1	+/-20	Private
004CO	Park	Not recorded	1?	5,000+	Private: The Nature Conservancy
046CO	Park	1	1	89 to 200	State of Colorado
013CO	Park	Not recorded	1?	2,000	State of Colorado Land Board
014CO	Park	Not recorded	1?	150	State of Colorado Land Board
015CO	Park	Not recorded	1?	50	State of Colorado Land Board
047CO	Park	Not recorded	1?	10 to 100	State of Colorado Wildlife Area
016CO	Saguache	Not recorded	1?	100+	Private

Table 3. Summary of abundance data for Wyoming occurrences of *Sisyrinchium pallidum* taken from Wyoming Natural Diversity Database element occurrence records and herbarium label data. Non-EOR numbers are collection numbers from specimens deposited at Rocky Mountain Herbarium, Laramie, WY.

EOR	County	Area (hectare)	Number of occurrences	Total number of plants	Land ownership
002WY	Albany	Not recorded	1?	Not recorded	Private
004WY	Albany	0.4	1	100	Bureau of Land Management
005WY	Albany	0.8 to 1.2	1	2,000 to 3,000	Private
006WY	Albany	2.4 to 3.2	1	10,000 to 20,000	Private
007WY	Albany	0.8 to 1.2	1	2,000 to 3,000	Private
008WY	Albany	8 to 12	1	3,000 to 4,000	Private
009WY	Albany	4 to 6.4	2	3,000 to 20,000	State of Wyoming/private
011WY	Albany	1.6 to 2	1	10,000	State of Wyoming
012WY	Albany	2.4 to 3.2	1	40,000 to 80,000	State of Wyoming
013WY	Albany	1.2 to 2.4	1	1,000 to 2,000	Private
014WY	Albany	2 to 2.8	1	1,000 to 2,000	State of Wyoming
015WY	Albany	1.2 to 2	1	2,000 to 3,000	Private
016WY	Albany	3.2 to 4	1	10,000	Private
017WY	Albany	5.6 to 7.2	1	30,000 to 40,000	Mortenson Lake Wildlife Refuge
018WY	Albany	4 to 4.8	1	30,000 to 40,000	Mortenson Lake Wildlife Refuge
019WY	Albany	3.6 to 4.4	2	5,000 to 10,000	Private
020WY	Albany	43.2 to 88	1	80,000 to 100,000	Private
021WY	Albany	2.4 to 3.2	1	2,000 to 3,000	Private
022WY	Albany	0.4	1	100	Private
023WY	Albany	2 to 3.2	1	1,000	Private
024WY	Albany	Not recorded	1?	Not recorded	Bureau of Land Management
7625*RM	Albany	Not recorded	1?	Not recorded	Unverified private
7626*RM	Albany	Not recorded	1?	Not recorded	Unverified private
010WY	Carbon	3.2 to 5.2	2	1,000 to 3,000	Private
19263*RM	Carbon	Not recorded	1?	Not recorded	Bureau of Land Management
19414*RM	Carbon	Not recorded	1?	Not recorded	Bureau of Land Management
2627*RM	Carbon	Not recorded	1?	Not recorded	Bureau of Land Management

* non-EOR voucher specimens

? indicates at least one occurrence, but lacks verifiable data

Voucher specimens were matched to element occurrence records (EORs) through data provided by CNHP, WYNDD, the Rocky Mountain Herbarium (RM, Laramie, WY), Stanley L. Welsh Herbarium (BRY, Provo, UT), Carter Herbarium (COCO, Colorado Springs, CO), University of Montana (MONTU, Missoula, MT), Kathryn Kalmbach Herbarium (KHD, Denver, CO), Chadron State College Herbarium (CSCN, Chadron, NE), R.L. McGregor Herbarium (KANU, Lawrence, KS), San Juan College Herbarium (SJNM, Farmington, NM), and University of Colorado Museum (COLO, Boulder, CO). Fourteen of the 39 Colorado locations are represented by voucher specimens located during the writing of this assessment. The authors were

unable to verify voucher specimens for the remaining 25 Colorado occurrences. Voucher specimens deposited at the Rocky Mountain Herbarium represent all of the Wyoming locations.

Sisyrinchium pallidum occurs in both a scattered and clumped pattern. Individual occurrences range in size from four individuals to over 100,000 individuals. An accurate estimation of ecological density in the strict sense is not possible given the available data. Based upon the available EOR data and estimates during a 1992 status report (Hartman 1992), rough estimates of density in Wyoming occurrences vary from approximately 0.01 individuals per m^2 to 25 to 50 plants per m^2. The largest occurrences are located in the Laramie Basin, Wyoming, and the smallest occurrences (under 100) are located in South Park, Colorado.

An inherent problem with assessments, particularly for a taxon with a range that extends into two or more states, is the variation in data collection between different heritage programs. The determination of abundance for *Sisyrinchium pallidum* is complicated further by the difficulty in field identification when the species is not in flower. The estimate of abundance given here is only as accurate as the data reported by CNHP and WYNDD. All estimates of abundance were accomplished through ocular estimates; no transects were established to determine abundance. Based on the available CNHP and WYNDD EOR data summarized in **Table 2** and **Table 3**, it is estimated that 9,500 to 11,500 individuals are located in Colorado, and approximately 233,000 to 354,000 are located in Wyoming, with the caveat that abundance data is missing for thirteen of the Colorado locations and seven of the Wyoming locations. Total rangewide abundance for *S. pallidum* is conservatively estimated to be between 200,000 and 350,000 individuals.

Population trend

There are no established demographic monitoring sites for *Sisyrinchium pallidum*, nor have records been maintained to note changes in population size at any of the known occurrences. No inferences about population trend for the species at the scale of individual populations or rangewide can be made. Due to the lack of data, no inferences can be made concerning the temporal pattern of abundance at any spatial extent.

Habitat

Sisyrinchium pallidum is a plant of wetlands, fens, riparian corridors, and meadows. Elevation ranges from 1,999 m in the Laramie Basin (Wyoming) to 2,956 m in South Park (Colorado). This species generally occurs in areas where the soils are typically inundated in the spring and where plentiful, often standing, fresh water is available throughout the growing season. **Figure 5** and **Figure 6** provide photographs showing generalized habitat for *S. pallidum*. In nearly all cases, this species is recorded in an open, seasonally-flooded or saturated, fresh water, palustrine, emergent wetland meadow dominated by grasses and/or sedges and may occur in areas dominated by low stature shrubs (Cowardin et al. 1979, Wyoming Natural Diversity Database 2002, Colorado Natural Heritage Program 2003). *Sisyrinchium pallidum* has not been assigned a wetland indicator status by the U.S. Army Corps of Engineers or the U.S. Fish and Wildlife Service. It tends to occupy soils derived from Quaternary alluvium and colluvium and often calcareous. **Table 4** presents a summarization of EOR site data, information from herbarium specimen labels, and status reports including elevation, substrate, hydrology source, and vegetation cover.

Very few estimates of total vegetation cover are available for *Sisyrinchium pallidum* habitat; they range from 70 to 100 percent ground cover (graminoids and forbs). One record noted 13 percent shrub cover, and one 3 percent bare ground. No other data exist to quantify percent total vegetation cover of *S. pallidum* habitat. The closest vegetation type classification that can accurately be applied to the species as a whole is that characterized as a "montane wet meadow ecological system, small patch" by Rondeau (2001) for the CNHP. The montane wet meadow ecological system is characterized by a dominance of *Carex* species (including species listed with an * in **Table 5**) and by hydrology, with water levels frequently at or near the surface. Soils are saturated for most of the year (sometimes year round). The surface may become inundated, but this usually does not last for extended periods. Wet meadows occur on hydric soils, often derived from mineral parent materials, and they typically are characterized by organic materials and redoximorphic features (Rondeau 2001). Adjacent vegetation types vary for this species; recorded vegetation found within proximity to occurrences includes sagebrush/grassland, cottonwood riparian (species not given), and human-disturbed areas such as managed hay meadows and roadside ditches.

Based on CNHP and WYNDD EOR data, herbarium label data, and status reports, the most common dominant species found associated with this taxon are *Juncus arcticus* Willd. (arctic rush) and *Pentaphylloides floribunda* Pursh Löve (shrubby cinquefoil). Other dominant taxa include *Carex*

Figure 5. Generalized habitat of *Sisyrinchium pallidum*. High Creek fen, South Park (EOR 004CO) (photograph by Colorado Natural Areas Program, accessed at http://parks.state.co.us/cnap/Natural_Areas/NA%20pages/highcrkfen.htm on 10/20/2003).

Figure 6. Generalized habitat of *Sisyrinchium pallidum.* Pink flowers are *Pedicularis crenulata* (photograph by J. Sanderson 1999, used with permission).

Table 4. Summary of habitat data for known Colorado and Wyoming occurrences of *Sisyrinchium pallidum*. Information taken from element occurrence record data forms (Wyoming Natural Diversity Database 2002, Colorado Natural Heritage Program 2003, Hartman 1992), herbarium specimen labels, and USGS 7.5 minute topographic maps. Non-EOR numbers indicate collection numbers of specimens deposited at the Rocky Mountain Herbarium, Laramie, WY.

Colorado

EOR	Elevation (meters)	Substrate	Hydrology source	Vegetation cover**	Habitat characteristics and association
†001CO	2,895	Quaternary alluvial gravels/rich muck	Surface and groundwater discharge	Not available (N/A)	High elevation wetlands, large moist meadow. Graminoid dominated.
†002CO	2,705 to 2,712	Modern alluvium Fine textured silty brown soils	Adjacent stream?	N/A	Meadow vegetation along moist stream banks.
003CO	2,456 to 2,462	Quaternary glacial drift overlying Precambrian granite and gneiss, damp alkaline soil	Adjacent stream?	N/A	Meadow along stream. Alkaline indicator plants, names not available.
†!004CO	2,834	Quaternary gravels and alluvium/ peat	Surface and groundwater discharge	N/A	Minerotrophic peatland. Graminoid dominated fen.
†005CO	2,804 to 2,895	Quaternary gravels and alluvium/ fine textured silty brown soil/ alkaline	Surface and groundwater discharge	N/A	Moist meadow dominated by *Juncus balticus*.
†006CO	2,895	Quaternary gravels and alluvium/ brown fine textured soil	Surface and groundwater discharge	N/A	Moist meadow dominated by graminoids.
†007CO	2,834 to 2,849	Tertiary South park formation/ brown fine textured soil	Surface and groundwater discharge	N/A	Small drier island within wet meadow. Graminoid dominated.
†008CO	2,804	Evaporitic facies of Minturn and Belden formations	Surface and groundwater discharge	N/A	Not available (N/A).
009CO	2,414	Tertiary North Park formation/ damp alkaline soil	Seep from adjacent reservoir	N/A	Narrow band of wetland along edge of reservoir. Plants not growing in standing water.
†010CO	2,700	Tertiary andesitic lavas, breccians, tuffs, and conglomerates/peat	Surface and groundwater discharge	N/A	Peat fen.
011CO	2,633	Quaternary alluvium overlying granite of 1400my age/alkaline clay	Not available (N/A)	N/A	N/A.
†012CO	2,712	Quaternary Wisconsin outwash/ Maroon formation/alkaline clay	Adjacent stream?	N/A	Flood plain and riparian area scattered along creek. Plants about 35 cm above water line.
†013CO	2,740	Quaternary alluvium/Maroon Formation/peat	Surface and groundwater discharge	N/A	Wet peatland on river floodplain.
†014CO	2,865	Quaternary alluvium and Tertiary andesitic lavas, breccians, tuffs, and conglomerates/stony silty loam	Adjacent stream?	N/A	Groups of plants about 30 to 45 cm above waterline.
†015CO	2,743	Quaternary alluvium and Tertiary andesitic lavas, breccians, tuffs, and conglomerates/organic rich	Surface and groundwater discharge	N/A	Wet meadow.
016CO	2,407	Modern alluvium/ alkaline soil	N/A	N/A	*Carex* dominated wetland. Along drier edges of fen.
021CO	2,621	Quaternary gravels alluvium/ sandy loam	N/A	N/A	Scattered along trail.
†025CO	2,926	Quaternary gravels alluvium/peat	Surface and groundwater discharge	N/A	*Kobresia myosuroides*/*Thalictrum alpinum* plant association. Occurs with *Ptilagrostis mongholica* ssp. *porteri*. On hummocks.
†026CO	2,718	Tertiary South Park Formation	Spring	N/A	Wetland along banks of river.

Table 4 (cont.).

EOR	Elevation (meters)	Substrate	Hydrology source	Vegetation cover**	Habitat characteristics and association
†027CO	2,749	Modern alluvium	Surface and groundwater discharge	N/A	Old braided riverbed dominated by graminoids.
†028CO	2,470	Modern alluvium	Spring fed wetland with pools	N/A	Wetland dominated by graminoids.
†029CO	2,724	Evaporitic facies of Minturn and Belden formations	Spring fed complex and creek with dam	N/A	Wetland dominated by graminoids.
†030CO	2,865	Tertiary South Park Formation/ alluvium	Surface and groundwater discharge	Total cover 100 percent	Natural wetland dominated by graminoids.
†031CO	2,840	Quaternary gravels alluvium	Seasonally saturated perennial creek and irrigation	S=50 percent F=50 percent	Wetland along creek and irrigated meadows.
†032CO	2,849	Tertiary South Park Formation	Spring/seep	G=70 percent	Wetland and meadows. Graminoid dominated.
†033CO	2,871	Quaternary alluvium	Spring	G=80 percent	Moist flat fen along creek. Graminoid dominated.
034CO	2,364	Quaternary gravels alluvium	Spring/seep irrigation	G=100 percent	Open moist bog.
035CO	2,444	Pierre shale	Perennial creek/ spring/ groundwater discharge	N/A	Along creek.
036CO	2,596	Triassic and Permian rocks	N/A	N/A	*Carex* spp. dominated wetland on hummocks.
037CO	2,596	Quaternary glacial drift	Adjacent creek/seep?	G=100 percent	Bog and seep near creek.
†039CO	2,804	Tertiary andesitic lavas, breccians, tuffs, and conglomerates /silty clay	Surface and groundwater discharge	S=13 percent G=80 percent B=3 percent	Hummocks in wet meadow. Graminoid dominated.
†040CO	2,865	Quaternary gravels alluvium/ alkaline/peat soils	Surface and groundwater discharge	N/A	Low stature shrub dominated fen.
041CO	2,438 to 2,781	Rocks of Pikes Peak batholith/ granite of 1400my age	N/A	N/A	Along banks of river.
†042CO	2,609 to 2,621	Quaternary gravels alluvium	Surface and groundwater discharge	N/A	Along moist banks of river.
†043CO	2,770 to 2,788	Pierre shale	Surface and groundwater discharge	N/A	Moist flats along river with sedge and rush species.
†044CO	2,852	Dolomite limestone/ alluvium and glacial outwash/peat/high dissolved mineral content	Surface and groundwater discharge	N/A	Wetland separate from adjacent river.
†045CO	2,956	Quaternary gravels	Surface and groundwater discharge	Surface and groundwater discharge	Hummocks.
†046CO	2,712	Modern alluvium/ fine textured soil	Surface and groundwater discharge	N/A	*Juncus* spp. dominated wetland and seasonally wet meadow.
†047CO	2,718 to 2,724	Quaternary alluvium fine textured soils	Surface and groundwater discharge	N/A	Mesic seasonally wet meadow dominated by graminoids.

Wyoming

EOR	Elevation (meters)	Substrate	Hydrology source	Vegetation cover**	Habitat characteristics and association
††002WY	2,133	Quaternary alluvium and colluvium	Springs?	N/A	Moist meadow dominated by graminoids.
††004WY	2,316	Tertiary Wind River Formation	Seepage from pond?	N/A	Wet area around pond.
††005WY	2,164	Quaternary alluvium and colluvium	N/A	N/A	Marshy meadow.

Table 4 (concluded).

EOR	Elevation (meters)	Substrate	Hydrology source	Vegetation cover**	Habitat characteristics and association
††006WY	2,392	Quaternary alluvium and colluvium	N/A	N/A	Wet meadows.
††007WY	2,377	Quaternary alluvium and colluvium	Adjacent stream?	N/A	Wetlands along stream.
††008WY	2,225	Quaternary alluvium and colluvium	Irrigation, springs?	N/A	Marshy meadows and hay fields.
††009WY	2,377	Quaternary pediment and fan deposits	Irrigation, springs?	N/A	Marshy areas, wet meadows, and hay meadows.
††010WY	2,255	Quaternary alluvium and colluvium	Seepage creek?	N/A	Wetlands along creek.
††011WY	2,194	Quaternary alluvium and colluvium	N/A	N/A	Drier portions of wet meadow.
††012WY	2,218	Quaternary alluvium and colluvium	Road run off? Irrigation	N/A	Roadside ditch and wet fields.
††013WY	2,194	Frontier Formation	Seep from dam below lake	N/A/	Seep area below earthen dams in saturated to inundated soil.
††014WY	2,225	Forelle limestone and Satanka shale	Seep from dam below lake	N/A	Dried up areas near seep below earthen dam.
††015WY	2,243	Quaternary alluvium and colluvium	N/A	N/A	Marshy area.
††016WY	2,194	Quaternary alluvium and colluvium	N/A	N/A	Marshy area.
††017WY	2,209	Quaternary alluvium and colluvium	Spring and seep	N/A	Seep area above dark green band of Juncus balticus and near spring.
††018WY	2,225	Quaternary alluvium and colluvium	N/A	N/A	Marshy area.
††019WY	2,194	Quaternary alluvium and colluvium	Road run off?	N/A	Roadside ditch and wet to marshy higher ground above ditch.
††020WY	2,249	Quaternary pediment and fan deposits	Irrigation canal?	N/A	Marshy meadow.
††021WY	2,240	Mesaverde Group	N/A	N/A	Wet meadow.
††022WY	2,194	Quaternary alluvium and colluvium	Adjacent stream?	N/A	Seepage area and grassy bottomlands.
††023WY	2,194	Quaternary pediment and fan deposits	N/A	N/A	Marshy area.
024WY	2,121 to 2,184	Goose-egg Formation	N/A	N/A	Wet to dry stream bottom meadow.
2627/RM	2,194	Lewis shale	Seep from reservoir?	N/A	Perimeter of reservoir dominated by graminoids and forbs.
††7625/RM	2,225	Wind River Formation	Adjacent stream?	N/A	Wet meadow along creek.
††7626/RM	2,225	Lewis shale	N/A	N/A	Wet meadow.
19414/RM	2,097	Quaternary dune and sand loess/ alkaline soil	Seepage from pond?	N/A	Banks of pond in depression adjacent to sand dune.
19263/RM	1,999	Quaternary dune and sand loess/ sandy clay	Seepage from pond?	N/A	Moist community of *Juncus balticus*/*Distichlis stricta*/*Scirpus pungens* in low swale below pond and sand dune.

**T=trees; S=shrubs; G=grass/forb; B=bare ground.

† South Park occurrence

! High Creek fen occurrence

†† Laramie Basin occurrence

Table 5. List of species documented to occur with *Sisyrinchium pallidum* including common name and regional wetland indicator status. An * indicates species listed in Rondeau montane wet meadow vegetation classification (Rondeau 2001).

Scientific Name	Common Name	Wetland Indicator Status*
Agoseris glauca (Pursh) Raf. var. *glauca*	pale agoseris	FACU
Antennaria microphylla Rydb.	little leaf pussytoes	N/A
Astragalus bodinii Sheld.	Bodin's milkvetch	FACU-
Betula nana L.	dwarf birch	N/A
**Carex aquatilis* Wahl.	water sedge	OBL
Carex hallii Olney	deer sedge	OBL
**Carex lasiocarpa* Ehrh. var. *americana* Fern.	American woollyfruit sedge	NI
Carex nebrascensis Dewey	Nebraska sedge	OBL
Carex nelsonii Mackenzie	Nelson's sedge	OBL
**Carex praegracilis* Boott	clustered field sedge	FACW
**Carex simulata* Mackenzie	analogue sedge	FACW+
Carex scirpoidea Michx.	northern singlespike sedge	FACU
**Carex utriculata* F. Boott	Northwest Territory sedge	OBL
Cicuta maculata L. var. *angustifolia* Hook.	spotted water hemlock	OBL
Crepis runcinata (James) Torr. & Gray ssp. *glauca* (Nutt.) Babcock & Stebbins	fiddleleaf hawksbeard	FACW
Crepis runcinata (James) Torr. & Gray ssp. *runcinata*	fiddleleaf hawksbeard	FACW
Deschampsia caespitosa L. var. *caespitosa*	tufted hairgrass	FACW
Distichlis spicata (Torr.) Rydb.	inland saltgrass	FAC+
Dodecatheon pulchellum (Rafinesque) Merrill	dark throat shooting star	FACW
Gentianopsis thermalis (Kuntze) Iltis	Rocky Mountain fringed gentian	OBL
Glaux maritime L.	sea milkwort	OBL
Hordeum jubatum L.	foxtail barley	FAC
Iris missouriensis Nutt.	Rocky Mountain iris	OBL
**Juncus arcticus* Willd.	arctic rush	FACW
Juncus longistylis Torr. var. *longistylis*	long style rush	FACW+
Kobresia myosuroides (Villars) Fiori & Paoli	Bellardi bog sedge	FACU
Kobresia simpliciuscula (Wahl.) Mackenzie	simple bog sedge	FACW
Muhlenbergia filiformis (Thurber ex S. Watson) Rydb.	pullup muhly	FACW+
Muhlenbergia richardsonis (Trinius) Rydb.	mat muhly	FACU
Parnassia palustris L. var. *montanensis* (Fern. & Rydb. Ex Rydb.) Hitchc.	mountain grass of Parnassus	OBL
Pedicularis crenulata Benth.	meadow lousewort	OBL
Pentaphylloides floribunda (Pursh) Löve	shrubby cinquefoil	NS
Plantago eriopoda Torr.	redwool plantain	FAC+
Plantago major L.	common plantain	PIF
Potentilla anserina L.	silverweed cinquefoil	OBL
Potentilla hippiana Lehm.	woolly cinquefoil	Not listed
Primula egaliksensis Wormskjold	Greenland primrose	FACW
Primula incana Jones	silvery primrose	FACW
Ptilagrostis porteri (Rydb.) W.A. Weber	Porter's false needlegrass	Not listed

Table 5 (concluded).

Scientific Name	Common Name	Wetland Indicator Status*
Ranunculus acriformis Gray var. *acriformis*	sharpleaf buttercup	FACW+
Salix brachycarpa Nutt.	shortfruit willow	FACW
Salix candida Fluegge	sageleaf willow	OBL
Salix exigua Nutt.	narrowleaf willow	OBL
Salix planifolia Pursh	diamondleaf willow	OBL
Scirpus pungens Vahl.	common threesquare	OBL
Senecio debilis Nutt.	weak groundsel	FACW
Senecio pauciflorus Pursh	alpine groundsel	NI
Sidalcea neomexicana Gray var. *neomexicana*	salt spring checkerbloom	FACW
Sisyrinchium idahoensis Bicknell var. *occidentale* (Bicknell) Henderson	Idaho blue-eyed grass	OBL
Sisyrinchium montanum Greene	strict blue-eyed grass	FAC-
Thalictrum alpinum L.	alpine meadow-rue	FAC
Trifolium repens L.	white clover	FACU
**Triglochin maritimum* L. var. *elatum* (Nutt.) Gray	seaside arrowgrass	OBL
Zigadenus elegans Pursh.	mountain deathcamas	FACU

***OBL** (Obligate Wetland). Occur almost always (estimated probability >99 percent) under natural conditions in wetlands.

FACW (Facultative Wetland). Usually occur in wetlands (estimated probability 67 to 99 percent), but occasionally found in non wetlands.

FAC (Facultative). Equally likely to occur in wetlands or non wetlands (estimated probability 34 to 66 percent).

FACU (Facultative Upland). Usually occur in non wetlands (estimated probability 67 to 99 percent), but occasionally found on wetlands (estimated probability 1 to 33 percent).

UPL (Obligate Upland). Occur in wetlands in another region, but occur almost always (estimated probability >99 percent) under natural conditions in non wetlands on the region specified.

NI (No indicator) Insufficient information available to determine an indicator status.

PIF (Perennial introduced shrub).

NS (Native shrub).

utriculata F. Boott (Northwest Territory sedge), *C. nebrascensis* Dewey (Nebraska sedge), and other unidentified species of *Carex* (sedge). Several willows were recorded, but none were noted more than once.

Pedicularis crenulata Benth. (meadow lousewort), *Pentaphylloides floribunda*, and *Juncus arcticus* may function as indicator species for *Sisyrinchium pallidum* (D. Cooper personal communication 2004, Hartman 1992, 2004). *Pedicularis crenulata* is a showy herbaceous perennial that was recorded from 20 of the 25 Wyoming locations and from 12 of the 39 Colorado locations (when associate species were noted at all). Other taxa consistently occurring with *S. pallidum* include *Triglochin maritimum* L. var. *elatum* (Nutt.) Gray (seaside arrowgrass), *Deschampsia caespitosa* L. var. *caespitosa* (tufted hairgrass), *Primula incana* Jones (silvery primrose), and *Iris missouriensis* Nutt. (Rocky Mountain iris). One occurrence (003CO) noted alkaline indicator species, but no names of these plants were recorded on the EOR information that the authors received.

Other taxa documented as occurring with *Sisyrinchium pallidum* are listed in **Table 5**. This list was generated by synthesizing herbarium label data, status reports, and EORs. Wetland indicator status for all species in **Table 5** is given, if available. Not all of these species were present at every site, and typically only two or three per site were mentioned in the available records. As a result, it is not possible to determine a hydrophytic vegetation status as per the U.S. Army Corps of Engineers (1987) Wetland Delineation Manual for any of the occurrences. However, wetland indicator status of the plants in **Table 5** shows an overwhelming presence of hydrophytic vegetation. Of the 54 plant species listed in **Table 5**, 70 percent (38) are FAC, FAC+, FACW, or OBL. The remaining 29 percent (16) are either FAC- or FACU. See bottom of **Table 5** for definitions of indicator status. Based on associated

vegetation and habitat records, it is likely that *S. pallidum* is either a FACW or an OBL wetland species.

Sisyrinchium pallidum is consistently reported to occur in fens. Most of these fens are located in South Park, Colorado (see **Table 4** for occurrences located in South Park). There are numerous definitions of a fen. Three definitions are given in the glossary of this assessment, but the most useful for the purpose of characterizing habitat for *S. pallidum* is given by Crum (1988):

> Fens are mineral-rich peatlands with a pH of 4.0 to 7.5 and are dominated by graminoids, particularly sedges. These peatlands are in contact with the groundwater and derive their water and nutrients from groundwater, surface water, and precipitation.

Elliot-Fisk (1988), in the context of boreal forests, defines a fen as a bog that forms under more alkaline conditions. The important thing about fens is that they derive their hydrology from ground water that accumulates as runoff from surrounding lands; thus they are relatively high in nutrients compared to bogs, which receive their water from rain and snow. Another feature of fens and bogs are areas of maximum moisture with different associations encircling them, each circular zone becoming drier (Emerick and Mutel 1992). These areas sometimes form hummocks. It has been reported in the available occurrence records that *Sisyrinchium pallidum* tends to occupy these circular zones in areas that are slightly drier than the central wet area (Colorado Natural Heritage Program 2003).

An intensive study documenting the water chemistry, soil chemistry, and floristics of High Creek fen in South Park, Colorado was accomplished by David Cooper in the early 1990's (1996). High Creek fen is considered an extremely rich fen (i.e., well supplied with mineral nutrients). *Sisyrinchium pallidum* was found in the study area (EOR 004CO) and was consequently classified with four different vegetation types within High Creek fen. The results of the study found *S. pallidum* occurring in three peatland expanse hummock communities and one meadow community. The hummock communities differed by the two dominant species and included: 1) *Thalictrum alpinum* L.-*Kobresia myosuroides* (Villars) Fiori & Paoli (alpine meadow rue-Bellardi bog sedge), 2) *Crepis runcinata* Torr. & Gray-*Carex scirpoidea* Michx. (fiddleleaf hawksbeard-northern singlespike sedge), and 3) *Muhlenbergia richardsonis* (Trinius) Rydb-*Carex hallii* Olney (mat muhly-deer sedge). The meadow community was dominated by *Potentilla anserina* L.-*Juncus arcticus* Willd. (silverweed cinquefoil-arctic rush) (Cooper 1996). These communities are specific to High Creek fen, and they are not necessarily diagnostic of *S. pallidum* habitat. *Sisyrinchium pallidum* tends to occur in calcareous fens and meadows dominated by *Pentaphylloides floribunda* (Pursh) Löve and *Juncus arcticus* Willd. These two species require seasonal high water tables, do not tolerate long duration flooding, and are not necessarily hummock species (D. Cooper personal communication 2004).

High Creek fen has three groundwater sources, each supplying three different water types: calcium bicarbonate, calcium and magnesium bicarbonate, and calcium sulfate. Dr. Cooper found the water pH of High Creek fen to be 7.84 from the two water sources entering the fen from the north, northwest, and northeast (calcium bicarbonate and calcium and magnesium bicarbonate sources) and 8.13 from the water source entering from the southwest (calcium sulfate source) (Cooper 1996).

Documented habitat descriptions from EOR and herbarium label data consistently note this species occurring on wet, fine textured soils. It has been observed in organic rich peat. Cooper (1996) found the High Creek fen communities in which *Sisyrinchium pallidum* occurred to have a percent organic content ranging from 24 to 45 percent. Sixty four percent (42 occurrences) of the known locations have a surface geology of some form of Quaternary parent material including alluvium, colluvium, pediment, gravels, or sand loess. Some Tertiary and Cretaceous shales, limestones, and dolomites also contribute substrate material. Some of the Colorado EOR data mention alkaline soils, particularly for those occurrences located in the fens in South Park, Colorado. South Park is bordered on the west by the Mosquito Range capped by Leadville Limestone with dolomites occurring throughout the Mosquito Range; thus surface and groundwater discharge are influenced by calcareous parent materials (Cooper 1996). Wyoming occurrences are also influenced by calcareous substrates such as the Forelle limestone. Six of the 66 occurrence records note "alkaline soil." No measurement of pH was recorded on any of the EORs, except for the High Creek fen occurrence (004CO).

Plants that are characteristic of limestone and other base-rich neutral soils are loosely termed calcicoles (Lincoln et al. 1982). It has been speculated in past status reports of *Sisyrinchium pallidum* that this species appears to require calcareous waters (Jennings

1990). Hartman (1992) suggested that the hydrology source of the occurrences that he observed were from natural springs and therefore not significantly alkaline. There is not enough evidence to support or refute the idea that this species is a calcicole. This species may prefer fresh water sources that are relatively neutral to somewhat basic. The most that can be said about *S. pallidum* as a calcicole plant is to recognize that we are dealing with one of many species that persist on calcareous soils without necessarily implying any obligatory association with, or even preference for, such soils (Salisbury 1920). Additionally, *S. pallidum* is frequently associated with communities that are dominated by *Pentaphylloides floribunda* (Pursh) and *Juncus arcticus*, and these tend to have relatively broad tolerances for water, soil chemistry, and water table depth (D. Cooper personal communication 2004).

None of the occurrence data identify a formal wetland delineation for any location on public land. However, we can speculate that all sites are wetlands based on two criteria: (1) 33 of the 66 occurrences report a source of hydrology and (2) 70 percent of the documented species that occur with *Sisyrinchium pallidum* are hydrophytic plants.

No quantitative data exists to determine the exact nature of microsites for *Sisyrinchium pallidum*. Observations have been noted on herbarium label data and EORs that may serve to guide research toward determining microhabitats for this species. This species has been noted as occurring 10 to 30 meters upland from the first or second concentric ring of vegetation above the waterline of a lake (Hartman 1992). It has been associated with the drier areas around the margins of ponds, 18 to 35 cm up to several meters above the waterline of a creek, and on top of hummocks situated throughout the wetland (Colorado Natural Heritage Program 2003). No evidence was recorded to indicate the groundwater level (such as depth to standing water in a soil pit) of any of these microhabitats. These observations suggest that *S. pallidum* may prefer slightly drier areas within and along the margins of the greater wetland.

Herbarium label data and EORs describe this species as occurring on flat to slightly sloping areas (0 to 5 percent slope). *Sisyrinchium pallidum* occurs on all aspects, typically occupying areas with full sun. This species tends to occupy topographic features characterized by bottomlands and depressions where water can accumulate. Other topographic features include lake and river margins and areas downstream from natural or manmade water sources, such as earthen dams, canals, and irrigation ditches. The elevation range of *S. pallidum* varies between 1,999 and 2,956 meters, with an average elevation in Wyoming of 2,215 meters and in Colorado of 2,594 meters.

A succession sequence is difficult to identify in wetland habitats. A wetland may be a toposequence and thus bear no successional relationship to other communities within the mosaic (Barbour et al. 1987). By definition, a wetland is completely dependent upon the hydrology of a given area. If the hydrology remains unchanged, a wetland could be considered a climax community. It may be stabilized through seasonal flooding and soil saturation (Barbour et al. 1987). There have been no studies accomplished determining the stage of succession for any of the known wetlands in which *Sisyrinchium pallidum* occurs.

Sisyrinchium pallidum is distributed across South Park, Colorado and the Laramie Basin, Wyoming. Potential habitat can be found in wetlands, fens, and moist meadows located along the margins of rivers, lakes, ponds, and irrigated hay meadows throughout the central Rocky Mountain parks and basins, particularly those areas associated with the South Platte River drainage. Recently, WYNDD prepared a statistical model using soils, precipitation, land cover, surface geology, relief, and various other identified variables to predict likely areas of distribution of *S. pallidum* within Wyoming. The model constructed for *S. pallidum* is a wetland model where the predicted distribution of wetland habitat is the intersection of the classification tree model with specified riparian types. The ARCINFO grid size of the model is a 60-meter cell with a single cell as the minimum mapping unit. The area of a single cell is 0.36 hectare (Fertig and Thurston 2003). According to the model, the majority of wetlands in Wyoming are located in the Laramie Basin and in Crook County. Refer to **Table 4** for occurrences that are located in the Laramie Basin.

Variables used in the model to predict potential distribution of *Sisyrinchium pallidum* include soil type, number of wet days per year (>77.8 days), centimeters of October precipitation (>279.5 cm), and GAP land cover vegetation (human disturbed, mixed grass prairie, and shrub dominated riparian). Several other variables were identified, but of primary interest is the resulting map shown in **Figure 7**. Fertig and Thurston (2003) note that in all probability this model does an excellent job of predicting where this species is not likely to occur, and it does a good job of predicting where it is likely

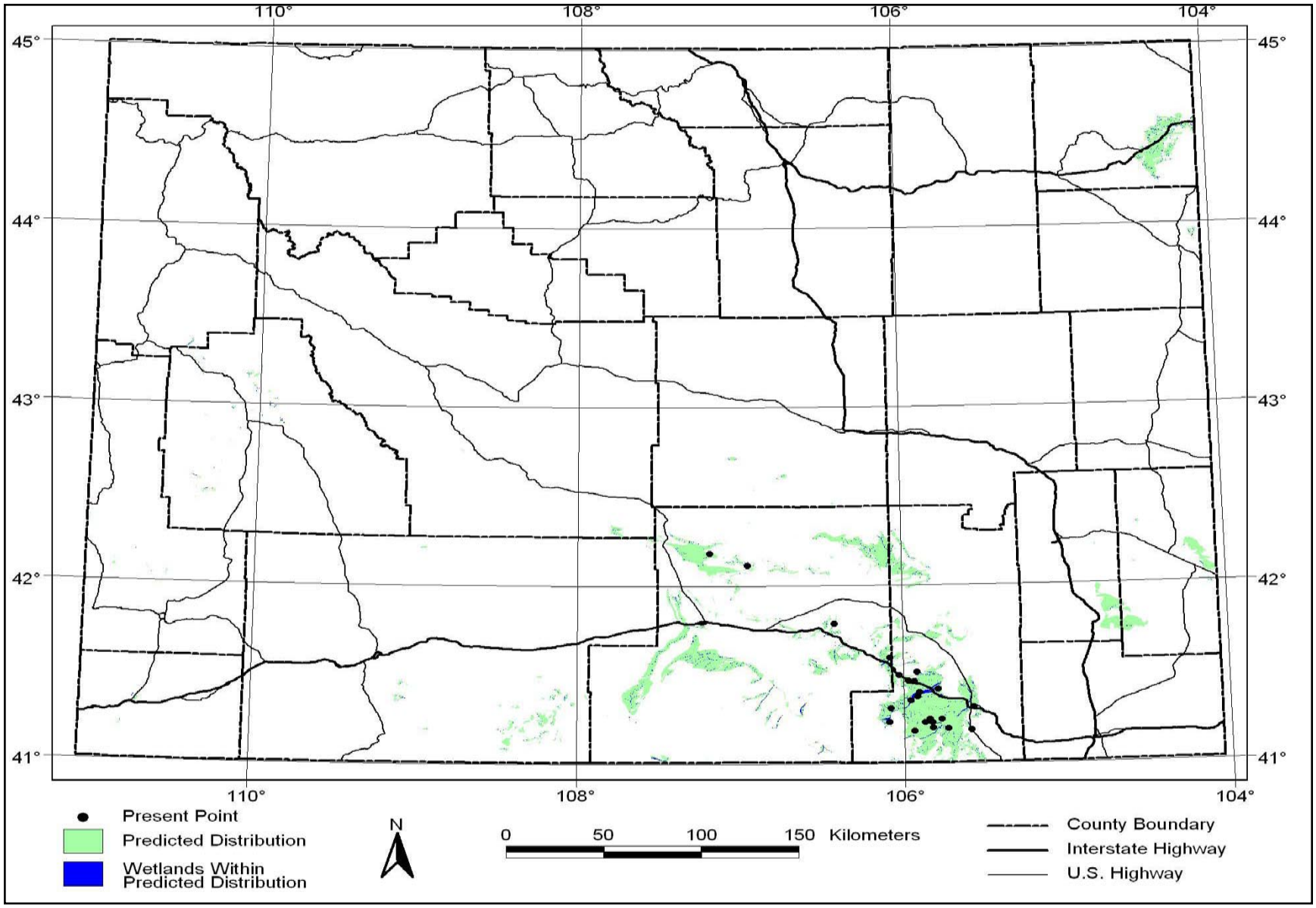

Figure 7. Predicted distribution of *Sisyrinchium pallidum* in Wyoming, using classification tree analysis (Fertig and Thurston 2003).

to occur. Nevertheless, the model identifies target areas for future surveys in Wyoming. There is no comparable modeling data for the Colorado occurrences.

Presence or absence surveys for *Sisyrinchium pallidum* have been an integral part of the CNHP and WYNDD tracking programs, and new occurrences are discovered periodically. Undiscovered occurrences may be located in the upper Laramie River basin in northern Larimer County in Wyoming and in unsurveyed wetlands south along the eastern slopes of the Front Range, particularly tributaries of the South Platte River. The results of the modeling of predicted distribution of *S. pallidum* (Fertig and Thurston 2003) also show possible habitat in wetland areas in Crook County, Wyoming (northeastern Wyoming). Other areas in Colorado that are good candidates for *S. pallidum* habitat would include the numerous wetlands located in the San Luis Valley in Saguache County. The upper North Platte River basin and wetlands in North Park may also harbor undiscovered occurrences of *S. pallidum*. It is conceivable that additional occurrences are likely to exist on private lands adjacent to known occurrences. Hartman (1992) suggests that in Wyoming, the development of irrigated hay meadows during historical times has expanded the potential habitat for this species. This may also be true for some areas in Colorado. Given the inherent difficulty of field identification of this species, it would be difficult to ascertain occurrences in managed hay meadows unless flowering occurred after mowing.

Reproductive biology and autecology

An extensive literature search resulted in no empirical data describing ecological strategies for *Sisyrinchium pallidum*. Grime (1979) developed a system of classifying plant strategies based on three basic stress responses: competitor, stress tolerant, and ruderal. He also proposed four guidelines to aid in classifying plant stress responses: morphology, life history, physiology, and miscellaneous (e.g., litter and palatability).

Sisyrinchium pallidum is an herbaceous perennial with thin, grass-like leaves. This morphology can be associated with both competitive and ruderal strategies. The longevity of mature individuals of this species is not known. There are no available data characterizing the phenology of the leaves. It appears that this species flowers consistently year after year, demonstrating a competitive ability, as per Grimes' guidelines (1979). The amount of annual reproductive allocation devoted to seeds is not known, nor have any observations been made as to the presence or number of seedlings. This species appears to be palatable to livestock or native mammals to some degree, as several observations have been made of closely cropped plants. Palatability is considered a competitive and a ruderal strategy. Nothing is known about the physiology of this species other than the location of its photosynthate storage system at the base of the plant (tubers). In reality, a species can take on a combination of characteristics of ruderal, competitor, and stress tolerant responses. There is not enough data to classify *S. pallidum* definitively, but it appears to fall within a combined strategy of competitive and ruderal responses. This is not surprising as a wetland is a resource rich environment, therefore any species that can persist would need the ability to compete and expand into newly opened habitat. It is possible that *S. pallidum* may prefer microsites along the margins of inundated areas; the ability to take advantage of newly exposed habitat, as might happen if the water level drops and saturated soils become available, is a ruderal and a competitive strategy. Grime's system (1979) is not a foolproof method of classifying autecological strategies for individual species. However, it can tell us where an individual species can be placed in the broader picture.

Sisyrinchium pallidum reproduces sexually by seed. It flowers from June through July. The inflorescence consists of spathes with one to five perfect flowers born on erect pedicels. Capsules produce 20 to 35 seeds per capsule, three to 12 capsules per plant, with undispersed fruits present from June to late August. The genus *Sisyrinchium* is reported to undergo both selfing and outcrossing. Outcrossing is promoted primarily by self-sterility, protandry, or the activities of insects (Cholewa and Henderson 1984). *Sisyrinchium pallidum* was reported to be 100 percent self-compatible and 78 percent self-pollinating in the systematic investigation done by Cholewa and Henderson (1984)

The base chromosome number of *Sisyrinchium pallidum* is $n = 32$. Cholewa and Henderson (1984) did artificial hybridization studies of *S. pallidum*. They found that this species has a relatively high rate of interspecific crossability. Seed production resulted from crosses with *S. montanum* $n = 48$ (40 percent seed set), *S. idahoense* $n = 32$ (58 percent seed set), and *S. radicatum* $n = 32$ (100 percent seed set). It is interesting to note the crossing results with *S. radicatum* (100 percent seed set); the nearest known occurrence of this species to *S. pallidum* is approximately 644 km away in Utah. Molecular data and additional crossing studies may yield interesting answers and questions into the phylogenetic relationships of these two taxa. Artificial hybridization was used to determine genetic relationships within

the *Bermudiana* section of *Sisyrinchium*. Natural hybridization would have significant implications for management purposes giving rise to questions such as 1) is the species being managed a viable entity? and 2) where do populations start and stop? At this time, there are no reports of naturally occurring hybridization of *S. pallidum* with other species.

Selfing may promote homozygosity over time and possibly reduce fitness and the ability of the species to adapt to changing environmental conditions (inbreeding depression). Based upon the systematic study discussed above (Cholewa and Henderson 1984), inbreeding depression could be a significant factor for isolated or small occurrences of *Sisyrinchium pallidum*. On the other hand, selfing provides a mechanism to overcome a lack of pollinators, giving this species a reproductive advantage in the short term, in the event pollination vectors are absent. However, as an outcrosser in the wild, *S. pallidum* would have a long-term reproductive advantage by maintaining higher heterozygosity. Conversely, in the short term, any loss of pollination vectors could theoretically reduce seed set. It is likely that *S. pallidum* may have features of both breeding systems in the wild.

The flowers of *Sisyrinchium pallidum* are showy. There is no empirical evidence describing the mechanisms of pollination. Some occurrences of Rocky Mountain *Sisyrinchium* (species not given) are pollinated by solitary bees of the genus *Lasioglossum* Curt. (Halictidae) (Cholewa and Henderson 1984). Observations indicate that these bees apparently visit *Sisyrinchium* flowers randomly. Sometimes the bee would visit neighboring plants, and at other times, several flowering plants would be passed by before the next visit (Cholewa and Henderson 1984).

Botanists have thought that insect pollination promotes outcrossing. Because *Sisyrinchium* can be self-compatible and self-pollinating, Cholewa and Henderson (1984) suggested that solitary bee behavior might also effect self-pollination. Pollen collection by the bee could cause self-pollination if the anthers dehisced and stigmas matured at the same time, and if the style length brought the stigma to the same height as the anther sacs. This was found to be the case in *S. radicatum* Bicknell, a relative to *S. pallidum*.

No information is available about the physiology of germination or the establishment of seedlings for *Sisyrinchium pallidum*. Moreover, no experimental data exist concerning the fertility or viability of the seeds. No investigations into seed dispersal have been accomplished for this species. The small seeds are dispersed from the capsules and likely fall close to the parent plant. Water may function as a dispersal agent during periods of high water. Hartman (1992) observed that an unknown organism occasionally consumes the fruits. No other observations have been made concerning seed predation of *S. pallidum* fruits. It is not known if *S. pallidum* maintains a persistent seed bank or how long the seeds are viable. There are no other known cryptic phases in the life history of *S. pallidum*.

Phenotypic plasticity is defined as marked variation in the phenotype as a result of environmental influences on the genotype during development. These differences in phenotype may also be due to the age of the individual plant. In the genus *Sisyrinchium*, Cholewa and Henderson (2002) note that immature plants of branched species may appear single-stemmed, and those of typically single-stemmed species are occasionally branched. No observations of phenotypic plasticity have been recorded for *S. pallidum*.

Current literature indicates that relationships commonly exist between most higher plants and mycorrhizal fungi. There are no documented or observed mycorrhizal associations for *Sisyrinchium pallidum*.

Genetic factors such as inbreeding depression and outbreeding depression should be considered in analyzing the genetic fitness of a species. *Sisyrinchium pallidum* is capable of self-pollination and outcrossing (Cholewa and Henderson 1984), both of which may facilitate inbreeding depression and outbreeding depression, respectively. The habitat of *S. pallidum* (wetlands and meadows) is highly favorable to a large number and variety of possible pollinators available to facilitate outcrossing. There is no empirical data to support this idea. As stated in the above discussion, there is evidence of interspecific crossability in *S. pallidum*, albeit through artificial hybridization. Natural hybridization is a facilitator of outbreeding depression (Fenster and Dudash 1994). There is no evidence that *S. pallidum* undergoes natural hybridization; therefore no conclusions can be drawn concerning the effect of outbreeding depression on this species. Given the lack of evidence and understanding, no inferences can be made by the authors concerning inbreeding and outbreeding depression, or any other genetic issue possibly associated with *S. pallidum*.

Demography

The life history of *Sisyrinchium pallidum* remains uninvestigated at this time. No information concerning vital rates, recruitment, survival, reproductive age, or lifespan has been recorded. Field botanists noted estimates of the proportion of populations reproducing on herbarium label data and in CNHP and WYNDD element occurrence records. Approximately 50 to 100 percent of individuals within some occurrences were estimated to be in flower. An estimated 50 to 100 percent of the individuals were in fruit, and 25 to 100 percent of select occurrences were in a vegetative state. None of these data are statistically accurate and only reflect casual visual observations in the field. The only inference to be made is that *S. pallidum* is consistently flowering in those occurrences that were observed, and does not include occurrences that are in a vegetative stage. Revisits to some sites occur approximately every 8 to 10 years noting flowering and fruiting individuals.

A demographic projection matrix provides valuable information about the vital rates of a species and is determined by tracking the fate of individuals over time. There are no established demographic monitoring sites for *Sisyrinchium pallidum*. No data exist in which a population projection matrix or life-cycle diagram as per Caswell (2001) can be constructed. Nevertheless, a simple life-cycle diagram is presented in **Figure 8**. It identifies the limited knowledge available for the species. Question marks in the diagram reflect a lack of understanding of the mechanisms between stages. It is not known if immature stages exist. If there is a juvenile stage, it is unknown if juveniles must attain a certain size before becoming reproductive nor is it known if reproductive adults can revert to a vegetative state. Seed bank dynamics (recruitment rates, seed longevity, necessary scarification, abundance) are unknown but are represented in the diagram by a question mark between seed bank and seed. No information is available on germination rate or seedling survival, depicted in the diagram by a question mark between seed and seedling. The only known cycle is that reproductively mature individuals of *S. pallidum* do set seed, and some of those seeds germinate and eventually become reproductive (Cholewa and Henderson 1984).

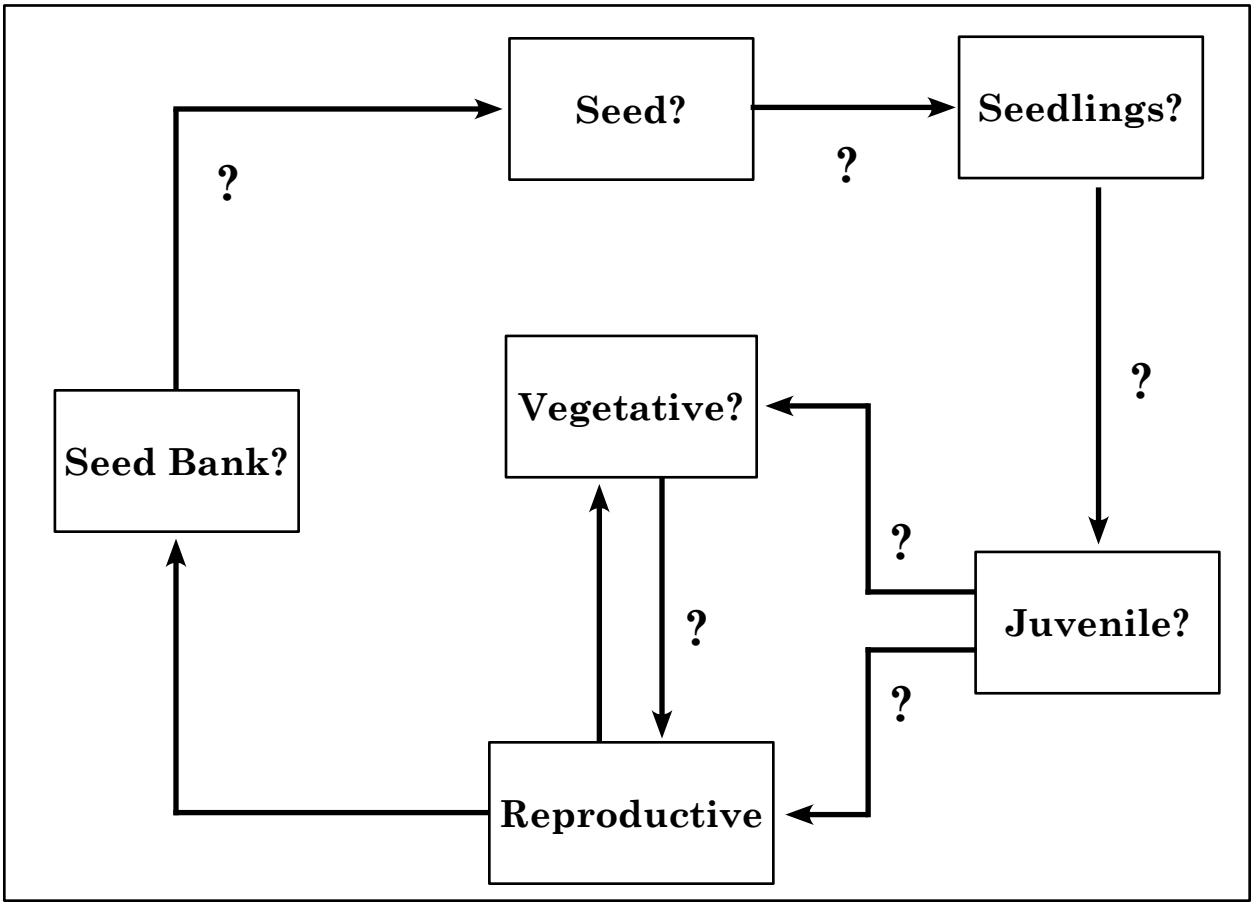

Figure 8. Life cycle diagram for *Sisyrinchium pallidum*.

A population viability analysis (PVA) is a rigorous quantitative analysis that uses demographic data to predict the future status of a given species. A literature search for PVA models for this species was performed, but there has been no PVA accomplished at this time. The minimum viable population (MVP), or the minimum population size necessary to have an acceptably low extinction probability, can provide useful information for management purposes. It has been suggested that demography is of more immediate importance then genetics in determining the MVP of a plant population (Landes 1988, Menges 1991, Schemske et al. 1994). Menges (1991) suggests that if a plant population is able to buffer environmental stochasticity, then the population will be sufficient to protect the genetic integrity of plant populations. No MVP has been determined for *Sisyrinchium pallidum* at this time.

Information concerning the demographic spatial characteristics for this species is limited. A source population is generally a large or overcrowded population patch that cannot support immigration from neighboring populations, but from which individuals can disperse to other population patches or create new population patches. A sink population is a small population that requires immigration in order to sustain itself. It is conceivable that sources and sinks could be identified if all of the EORs reported quantifiable data and if the genetic identity of each population could be identified so that the source of surrounding populations could be determined. However, at this time there is not enough statistically accurate, quantifiable abundance data or genetic information to identify sources and sinks of *Sisyrinchium pallidum* populations. The Distribution and abundance section provides a summary of what is known about the geographic distribution and abundance of *S. pallidum*.

No factors limiting the population growth of *Sisyrinchium pallidum* have been identified. Possible limiting factors include low germination, low seedling survivorship, seed predation by unknown organisms, or changes in substrate due to fluctuations in hydrology. Neither predation nor the effects of grazing pressure have been adequately investigated at any of the known occurrences. Grazing has been observed at 17 of the 39 Colorado occurrences. Currently, no empirical data exist that examine these or any other factors such as seed predation, competition, habitat destruction or fragmentation, or other possible causes of limited population growth.

Community ecology

Colorado Natural Heritage Program EORs document the presence of invasive species such as *Melilotus officinalis* (L.) Lam. (yellow sweet clover), *Phleum pratense* L. (timothy), *Trifolium repens* L. (clover), *Plantago major* L. (broadleaf plantain), and *Poa pratensis* L. (Kentucky bluegrass) at three occurrences (011CO, 009CO, 006CO). No density data were recorded for these species at any of the occurrences. It is unknown if interactions with native species have any effect on the distribution or abundance of *Sisyrinchium pallidum*. Observations of habitat preferences and the autecology of *S. pallidum* lead us to conclude that this species may be a good competitor.

There have been no recorded observations of interactions between *Sisyrinchium pallidum* and native herbivores. Native herbivory may be considered a possible community interaction. Possible native herbivores known to browse mountain meadows include deer, elk, shrews, and montane voles (Emerick and Mutel 1992).

There are no studies investigating parasites or diseases that may affect *Sisyrinchium pallidum*. Nor have there been any investigations of symbiotic or mutualistic interactions.

An envirogram is a useful tool for evaluating the relationship 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 the sugar pine (*Pinus lambertiana* Douglas) showed that the same principals used to construct one for animals could be equally applied to plants (Murphy and Knopp 2000). The envirogram is a series of webs that converge upon a centrum. The centrum consists of the basic components of environment that cause an increase, decrease, or no change in the expectation of fecundity and survivorship of a species. It is the most proximal level of the envirogram and directly affects the target species (Andrewartha and Birch 1984). For plants, the centrum consists of resources (light, soil moisture, and nutrients), reproduction (flowering/ fruiting, growth and development, and seedling establishment), and malentities (fire, extreme weather, human factors, and herbivory).

The envirogram is constructed as a modified dendrogram, with the centrum placed at the most proximal level to the species. From each of the centrum components a web is constructed distally, illustrating factors that affect the centrum component, termed Web 1. Web 2 consists of factors that affect Web 1, and Web 3 consists of factors that affect Web 2, and so on. One of the primary functions of an envirogram is to identify areas of research and to propose hypotheses (Andrewartha and Birch 1984). As with all analytical tools, the best envirogram is based upon a complete data set. An envirogram was constructed for *Sisyrinchium pallidum*. This envirogram reflects the lack of ecological and environmental data. Entries with a question mark denote areas in need of further research, such as pollination mechanisms, herbivory, flowering/fruiting, the effect of disturbance, and dispersal vectors. **Figure 9**, **Figure 10**, and **Figure 11** demonstrate a preliminary envirogram for *S. pallidum*. Web 4 levels and above (Web *n*) generally identify areas beyond the ecological and biological scope of the species. To aid in viewing, each centra is color-coded. The resources centrum is green, the reproduction centrum is yellow, and the malentities centrum is blue.

The resources centrum for *Sisyrinchium pallidum* is made up of three proximal factors: soil moisture, light, and nutrients. Soil moisture for *S. pallidum* is affected by precipitation, soil porosity (permeability), soil water retention, and runoff. Vegetation cover can affect light, and such things as substrate parent material and the addition of organic materials affect the nutrient centrum. The reproduction centrum consists of factors that affect flowering and fruiting (pollination, weather, dispersal), seedling establishment (possible safe sites, substrate, protection), and growth and development (weather, cover, substrate). The malentities centrum identifies factors that may negatively affect *S. pallidum*. These include such things as extreme weather conditions, for example drought or unusually cold weather during the flowering and fruiting season. Herbivory may cause damage through trampling, flower or seed predation, or leaf or root damage. This may result from either domestic livestock or native fauna, including mammals and waterfowl. Competition from invasive species, introduced through agriculture or development, may have a negative effect upon the ability of *S. pallidum* to occupy available habitat. The loss of hydrology through drought, development, or agriculture could seriously affect the overall survival of this species because it appears to require a substrate with high soil moisture.

CONSERVATION

Threats

The majority of the occurrences of *Sisyrinchium pallidum* (40 of 66 occurrences) are located on private lands. Viability concerns are associated with the management of the wetland habitats in which the species occurs on both public and private lands. O'Kane (1988) identified activities that drain wetlands (including ditching and water diversion projects) and may threaten the species' habitat. As discussed in the Habitat section, the hydrology that supports wetland communities where *S. pallidum* may occur has not been fully evaluated. Sources of hydrology identified in the EORs include springs, seeps from ponds, roadside runoff/accumulation, stream banks, and irrigation. Hydrology sources, depth to groundwater, and duration and seasonality of inundation have not been fully evaluated. Hartman (1992) suggests that agricultural irrigation may have possibly enhanced population growth and distribution. Extreme drought may lower water levels controlling the distribution of the species in wetland habitats. It is unknown if the current drought cycle in the Rocky Mountain Region has affected the wetlands in which *S. pallidum* occurs. Unusually cold springs or deep wet peat deposits may delay reproduction and subsequently seed set.

The 66 known occurrences of *Sisyrinchium pallidum* are generally located in accessible areas. No backcountry surveys specific to *S. pallidum* have been accomplished as far as the authors could determine. Road modification may present a potential threat to some occurrences on either public or private lands by impacting or altering the hydrology supporting the species' habitat. Road maintenance, including grading ditches, oiling dirt roads, applying herbicides, installing cattle guards, salting in winter, realignment, and other maintenance activities could affect the viability of occurrences of *S. pallidum*. Numerous occurrences are located near both state and county roads and other possible travel routes.

Herbicide use in or near occurrence areas could be detrimental to the species. Specific threats include the use of broad-spectrum herbicides during vegetative and reproductive periods. This could diminish vegetative growth or delay or stop the reproductive process. As a monocot, the species may not be impacted by application of broadleaf herbicides. No information is available to determine overall threat from herbicide use.

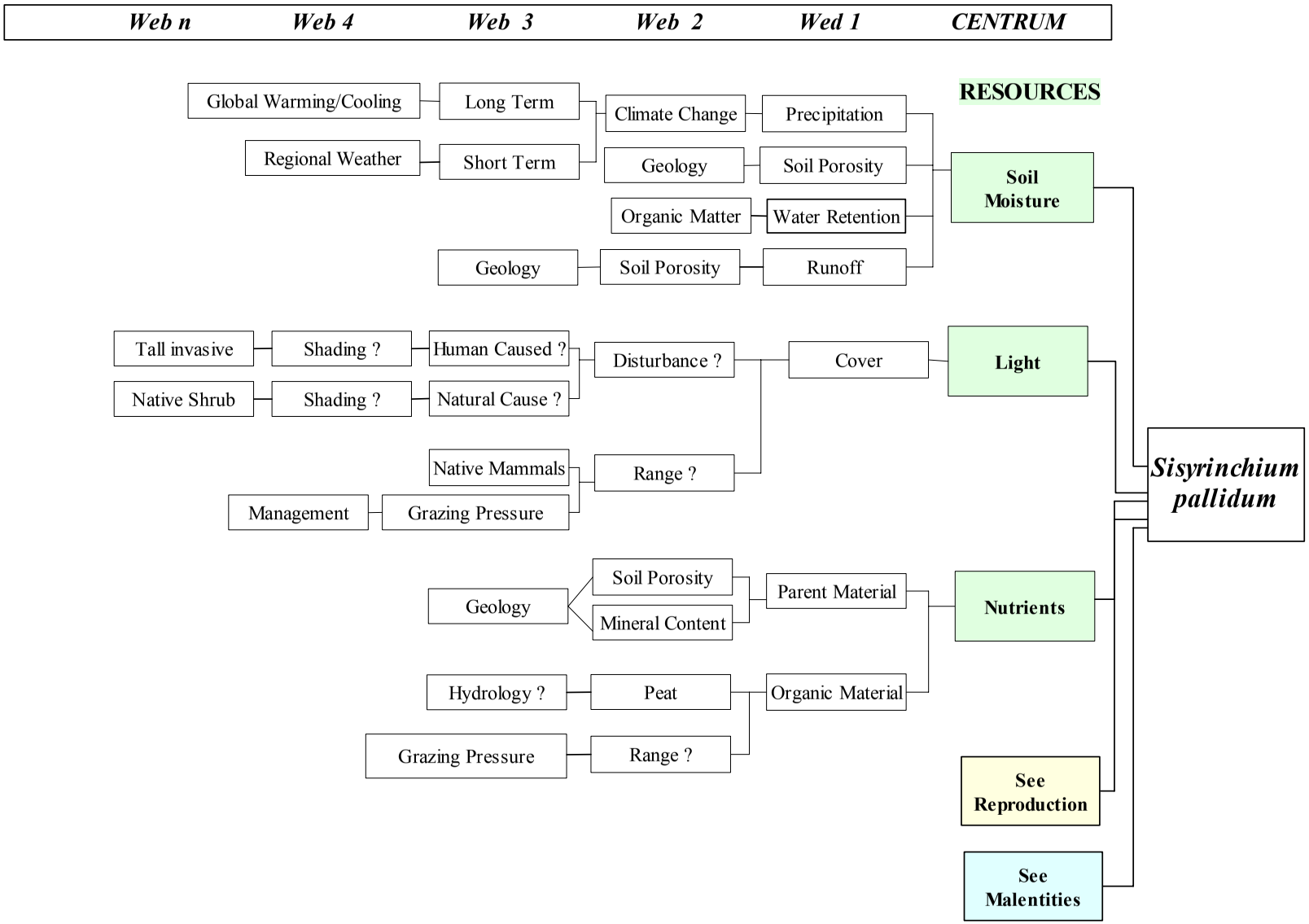

Figure 9. Envirogram for *Sisyrinchium pallidum*, resources centrum.

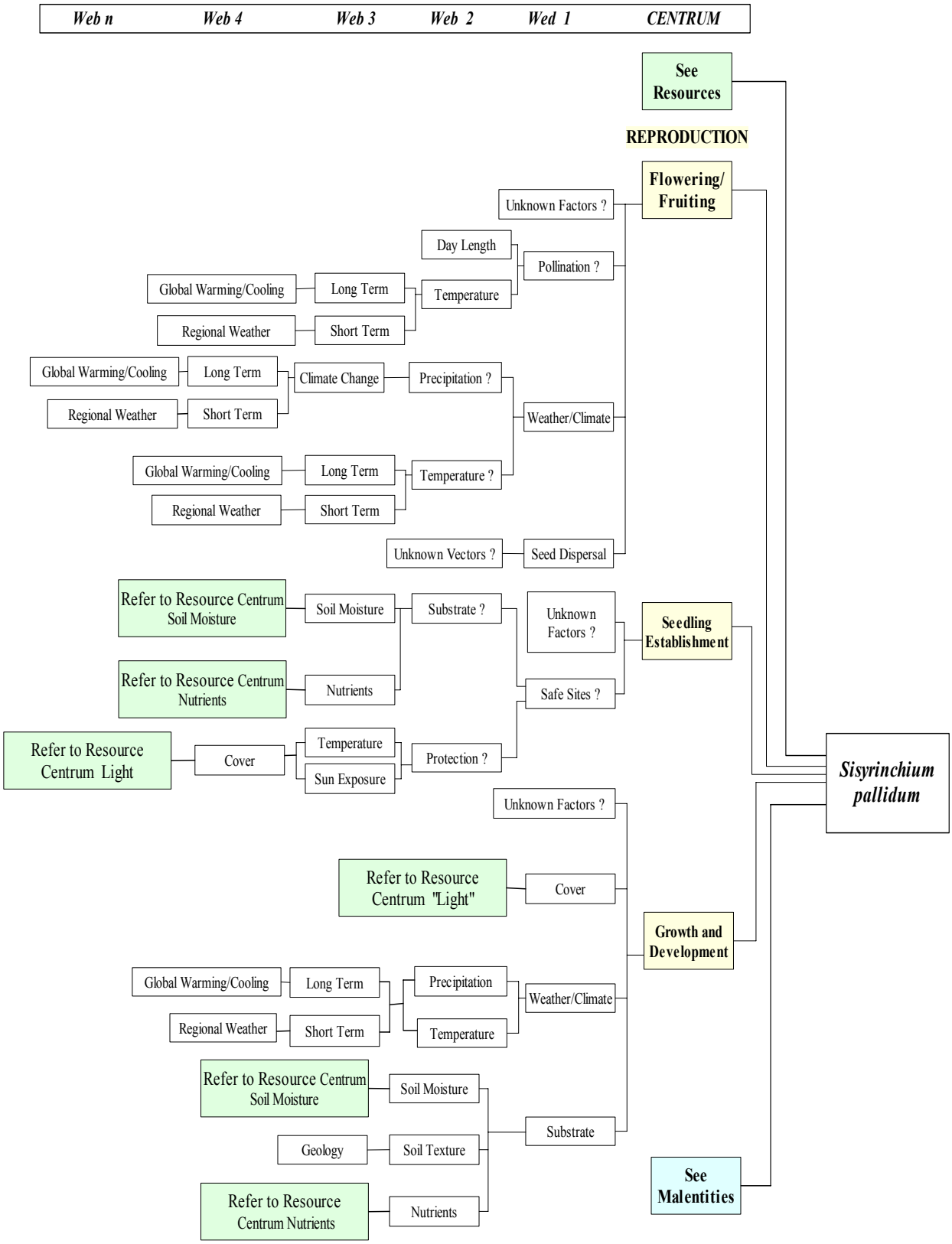

Figure 10. Envirogram for *Sisyrinchium pallidum*, reproduction centrum.

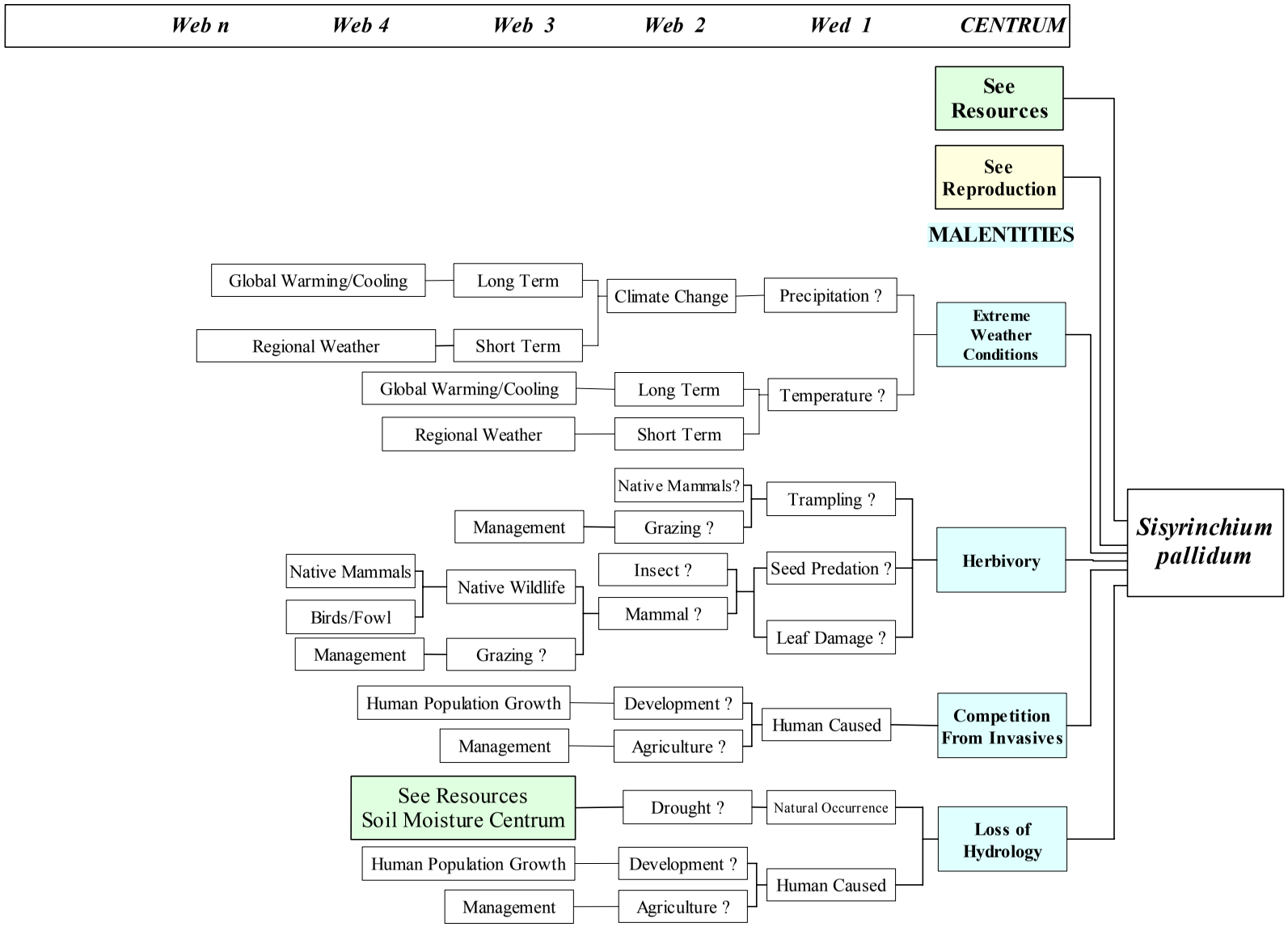

Figure 11. Envirogram for *Sisyrinchium pallidum*, malentities centrum.

Hartman (1992) identified residential development as having impacted one occurrence in Wyoming. This occurrence could be decimated in the future as the result of filling of the wetland. No information is available as to the status of this proposed development. The majority of the occurrences are located in rural areas of South Park, Colorado or Laramie Basin, Wyoming with limited potential residential development in these areas (J. Sanderson personal communication 2003).

Biologists at CNHP have identified grazing by cattle as a potential threat to individual plants, occurrences, and habitats in Colorado. **Table 6** summarizes the notes and observations of grazing of occurrences in Colorado. There are no data to determine quantifiable intensities; however, occurrence records either noted heavy, light, or, an undetermined level of grazing. Question marks indicate uncertainty about intensity, based upon the records available. Jennings (1990) reported that all occurrences of *Sisyrinchium pallidum* in Colorado (excluding the Rocky Mountain National Park occurrence) have been extensively grazed. However, at the time of Jennings' report, there were only 10 known occurrences of *S. pallidum* in Colorado. Current EOR information indicates that of the 39 occurrences in Colorado, 18 have been extensively grazed, and 21 occurrences record no observation of grazing. No comments were recorded on grazing or intensities near occurrences located on USFS lands, however, a CNHP biologist noted that at occurrence 011CO on the Pike-San Isabel National Forest that trampling was occurring near an existing stock tank and recommended moving the stock tank away from the occurrence to avoid trampling of the occurrence site. Hartman (1992) identified the primary land use in the vicinity of *S. pallidum* occurrences in Wyoming to be livestock grazing. No specific EOR locations were recorded as being grazed or intensity noted. General field observations include trampling, cutting of turf, and foraging damage. It is unknown what effect grazing may have upon pollinators in the general area.

It is not known if the timing of a grazing cycle may negatively or positively affect flowering and fruiting, or if impacts are minimized if grazing occurs after seed dispersal. It is possible that grazing may suppress woody plant growth and ultimately benefit *Sisyrinchium pallidum*, but no observations or evidence are available to either support or refute this. It has been suggested in the occurrence records that deferred grazing may be a viable management tool. Palatability of this species has been suggested but not verified.

Placement of water tanks or loading areas near known occurrences may impact the species through trampling or grazing. Damage to the wetland habitat and stream banks from trampling has been identified (Jennings 1990). Secondary grazing impacts from trailing, soil compaction, erosion and spread of noxious weeds may occur. Modification of hydrology as a result of grazing in the wetland habitats associated with *Sisyrinchium pallidum* has not been evaluated. Agricultural activities, including the harvesting of native grass hay in the South Park vicinity, may pose a potential threat to the species if harvesting is conducted before seed set (Jennings 1990). Conversely, irrigation associated with agricultural activities has greatly enhanced occurrences in Wyoming (Hartman 1992).

In Wyoming, threats to specific occurrences include alteration or reduction of irrigation regimes on private lands (Hartman 1992). In Colorado, alterations of irrigation patterns have been identified as potential threats, namely reducing the water used (Jennings 1990). Water rights utilized for irrigation have reportedly been subject to acquisition by urban centers located in the Front Range of Colorado. The Aurora Conjunctive Use Project was proposed in the 1990's to remove water from irrigated rangelands in the South Park valley of Colorado (J. Sanderson personal communication 2003). The status of this project is undetermined at the time of this assessment, but it could pose a direct threat to species occurrences located in South Park, should the project be implemented.

Occurrences of *Sisyrinchium pallidum* have been threatened in the past by peat mining. Peat fens have been estimated to occupy 1,500 hectares in South Park, Colorado. Historic mining of these fens has impacted 20 percent of the total area (290 hectares). These fens are naturally occurring and not the result of irrigation. Current levels of peat mining activity in the South Park valley have been reduced due to regulation by the U.S. Army Corps of Engineers and consultations with the U.S. Fish and Wildlife Service (J. Sanderson personal communication 2003). Protection and rehabilitation of the High Creek Fen Preserve by The Nature Conservancy will preserve occurrences located in that area.

Observations by CNHP biologists suggest that competition from invasive species from adjacent pastures may pose a threat to this species (see Community Ecology section). This possibility has never been adequately studied, and there is no evidence to suggest a positive or negative effect. Observations of

Table 6. Grazing observations of Colorado occurrences of *Sisyrinchium pallidum*. Taken from element occurrence records (Colorado Natural Heritage Program 2003).

EOR	County	Grazed? Yes/No	Intensity Heavy/Light/None	Land ownership
001CO	Park	Yes	Light	Private
002CO	Park	Yes	Heavy	Denver Water Department: leased to State of Colorado
003CO	Larimer	No	None	National Park Service: Rocky Mountain National Park
004CO	Park	Yes	Light	Private: The Nature Conservancy
005CO	Park	Yes	Heavy	State of Colorado: Tomahawk State Wildlife Area/private
006CO	Park	No	None	Private
007CO	Park	Yes	Light	Private
008CO	Park	No	None	Private
009CO	Larimer	No	None	State of Colorado /private
010CO	Park	Yes	Light?	Private
011CO	Park	No	None	Pike-San Isabel National Forest
012CO	Park	Yes	Heavy	Private
013CO	Park	Yes	Heavy	State of Colorado Land Board
014CO	Park	Yes	Heavy	State of Colorado Land Board
015CO	Park	Yes	Heavy	State of Colorado Land Board
016CO	Saguache	Yes	Light?	Private
021CO	Jackson	No	None	Routt National Forest
025CO	Park	No	None	State of Colorado/private
026CO	Park	Yes	Light?	Unverified private
027CO	Park	No	None	Unverified private
028CO	Park	No	None	Unverified private
029CO	Park	No	None	Unverified private
030CO	Park	No	None	Unverified private
031CO	Park	No	None	Unverified private
032CO	Park	No	None	Unverified private
033CO	Park	Yes	Heavy	Unverified private
034CO	Chaffee	Yes	Light	Unverified private
035CO	Larimer	Yes?	Light?	Unverified private
036CO	Larimer	Yes	Heavy	State of Colorado
037CO	Larimer	Yes	Light?	Private
039CO	Park	No	None	Pike-San Isabel National Forest
040CO	Park	Yes	Heavy	Unverified private
041CO	Park	No	None	Pike-San Isabel National Forest
042CO	Park	No	None	Unverified private
043CO	Park	No	None	Unverified private
044CO	Park	No	None	Private
045CO	Park	No	None	Unverified private
046CO	Park	No	None	State of Colorado
047CO	Park	No	None	State of Colorado Wildlife Area

seed predation by an unknown organism were recorded for an occurrence in Wyoming (Hartman 1992). No investigations have been conducted to determine the nature or extent of this threat.

The Moraine Park occurrence is located on lands administered by the National Park Service (Rocky Mountain National Park). Recreation poses a potential threat to the species in the form of roads, trails, and campgrounds located in the vicinity. The wetland habitat supporting the occurrence has not been directly impacted by the recreational activities due to its marshy nature; however surrounding activities have the potential to increase erosion adjacent to the occurrence (Jennings 1990).

Four occurrences are located on USFS lands (011CO, 021CO, 039CO, and 041CO). Specific threats to two of the occurrences located on the Pike-San Isabel National Forest have not been identified (039CO and 041CO). Occurrence 011CO, on the Pike-San Isabel National Forest, is located near U.S. Hwy 24. Observers have noted exotic species encroaching into *Sisyrinchium pallidum* habitat where the culvert crosses the highway. Additionally, CNHP biologists noted that a nearby stock tank encouraged trampling of the plants and recommended moving the stock tank away from the occurrence. Occurrence 0021CO is located on the Routt National Forest. The occurrence consists of approximately four plants that are growing approximately six inches from the edge of a multi-use trail. Potential threats include trampling from hiker, equestrian, or off-road vehicle use. Other potential impacts may include picking the plants or introducing exotic species from the adjacent trail.

No research has been conducted evaluating whether the species has been over-utilized for commercial, recreational, scientific, or educational purposes or if it has been threatened by disease, predation, or other natural or manmade factors that affect its continued existence.

Little knowledge is available to determine the degree of threat posed by natural or prescribed fire. Occurrences are located in wetland areas with minimal tree and shrub cover; there is a small likelihood for natural or prescribed fire during the growing season. A bibliography of fire effects on threatened and endangered species can be found in Hessl and Spackman (1995), and effects of wildland fire to plant species in general are discussed in Brown and Smith (2000). No references were identified in these publications specifically concerning effects of fire to *Sisyrinchium pallidum*.

Conservation Status of the Species in Region 2

There are no established demographic monitoring sites for *Sisyrinchium pallidum*, nor have records been maintained noting changes in population size at any of the known occurrences. No inferences about population trend for the species at the scale of individual occurrences or rangewide can be made. Due to the lack of data, no inferences can be made concerning the temporal pattern of abundance at any spatial extent. Historically, occurrence information indicated that population distribution was limited to South Park, Colorado with occasional peripheral occurrences identified in wetland areas surrounding the South Park valley. However, botanical surveys conducted in Wyoming in 1992 showed that the range of the species included southern Wyoming (Hartman 1992). New discoveries in Wyoming indicated that occurrences are much larger than originally thought. *Sisyrinchium pallidum* occurs in expansive population centers in the Laramie Basin (occurrences estimated at 100,000 individuals or more), while occurrences in Colorado (including those on USFS Region 2 lands) report small population sizes ranging from 4 to thousands (see **Table 4** for information on occurrences in both areas).

Knowledge concerning optimal habitat quality and ecology of the species is limited. Hydrology and function of these habitats have not been investigated. Original observations indicated that perhaps the species was an alkaline obligate or calicole. However, information collected as part of this assessment indicates that perhaps this species may tolerate a wider range of soil pH. As stated in the Reproductive Biology and Autecology section, no empirical data is available describing ecological strategies for *Sisyrinchium pallidum*. As stated above in the Threats section, viability concerns are associated with the management of the wetland habitats in which the species occurs. All occurrences were associated with wetland habitat types. If the hydrology is lost, then negative impacts could occur. However, should water be introduced, it is possible that the habitat could be extended.

Occurrences of *Sisyrinchium pallidum* may not be at risk from environmental or demographic stochasticity due to the large size of occurrences in Wyoming. Factors reducing such risks include the fact that distribution does not appear to be restricted to a particular soil type

and that occurrences are not geographically isolated. So far, there are no identified specific mutualisms including mycorrhizal partners, pollinators, or dispersers. However, no investigations have been conducted concerning these mutualisms. There is no evidence to suggest inbreeding or outbreeding depression or that natural hybridization may increase its vulnerability to stochastic risk. *Sisyrinchium pallidum* is known to be self-compatible and assumed to outcross (Cholewa and Henderson 1984). This combination may reduce its vulnerability (Menges 1991).

There is little direct evidence to indicate whether or not specific occurrences of *Sisyrinchium pallidum* in Region 2 or rangewide are at risk. Only two of the four USFS Region 2 occurrences have identified threats, including presence of exotic species, a stock tank, and a multi-use trail (see previous section). The discussion in the preceding paragraphs indicates that perhaps several threats may affect *S. pallidum* rangewide. Evaluation of effects of management on species fitness has not been conducted. However, any management direction that would affect the hydrology of the species habitat on private or public lands should be evaluated for impacts to the species.

Potential Management of the Species in Region 2

Implications and potential conservation elements

No federal protected areas that include the conservation of this species or its habitat as an explicit goal have been designated. *Sisyrinchium pallidum* has documented occurrences in two national forests: the Pike and San Isabel National Forest (three occurrences) and the Routt National Forest (one occurrence). Primary population centers are located outside National Forest System lands, but several are located within close proximity to USFS boundaries. These populations could extend into national forest or be impacted by activities conducted on these lands. Viability concerns for *S. pallidum* are associated with the management of the wetland habitats in which the species occurs.

No evidence was identified that suggested that *Sisyrinchium pallidum* naturally hybridizes. Experimentally this species has been shown to readily cross with *S. montanum* and *S. idahoense* var. *occidentale*, two members of the genus that sometimes grow with *S. pallidum*. Should hybrids be common, a metapopulation analysis will need to be conducted to define the populations. Hybrid populations may reduce the vigor of the species and blur the boundaries of known species. *Sisyrinchium pallidum* has been shown to readily self-fertilize under laboratory conditions (Cholewa and Henderson 1984), therefore small or isolated populations may be at risk of inbreeding depression. Field studies designed to determine the extent of selfing and outcrossing, as well as to identify pollinators for this species, would discover if this is a viable risk for the species.

Management activities may have direct or indirect impacts to individuals or occurrences of *Sisyrinchium pallidum*. No experimental data are available on the response of this species to management actions. Activities potentially occurring on National Forest System lands that may pose a threat to individuals or occurrences of *S. pallidum* include grazing, road construction, recreational activities, fire, herbicides use, and competition from invasive species. 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.

Tools and practices

Little historical abundance data were available before the Colorado and Wyoming Natural Heritage Programs began tracking this species. Continued efforts in the location of other occurrences through surveys may provide additional information concerning distribution and abundance of the species. Search parameters for both private and public land include:

- wetlands, fens, riparian corridors, and wet meadows
- areas where soils are typically inundated in the spring and soils are derived from Quaternary alluvium and colluvium that remain saturated throughout the growing season, particularly those areas that derive their water source from calcareous-based watersheds
- elevations ranging between 1,999 and 2,956 meters
- timing of surveys to be conducted from the middle of June through the middle of July when *Sisyrinchium pallidum* flowers

- presence of *Pedicularis crenulata* Benth., *Juncus balticus* Willd., and *Pentaphylloides floribunda* (Pursh) that may function as indicator species.

Population monitoring should be designed to efficiently ascertain parameters of the species' life history, including generation time, net reproductive rate, age distribution, and potential reproductive output lost to abortion and predation. Periodic estimates of population size alone may not provide adequate information for management decisions (Elzinga et al. 1998).

Additional quantitative data that document the condition of the community where *Sisyrinchium pallidum* occurs including the plant composition, structure, and function would make information available to infer existing conditions should an increase or decline in *S. pallidum* occurrences take place. This information may also provide clues as to possible limiting factors that control the distribution of the species. Common variables to be measured include cover or density of all plant species, demographic parameters of important species, soil surface conditions, frequency of inundation, and depth to ground water. Measurement and scheduled remeasurement would provide long-term ecological information to document rates and types of change that can occur in response to natural processes, such as succession and disturbance, and to management activities (Elzinga et al. 1998).

Habitat monitoring describes how well an activity meets the objectives or management standards for the habitat (Elzinga et al. 1998). Establishing a minimum total vegetative plant cover and type of forage species in a grazing allotment would be an example. Habitat monitoring is most effective when research has shown a clear link between a habitat parameter and the condition of a species (Elzinga et al. 1998). Without additional knowledge of specific factors controlling the growth and distribution of *Sisyrinchium pallidum*, it would be difficult to utilize this type of sampling program. Collection of quantitative data relevant to community structure and composition as mentioned above would provide a baseline for use of this methodology.

Investigations into the effects of grazing by commercial livestock on *Sisyrinchium pallidum* habitat need to be initiated. Possible tools include construction of grazing enclosures with subsequent analysis of reproductive output and density compared to similar sites that are grazed. Information from an investigation of this type could yield answers to questions such as 1) are the introduced animals suppressing woody plant growth to the benefit of *S. pallidum*? 2) are the current stocking rates too high 3) would the elimination of grazing result in more reproduction 4) how long would it take to realize an increase or decrease in *S. pallidum* after constructing an enclosure?

No management approaches have been identified for the species. Jennings (1990) and Hartman (1992) suggested that hydrology was critical for maintaining the species' distribution. Any management objectives affecting the hydrology of known occurrence areas should be evaluated to determine potential impact to *Sisyrinchium pallidum*.

Information Needs

Continued efforts in the location of other occurrences of *Sisyrinchium pallidum* through surveys may provide additional information concerning distribution and abundance of the species to assist in the formulation of conservation strategies for Region 2. Monitoring studies were proposed for The Nature Conservancy's High Creek fen site, but these were not implemented due to the difficulty of identifying individuals in the vegetative state (T. Schultz personal communication 2004).

Areas for further study include:

- Continued efforts in the location of other occurrences of *Sisyrinchium pallidum* through surveys on both public and private lands, including utilization of the model prepared by Fertig and Thurston (2003) for Wyoming

- Surveys on both public and private lands for other species of *Sisyrinchium* to determine the extent of overlap and to clarify the identification of known occurrences

- Data collection at High Creek fen site managed by The Nature Conservancy, including monitoring the species' response to fen reclamation projects and to alteration of grazing regime.

- Collection of quantitative data relevant to species composition and wetland criteria on both public and private lands to provide a baseline for use of habitat monitoring in the future.

- ❖ Collection of quantitative data relevant to hydrology and soils controlling species distribution on both public and private lands to provide a basis for effective management.

- ❖ Initiation of field studies on both public and private lands to determine the extent of selfing and outcrossing as well as to identify important pollinators.

- ❖ Answering basic demographic quest-ions (vital rates, recruitment, survival, reproductive age, lifespan or proportion of populations reproducing, seed viability, seed bank dynamics, longevity) that have not been addressed by population viability studies on either public or private lands.

- ❖ Storing plant material (seeds) with the Center for Plant Conservation, whose mission is to conserve and restore the rare native plants of the United States.

The primary concern for the viability of *Sisyrinchium pallidum* is its limited global distribution, which is at risk as a result of the management of the wetland habitats in which it occurs. No information is available concerning impacts of management to the species.

DEFINITIONS

Alleles — Any of the different forms of a gene occupying the same locus (Lincoln et al. 1982).

Fen — A palustrine persistent emergent wetland with fresh/alkaline water chemistry (Cowardin et al. 1979). A eutrophic mire with a winter water table at ground level or above (Lincoln et al. 1982). A peat bog, which forms under alkaline conditions (Elliot-Fisk 1988).

Heterozygosity — Having two different alleles at a given locus of a chromosome pair (Lincoln et al. 1982).

Homozygosity — Having identical alleles at a given locus of a chromosome pair (Lincoln et al. 1982).

Inbreeding — Mating or crossing of individuals more closely related than average pairs in the population (Lincoln et al. 1982).

Inbreeding depression — Reduction of fitness and vigor by increased homozygosity as a result of inbreeding in a normally outbreeding population (Lincoln et al. 1982).

Locus — The position of a given gene on a chromosome (Lincoln et al. 1982).

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

Monophyletic — Derived from the same ancestral taxon; used of a group sharing the same common ancestor (Lincoln et al. 1982).

Phenology — Study of the impact of climate on seasonal occurrence of flora (dates of flowering, budding etc.) and the periodically changing form of an organism, especially as it affects its relationship with its environment (Allaby 1992).

Polyphyletic — Derived from two or more distinct ancestral lineages; used of a group comprising taxa derived from two or more different ancestors.(Lincoln et al. 1982).

Polyploid — Having more than two sets of homologous chromosomes (Lincoln et al. 1982).

Protandry — The maturation of the anthers before the carpels (Allaby 1992).

Outbreeding depression — Reduction of fitness and vigor in the progeny when individuals mate from distant source populations (Lincoln et al. 1982).

Outcrossing — Mating or crossing of individuals that are either less closely related than average pairs in the population, or from different populations (Lincoln et al. 1982).

Self-compatible — Used of a plant that can self-fertilize (Lincoln et al. 1982).

Selfing — Self-fertilizing or self pollinating (Lincoln et al. 1982).

Toposequence — A mosaic with a group of communities that reflect topographic differences and do not share a successional sequence. For example, a wetland may be dependent upon a depression where water accumulates, and is therefore not part of the surrounding community that may reflect a different sequence (Barbour et al. 1987).

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

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