Eleocharis elliptica Kunth (elliptic spikerush): A Technical Conservation Assessment

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James E. Nellessen, Ph.D.
Taschek Environmental Consulting
8901 Adams St., NE, Suite D
Albuquerque, NM 87113

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AUTHOR'S BIOGRAPHY

James E. Nellessen has an extensive background in botany, biology, ecology, and plant pathology. He is experienced in environmental compliance surveys, including threatened and endangered species surveys, vegetation analysis and mapping, wetland delineation, and baseline biological surveying. He obtained his Ph.D. in Botany in 1989 from Ohio University. His Ph.D. research work centered on the population biology and physiological ecology of the grass, *Andropogon virginicus*, in abandoned coal strip mine and old field habitats in Ohio. He has a B.S. in Biology from the University of Minnesota (1979) and obtained his M.S. in Plant Pathology from Virginia Tech (1983). His research at Virginia Tech focused on the impacts of air pollution to vegetation. He did postdoctoral work at the University of Oklahoma where he worked on developing computer databases containing information on the toxicity and accumulation of environmental contaminants in plants. This work was funded by the US Environmental Protection Agency. He has been working in New Mexico since 1994. He has previously worked with the New Mexico Environment Department and the New Mexico State Highway and Transportation Department. He has written biological assessments for the Lincoln National Forest (Scott Able Fire) and Santa Fe National Forest (Cerro Grande Fire) in New Mexico. He has written brief but comprehensive reports on the biology and ecology of 13 species of shrubs for the USDA Forest Service Shrub Sciences Lab in Provo, Utah (as part of the Wildland Shrub Project). He is also experienced in conducting noxious weed surveys and management planning, research designs, rangeland health assessments, air quality regulations, air toxics programs, smoke management plans, plant toxicity, and contaminated soil bioremediation. Jim has given numerous meeting presentations on biological and environmental topics and has published many articles between 1983 and 2004. Jim is a member of the American Institute of Biological Sciences, the Society for Ecological Restoration, the Association of Southwestern Naturalists, the Native Plant Society of New Mexico, and the American Society of Mining and Reclamation.

COVER PHOTO CREDIT

Eleocharis elliptica (elliptic spikerush). Photograph by Emmet J. Judziewicz. Used with permission.

SUMMARY OF KEY COMPONENTS FOR CONSERVATION OF *ELEOCHARIS ELLIPTICA*

Status

The USDA Forest Service (USFS) Rocky Mountain Region (Region 2) has included *Eleocharis elliptica* (elliptic spikerush) on the Regional Forester's Sensitive Species List since 2002 (USDA Forest Service 2005). The only other conservation ranking status for the species in USFS Region 2 is in Wyoming. The Wyoming Natural Heritage Program has classified it as S1 (critically imperiled), but stated that it has a low conservation concern because it has a peripheral distribution relative to Region 2 (i.e., Region 2 is on the southwestern edge of the species' overall range). *Eleocharis elliptica* has a Nature Conservancy global ranking of G5 (secure).

The actual frequency of its occurrence in Region 2 is unclear due to uncertainties regarding the taxonomic identity of specimens housed within Region 2 herbaria. There is also a general lack of information on its abundance, biology, and ecology. *Eleocharis elliptica* is a perennial plant species found in wetlands. Its occurrences in central and western North America (including USFS Region 2) may be more correlated with calcareous or saline wetlands than elsewhere across its distribution.

Primary Threats

The following summary of threats to *Eleocharis elliptica* and its habitats is not a prioritized list. Although items near the top may be of greater concern, any one of these threats could be of greater or lesser concern to a particular occurrence of *E. elliptica* in USFS Region 2 at a particular point in time. The primary threats to this species include:

1) impacts to or loss of wetlands in general, including fragmentation; drainage of wetland sites is a specifically-identified type of wetland impact or loss affecting *E. elliptica*

2) off-road vehicle use

3) road building

4) increased influx of nutrients (e.g., nitrogen)

5) runoff from catastrophic events such as stand replacement wildfires

6) overgrazing of wetland sites by commercial livestock

7) seeding adjacent areas to non-native plants

8) invasive plant species (non-native or native)

9) long distance input of air pollutants

10) global climate change

Primary Conservation Elements, Management Implications and Considerations

Primary conservation elements and management implications were derived from an evaluation of the sparse literature on *Eleocharis elliptica*, as well as a general consideration for the wetland habitats in which it resides. Until more is known and clarified about its taxonomy, biology, and ecology, protecting wetland habitats will be the most important and primary element towards managing and conserving this species in USFS Region 2. The following list of conservation elements is not in a prioritized order. Land managers are encouraged to carefully evaluate the situation

at each *E. elliptica* site and make their own determination on which elements are most appropriate for a particular site at a particular point in time. The primary conservation elements for this species are:

1) protect and preserve wetlands, mitigate against impacts to wetlands, and use proactive approaches to protect and preserve wetlands

2) maintain a stable wetland environment while realizing that these sites in Region 2 may undergo seasonal wetting and drying cycles, and the drying cycles could become longer under drought conditions

3) maintain water depth and natural water regimes at *E. elliptica* sites (e.g., nearby irrigation systems may reduce wetland water tables)

4) protect the greater habitat matrix, including upland habitat, surrounding small, isolated wetland sites containing *E. elliptica*

5) use prescribed fire and mowing in surrounding uplands to prevent the colonization of wetland sites by woody species

6) avoid mid-summer mowing in and around wetlands with *E. elliptica* as this practice may prevent plants from flowering and thus eliminate or reduce seed production; consequently, mowing to manage woody species invasion is best done after *E. elliptica* has set seed and gone dormant for the season so that seed will be available to help establish new generations

7) avoid draining and ditching of wetland areas containing *E. elliptica* as this is expected to negatively impact its population viability

8) maintain species richness at known *E. elliptica* sites or potentially suitable sites as *E. elliptica* may exist in the more species-diverse zone of a wetland

9) avoid alterations to natural spring seeps that would divert water at sites with *E. elliptica* and be aware that such sites are potentially suitable for locating new occurrences; a constant source of ground water (e.g., spring seep) may be another indicator of microhabitat preference.

10) be aware that wetlands with calcareous or possibly saline substrates may be more likely places to locate new occurrences of *E. elliptica* as the species appears to be more common or adapted to these substrates (at least in the central and western portion [including Region 2] of its range

11) maintain a low available phosphorus level and prevent excessive influxes of nitrogen at a site as *E. elliptica* may be negatively impacted by an influx of nutrients to its habitat, especially nitrogen.

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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), USDA Forest Service (USFS). *Eleocharis elliptica* (elliptic spikerush; **Figure 1**) is the focus of an assessment because Region 2 is situated on the fringes of its distribution, there are infrequent occurrences of the species in Region 2, and because this species was placed on the Regional Forester's Sensitive Species List (USDA Forest Service 2005) in 2002. Within the National Forest System, a sensitive species is a plant or animal whose population viability is identified as a concern by a Regional Forester because of significant current or predicted downward trends in abundance and/or in habitat capability that would reduce its distribution (FSM 2670.5 (19)). A sensitive species requires special management, so knowledge of its biology and ecology is critical. This assessment addresses the biology of *E. elliptica* throughout its entire range and its range in Region 2. This introduction defines the goal of the assessment, outlines its scope, and describes the process used in its production. In this document, use of the term population will include both its most generally understood ecological meaning (i.e., a group of interbreeding individuals) and sites or locations where the species exists (i.e., occurrences).

Goal

Species 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

Figure 1. Photograph of *Eleocharis elliptica (*elliptic spikerush). Source: Freckmann Herbarium, University of Wisconsin (2004), Stevens Point, WI (photographed by Emmet J. Judziewicz). The specimen may be of *E. compressa* or intermediate with *E. elliptica* (Smith personal communication 2006). Used with permission.

scientific knowledge, discussions of broad implications of that knowledge, and outlines of information needs. The assessment does not seek to develop specific management recommendations. Instead, 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) that will be used by managers to direct land management decisions. Furthermore, this assessment cites management recommendations proposed elsewhere and examines the success of those that have been implemented.

Scope

This assessment examines the biology, ecology, conservation status, and management of *Eleocharis elliptica* with specific reference to the geographic and ecological characteristics of the USFS Rocky Mountain Region. However, the biology, ecology, and distribution of *E. elliptica* cannot be fully understood unless information across its entire geographic range is assessed. Also, much of the literature on this species originates from field investigations outside of Region 2. Consequently, this assessment discusses the species across its entire North American range, but it focuses on concerns in USFS Region 2 and places that literature in the ecological and social contexts of the central Rocky Mountains. Similarly, this assessment is concerned with reproductive behavior, population dynamics, and other characteristics of *E. elliptica* in the context of the current environment rather than under historical conditions. The evolutionary environment of the species is considered in conducting the synthesis, but it is placed in a current context. The reported historical presence of this species will be discussed herein as it is modified by the taxonomic uncertainties surrounding this species. There appear to be substantial differences between a recent Flora of North America publication (Smith 2002) and previous sources of information (including the field experience of professional botanists, ecologists, and Natural Heritage Program botanists across the region) as to whether *E. elliptica* even occurs within Region 2.

In producing the assessment, refereed literature, non-refereed publications, research reports, and data accumulated by resource management agencies were reviewed. Not all publications on *Eleocharis elliptica* are referenced in the assessment, nor were all published materials considered equally reliable. The assessment emphasizes refereed literature because this is the accepted standard in science. Non-refereed publications or reports were regarded with greater skepticism and used only when information was unavailable elsewhere. Unpublished data (e.g., Natural Heritage Program records) were important in estimating the geographic distribution of this species. These data required special attention because of the diversity of persons and methods used in collection.

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). Although critical experiments in the ecological sciences can be conducted, due to the numerous ecological and environmental variables involved, often the results are not straight forward. In the ecological sciences, multi-year experiments are preferred, but observations and results from one or two year studies are still useful towards understanding the species. Consequently, sometimes general (or short-term) observations, inference, good thinking, and models must be relied upon to guide the understanding of ecological relationships (Chamberlain 1897, Hilborn and Mangel 1997).

In this assessment, the strength of evidence for particular ideas is noted, and alternative explanations are described when appropriate. While well-executed experiments represent a strong approach to developing knowledge, alternative approaches such as modeling, critical assessment of observations, and inference were accepted as sound approaches to understanding *Eleocharis elliptica*. There is a paucity of scientific knowledge specifically relating to aspects about its biology and ecology.

Another topic of uncertainty concerns the taxonomic status of this species, which substantially affects its known distribution within USFS Region 2. Use of older information and a broad taxonomic definition for the species would result in *Eleocharis elliptica* occurring across most states in USFS Region 2. Use of a more recent and narrowed taxonomic circumscription would result in *E. elliptica* not occurring in USFS Region 2 at all. Consequently, uncertainty about this species will be an important part of the discussion. The level of uncertainty is mentioned in general terms as it is not reasonable to place a numerical figure on the kinds of uncertainty discussed in this document. In the Conservation section of this assessment, known

information is synthesized into management approaches, and a certain level of speculation and inference is used. This document attempts to thoroughly summarize pertinent information regarding this species' taxonomic status so that land managers and researchers are aware of these uncertainties. The status of the occurrence(s) of *E. elliptica* in USFS Region 2 will be an on-going process.

Publication of Assessment on the World Wide Web

To facilitate the use of this species assessment as part of the Species Conservation Project, it is being published on the USFS Region 2 World Wide Web site at www.fs.fed.us/r2/projects/scp/assessments/index.shtml. Placing this document on the Web makes it available to agency biologists and the public more rapidly than publishing it as a report. More importantly, Web publication facilitates revision of the assessment, which will be accomplished based on guidelines established by USFS Region 2.

Peer Review

This document, as others in the Species Conservation Project, has been peer reviewed prior to release on the Web. It was reviewed through a process administered by the Center for Plant Conservation, which chose two recognized experts to provide critical input on the manuscript. Peer review was designed to improve the quality and thoroughness of the information herein communicated and to increase the rigor of the assessment.

MANAGEMENT STATUS AND NATURAL HISTORY

Management Status

Table 1 lists the management status classifications for *Eleocharis elliptica* for various levels of global, national, state, and agency oversight. Because of its wide distribution across North America, NatureServe (2004) has given it a secure global ranking of G5. Due to this wide distribution, elliptic spikerush is not listed or ranked as a threatened, endangered, or species of concern by either the United States or Canada. It is likewise not ranked by most states or provinces.

In New Jersey, both NatureServe (2004) and the New Jersey Department of Environmental Protection (2005) list *Eleocharis elliptica* as S2 (imperiled). Noteworthy is the fact that the New Jersey Department of Environmental Protection lists 13 other taxa (species or varieties) of *Eleocharis* as S1 (critically imperiled), S2, or S3. Two of these listed taxa are part of the *E. tenuis-E. elliptica-E. compressa* complex (Smith 2002), *E. compressa* (listed as S1) and *E. tenuis* var. *pseudoptera* (listed as S3S4). The listing of 14 taxa of *Eleocharis* in New Jersey possibly reflects the general vulnerability of wetland habitats in a small and highly urbanized state.

Table 1. Conservation status and Natural Heritage Program ranking of *Eleocharis elliptica* at various levels.

	Conservation Status	Natural Heritage Program Ranking
Global		G5
United States		NR or U
Canada		NR or U
U.S. Fish and Wildlife Service	None	
USDA Forest Service	Sensitive	
U.S. States		
Illinois		S3S4
New Jersey		S2
Pennsylvania	Endangered	S2
Virginia		S2
Canadian Provinces		
Newfoundland		S3S4
Ontario		S5
All others		NR or U

Natural Heritage Program Rankings: G5=globally secure; NR=not ranked; U=unranked, not enough information; S1=critically imperiled; S2=imperiled; S3=vulnerable; S4=apparently secure; S5=secure.

In Pennsylvania, both NatureServe (2004) and the Pennsylvania Natural Heritage Program list *Eleocharis elliptica* as S2 (imperiled). The Pennsylvania Department of Conservation and Natural Resources (2005) officially has it listed as a state endangered species. Pennsylvania, although a much larger state than New Jersey, similarly has 11 taxa of *Eleocharis* officially listed as state endangered or threatened (or as S1 by the Pennsylvania Natural Heritage Program), including two additional species listed as extirpated. The taxa closely related to *E. elliptica* are also listed (both *E. compressa* and *E. tenuis* var. *verrucosa* are listed as state endangered (S1)). The listing of numerous species of *Eleocharis* would again superficially appear to reflect a general vulnerability to wetland habitats.

The Virginia Natural Heritage Program under the Virginia Department of Conservation and Recreation (2005) lists *Eleocharis elliptica* as an S2 (imperiled) species with eight reported occurrences statewide. Virginia appears to be on the southern fringe of the distribution of *E. elliptica* (Smith 2002, USDA Natural Resources Conservation Service).

In Ohio, the listing status of *Eleocharis elliptica* has gone through a state of flux. In 1980, *E. compressa* (with *E. elliptica* var. *compressa* as the synonym) was considered potentially threatened (McCance and Burns 1984). By 1982, it was elevated to proposed threatened and in 1984 was listed as threatened. By 1986, however, it was de-listed back to proposed threatened and separated from *E. elliptica*, so that both *E. compressa* (flatstem spikerush) and *E. elliptica* were both listed separately as proposed threatened (Ohio Division of Natural Areas and Preserves 1986). As currently reported on NatureServe (2004), neither taxon is currently listed for Ohio.

In Illinois, *E. elliptica* is listed as either S3 (vulnerable) or S4 (apparently secure) (NatureServe 2004). This range of classification indicates an uncertainty in its level of classification. Within Canadian provinces, NatureServe (2004) shows the Ontario listing of *E. elliptica* as S5 (secure), and the Newfoundland listing as being anywhere from S3 (vulnerable) to S5. No other states or provinces are known to have any official rankings for *E. elliptica*.

Although *Eleocharis elliptica* has a wide distribution outside of USFS Region 2, from northeastern North America across the Midwest and northern plains states to British Columbia, Canada, and a secure (G5) global ranking (NatureServe 2004), it was believed (USDA Forest Service 2002a) that the only known occurrence within Region 2 boundaries was in Wyoming (the Laramie Mountain Range in the Medicine Bow National Forest). Another Wyoming occurrence placed the species in Yellowstone National Park, which is located just outside of USFS Region 2 boundaries. The Wyoming Natural Heritage Program assigned the species a critically imperiled (S1) state ranking (Wyoming Natural Diversity Database 2004); this is an unofficial ranking as the State of Wyoming has no ranking for this species. Degradation of wetland habitats, timber harvesting, and livestock grazing were listed as threats to its habitat (Wyoming Natural Diversity Database 2004).

Elsewhere within Region 2, the South Dakota Natural Heritage Program (2004) identifies the closely related *Eleocharis tenuis* (slender spikerush) as a tracked plant species, but it has no federal or state status (state ranking of SU (unrankable)). The Colorado Natural Heritage Program (2005) does not have any species of *Eleocharis* on a tracking list. In Nebraska, although three species of *Eleocharis* are listed as either S1 or S2 by the Nebraska Natural Heritage Program (2005), none of these are part of the taxonomic complex that includes *E. elliptica*. In Kansas, seven *Eleocharis* species are listed as S1 or S2 by the Kansas Natural Heritage Program (2005), and two other species are listed as SH (possibly extirpated from the state). Of the Kansas listed species, only *E. verrucosa* belongs to the taxonomic complex that includes *E. elliptica*.

The National Forest Management Act of 1976 (NFMA) provides direction for managing species on USFS land, and USFS policy and regulations under NFMA seek to manage species in a proactive manner. *Eleocharis elliptica* became a part of this species assessment process when it was first evaluated for potential USFS Region 2 sensitive listing in early 2002 (USDA Forest Service 2002a). USFS Region 2 went through an internal evaluation process, analyzing eight ranking criteria, completing this initial evaluation on February 21, 2002 (USDA Forest Service 2002a). Final recommendations for USFS Region 2 sensitive listing was made on October 4, 2002 by Nancy Warren and Jeff Redders (with Bonnie Heidel and Scott Laursen as non-USFS experts assigned to help in the evaluation) (USDA Forest Service 2002a). The ultimate rationale for listing *E. elliptica* as a sensitive species was its rarity in USFS Region 2, its isolated distribution (both within and without the region), and its habitat threats.

Existing Regulatory Mechanisms, Management Plans, and Conservation Strategies

There are very few easily recognizable regulatory mechanisms, management plans, or conservation strategies targeted specifically for *Eleocharis elliptica*. This is likely due to its widespread occurrence across North America and Canada, a Natural Heritage Program ranking of G5, and a lack of ranking at national levels in the United States or Canada. The only U.S. state with an official regulatory ranking of this species is Pennsylvania, where it is listed as state endangered; this would provide for some "taking" protection under Title 17, Chapter 45, Conservation of Native Plants, January 1, 1988 (Pennsylvania Department of Conservation and Natural Resources 2005).

The fact that *Eleocharis elliptica* is classified as a wetland plant (U.S. Fish and Wildlife Service 1988, U.S. Fish and Wildlife Service 1996), essentially means that federal wetland regulations administered by the U.S. Army Corps of Engineers (USACE: Section 404 of the Clean Water Act, codified in 33 CFR Parts 320-330) are the strongest existing regulatory mechanism concerning the management and conservation of the species. Regarding individual species or their habitats, these regulations are non-specific; instead they are but aimed at protecting all kinds of natural wetland habitats across the United States. Under these regulations, small pieces of wetlands may be lost for individual projects, but the general national policy is "no net loss." This policy was ultimately derived from Executive Order 11990 (Protection of Wetlands 1977). Mitigation of losses through restoration (onsite or offsite) and through wetland banking (eventual restoration at a later time and/or location) has been implemented by the USACE and numerous federal and state agencies. More recently, the USACE has been adopting new mitigation guidelines published by the National Research Council (2001). Most USFS roads and trails exist under silvicultural exemption from CWA Section 404 permitting (Roche personal communication 2005, and see 33 CFR Part 323).

At various administrative levels, the USFS has policy, guidelines, and management plans for wetlands. The Medicine Bow National Forest Revised Resources Management Plan contains provisions to protect wet meadows, fens, bogs, and peatlands and more specific provisions for the protection of *Eleocharis elliptica* (USDA Forest Service 2003). These provisions are summarized in the Management of *E. elliptica* in Region 2 section of this document.

Eleocharis elliptica is listed as one of the common species in some wetland habitats within Sandhills areas of Nebraska and South Dakota of USFS Region 2 (USDA Forest Service 2004). Management comments for these habitats consist of plugging ditches of drained meadows to restore natural hydrologic conditions, eliminating mid-summer haying, and conducting occasional prescribed burning. One of the habitats in which *E. elliptica* is reported a dominant species, rich peat fens of the Sandhills in Nebraska and South Dakota, has been given a G1G2 ranking (imperiled to critically imperiled; The Nature Conservancy 2001). An Environmental Assessment for the Almeria Meadows Wildlife Management Area in Nebraska by the Nebraska Game and Parks Commission (2002), in conjunction with the U.S. Fish and Wildlife Service (USFWS), hints that fire is an important factor in nutrient recycling, grass maintenance, and the prevention of woody and weedy vegetation from overtaking wet sedge meadows on the wildlife management area. A mixed management protocol, including the timing of haying, could help to maintain plant community diversity.

Based on the current global and national ranking for *Eleocharis elliptica* and its widespread occurrence across the United States and Canada, it would appear that existing laws and regulations are adequate for protecting the species. The question arises as to how much regional and local regulation should or should not be implemented specifically regarding *E. elliptica*. This question becomes potentially more difficult to answer on the periphery of *E. elliptica* distribution, especially with regard to USFS Region 2.

Biology and Ecology

Classification and description

Classification and taxonomy

The species herein described and identified as *Eleocharis elliptica* (**Figure 1**) has a long, complicated, and confusing taxonomic history. To begin with, the genus *Eleocharis* is placed within the plant kingdom in the following commonly used hierarchical classification (NatureServe 2004, USDA Natural Resources Conservation Service 2004):

Kingdom Plantae (plants)
Subkingdom Tracheobionta (vascular plants)
Division Magnoliophyta (or Phlyum Anthophyta) (flowering plants)
Class Liliopsida (or Monocotyledoneae) (monocotyledons or monocots)

Subclass Commelinidae
Order Cyperales
Family Cyperaceae (sedges)
Genus *Eleocharis*

The family Cyperaceae has 100 genera and more than 5,000 species worldwide (Ball et al. 2002). *Eleocharis* comes from "eleo" or "helo" (Greek) for marsh and "charis" (Greek) for favor or grace (Borror 1960). *Eleocharis* is distributed worldwide with more than 200 species (Smith 2001) and more than 600 published names (Gonzalez-Elizondo and Peterson 1997). As most recently described (Smith 2002), there are 67 species within the genus *Eleocharis* in North America. Of these species, 29 are endemic to North America, and one is introduced. Eight species (not including *E. elliptica*) are of global conservation concern (ranked as G1 or G2 according to NatureServe).

Eleocharis elliptica Kunth (**Figure 1**) is variously known by the common names elliptic spikerush, slender spikerush, boreal spikerush, or yellow-seeded spikerush (Ohio Division of Natural Areas and Preserves 1986, Rhoads and Klein 1993, Smith 2002, NatureServe 2004). A wide variety of taxonomic synonyms may be found for the *E. elliptica* taxon and for several very closely related and easily confused taxa (Correll and Correll 1975, Mohlenbrock 1986, Kartesz 1994, Rolfsmeier 1995, Dorn 2001, Smith 2001) with Smith (2002) being the most recent. In older accounts, *E. elliptica* has been considered the northern phase of *E. tenuis* (i.e., *E. tenuis* var. *borealis*) (Gleason and Cronquist 1963).

Eleocharis elliptica is part of the very difficult *E. tenuis* complex that includes the following six species (Smith 2002): *E. occulta*, *E. bifida*, *E. nitida*, *E. compressa*, *E. elliptica*, and *E. tenuis*. *Eleocharis occulta*, *E. bifida*, and *E. nitida* are considered relatively distinct from the others in the complex, have much less variation, and have relatively limited distributions. *Eleocharis compressa*, *E. elliptica*, and *E. tenuis* are difficult to distinguish from one another and have widely overlapping distributions. **Table 2** presents a summary of the taxonomic synonyms of *E. elliptica* and closely related taxa or taxa potentially confused with *E. elliptica*. Taxonomic names as presented in their original sources will be used in this report. Attempting to convert taxonomic names from various sources and published reports into the taxonomy of Smith (2002), without actually being able to verify whether the original report author was correct in name usage, will possibly result in only more name corruption and confusion (consequently, refer to **Table 2** as needed). Searches on *E. elliptica* on the PLANTS Database (USDA Natural Resources Conservation Service 2004) will concurrently bring up a listing of *E. compressa* and *E. tenuis* var. *pseudoptera*, in addition to *E. elliptica*.

In this document, Smith (2002) is used as an ultimate or final authority on the taxonomy of *Eleocharis elliptica*. The recent Flora of North America (Smith 2002) did not map any *E. elliptica* state occurrences within USFS Region 2 because there was not enough time prior to final publication to examine specimens from Region 2, which included herbarium records from the University of Wyoming, Utah State University, the University of Colorado, and Nebraska State Museum (Smith personal communication 2006). Only states in which herbarium records were carefully examined by the author (Smith 2002) were allowed to be mapped for the Flora of North America (Smith 2002). Consequently, until the USFS Region 2 specimens are carefully examined, discussion of *E. elliptica* relative to Region 2 becomes somewhat difficult.

Since Smith (2002) is based on current scientific reviews of herbarium records, *Eleocharis elliptica* would not occur in USFS Region 2 (note the absence of this species in any Region 2 state in **Figure 2**). This conclusion potentially makes any management or conservation strategies for this species in USFS Region 2 a mute point. It further indicates that regional or locally specific research is still needed (especially for USFS Region 2), as several other botanical sources have previously placed *E. elliptica* in Wyoming, Colorado, Nebraska, and possibly in South Dakota and Kansas. The information supplied by these botanical sources is discussed below. Because Smith's (2002) account in the Flora of North America volume on the Cyperaceae is relatively new and highlights the long-standing taxonomic difficulties with separating the *E. tenuis*-*E. elliptica*-*E. compressa* complex, it probably warrants additional time for this most recent publication to settle into common use.

A continued discussion of the taxonomy of *Eleocharis elliptica* and a brief history of taxonomic accounts of this species, and others in the *E. tenuis*-*E. elliptica*-*E. compressa* complex, is warranted in order to move on to the discussions about its distribution, biology, ecology, and ultimate management. Rydberg (1919 and 1920) did not report the species (or its synonyms) in his phytogeographical notes for the Rocky Mountain region. Neither *E. elliptica* nor any members of the complex were reported within the sedge and rush flora of Colorado in 1944 (Smith and Durrell 1944). Similarly, none of these taxa were reported as occurring in the Colorado flora in 1954 or 1964

Table 2. Summary of taxonomic synonyms and names of *Eleocharis elliptica*, including synonyms of closely related taxa that are often confused or potentially confused with *E. elliptica*. Currently accepted names (Smith 2002) are in bold face type.

Synonyms for *Eleocharis elliptica* are based on Smith (2002), unless indicated otherwise. No varieties were recognized by Smith (2002).

Eleocharis elliptica Kunth

E. capitata (L.) R.Br. var. *borealis* Svenson

E. compressa Sullivant var. *atrata* Svenson

E. compressa Sullivant var. *borealis* Drapalik & Mohlenbrock

E. elliptica Kunth var. *elliptica*

E. elliptica Kunth var. *atrata* (Svenson) S.G. Smith (Smith 2001)

E. tenuis (Willd.) Schultes var. *atrata* (Svenson) B. Boivin

E. tenuis (Willd.) Schultes var. *borealis* (Svenson) Gleason

Other members of the *Eleocharis tenuis* complex or *E. tenuis-E. elliptica- E. compressa* complex (in alphabetical order). All synonyms based on Smith (2002), unless indicated otherwise.

Eleocharis bifida S.G. Smith (southeast United States only (Smith 2002))

Eleocharis compressa Sullivant var. ***acutisquamata*** (Buckl.) S.G. Smith

E. acutisquamata Buckl.

Eleocharis compressa Sullivant var. ***compressa***

E. acuminata (Muhl.) Nees, nom. conf. (Svenson 1932)

E. elliptica Kunth var. *compressa* (Sullivant) Drapalik & Mohlenbrock

Eleocharis nitida Fernald (northeast United States and Canada – Minnesota is the closest state of occurrence to Region 2 (Smith 2002))

Eleocharis occulta S.G. Smith (Oklahoma and Texas only (Smith 2002))

Eleocharis tenuis (Willd.) Schultes var. ***pseudotera*** (Weatherby) Svenson

E. capitata (L.) R.Br. var. *pseudoptera* Weatherby

E. elliptica Kunth var. *pseudoptera* (Weatherby) L.J. Harms

Scirpus quadrangulatus Muhl., non Michx. (as presented in Kartesz 1994)

Eleocharis tenuis (Willd.) Schultes var. ***tenuis***

Scirpus tenuis Willd.

Eleocharis tenuis (Willd.) Schultes var. ***verrucosa*** (Svenson) Svenson

E. capitata (L.) R.Br. var. *verrucosa* Svenson

E. verrucosa (Svenson) L.J. Harms

Other *Eleocharis* taxa occurring in USFS Region 2 that may be confused with *E. elliptica* (in alphabetical order). All synonyms based on Smith (2002), unless indicated otherwise.

Eleocharis erythropoda Steudel

Scirpus glaucus Torrey

Eleocharis geniculata (L.) Roemer & Schultes (synonyms based on Menapace (2002))

E. capitata R.Br. var. *capitata*

E. caribaea (Rottbøll) S.F. Blake

E. dispar E.J. Hill

Scirpus geniculatus L.

Eleocharis palustris (L.) Roemer & Schultes

E. smallii Britton

Scirpus palustris L.

Figure 2. Distribution of *Eleocharis elliptica* across North America. Source: Smith (2002). Used with permission.

(Harrington 1954, Harrington 1964). In Wyoming, neither *E. elliptica* nor others in the complex were listed for Yellowstone National Park in 1936 (McDougall and Baggley 1936). Similarly, none of the members of the *E. tenuis-E. elliptica-E. compressa* complex were listed for Wyoming in 1977 (Dorn 1977). In northeastern North America, *E. elliptica* and members of its complex were known and reported for similar time periods (Britton and Brown 1913, Deam 1940, Gleason and Cronquist 1963). This eastern versus western presence discrepancy may be explained by more botanists conducting field work earlier in eastern states than in western states, so that when the earlier western accounts were published, comparably fewer field investigations were conducted in the West than in the East. By 1980 and more recent times, the related *E. compressa* was reported for New Mexico (Martin and Hutchins 1980-81, Allred 2005). *Eleocharis elliptica* var. *compressa* was recently reported for Colorado (Weber and Wittmann 2001a and 2001b). *Eleocharis tenuis* var. *borealis* was recently reported for Wyoming (Dorn 2001).

While studying the Cyperaceae of Nebraska, Rolfsmeier (1995) came to the conclusion that *Eleocharis elliptica* was synonymous with *E. tenuis* var. *borealis*, but advocated a different classification for *E. compressa* than Smith (2002) currently does. Consequently, *E. elliptica* was identified as a new record for the state of Nebraska, and all *E. compressa* were reclassified as *E. elliptica* (Rolfsmeier 1995). *Eleocharis compressa* had previously been reported from many states in the Great Plains (Great Plains Flora Association 1986). Rolfsmeier (1995) stated that *E. compressa* and *E. elliptica* have had a history of taxonomic confusion, but that the Nebraska plants more closely represented the typical *E. elliptica* found in localities in northeastern North America.

Smith (2001) published a taxonomic account of the genus *Eleocharis* in North America (including partial revisions of the *E. tenuis-E. elliptica-E. compressa* complex), which became a basis for the taxonomy reflected in the recent Flora of North America treatment of *Eleocharis* (Smith 2002) including the *E. tenuis-E. elliptica-E. compressa* complex. Smith (2001) stated that *Eleocharis* identification is unusually complicated for two prominent reasons: 1) its simple vegetative structure of unbranched stems, two bladeless leaves, and small terminal spikelets provide very few

macroscopic characters for species separation; and 2) the genus includes several very difficult species complexes containing species that have needed much more precise definition. Other factors cited as adding to the complexity are interspecific hybridization, unstable chromosome structure, polyploidy (multiple sets of chromosomes), and aneuploidy (odd numbers of chromosomes).

Smith (2001) transferred *Eleocharis compressa* var. *atrata* to *E. elliptica* Kunth var. *atrata* (Svenson) S.G. Smith. Smith (2002) acknowledges the confusion and uncertainty of previous researchers (e.g., Rolfsmeier 1995) who have lumped all *E. elliptica* and *E. compressa* into one or the other species. Smith states that although the species should remain distinct, there are numerous indications of hybridization and that the new variety specified (*E. elliptica* var. *atrata*) included plants that approach *E. compressa*. The current Flora of North America (Smith 2002) reviewed the three varieties of *E. elliptica* previously identified: *E. elliptica* var. *elliptica*, *E. elliptica* var. *atrata*, and *E. elliptica* var. *pseudoptera*. Smith (2002) placed the variety pseudoptera into *E. tenuis* as it more closely resembles the *E. tenuis* portion of the complex. Ultimately, Smith (2002) does not formally recognize any varieties of *E. elliptica* due to the high degree of variation and intergradation into one another. Previous authors (e.g., Harms 1972) have reported fertile artificial hybrids between *E. elliptica* and *E. compressa*, but no voucher specimens have been found to document these (Smith personal communication 2006).

Although confusing, these taxonomic difficulties emphasize a degree of uncertainty. *Eleocharis elliptica*, *E. compressa*, and *E. tenuis*, or at least what is circumscribed to be these taxa, may be part of a single variable taxonomic group (possibly more so between *E. compressa* and *E. elliptica*; McCance and Burns 1984). At this point, some scientific theory and philosophy need to be interjected into this discussion. The concept of what defines and constitutes a species has been a long and difficult one in the scientific community. It is a natural human inclination to define, categorize, and order what is observed in the natural environment, but often with biological taxa or populations (i.e., species) that are dynamic and changing over time and space, this becomes much harder. Taxonomists seek reliable characteristics to help define a species (or taxon). Most plant species, however, exhibit a certain range of variation within what defines the species, with some species exhibiting much greater ranges of variation than others. Plant ecologists and evolutionary biologists often tend to view the species concept more broadly as sets of interbreeding populations (Mayr 1957, Briggs and Walters 1984), but numerous plant species have been demonstrated to hybridize either naturally or artificially, blurring some of the lines defining species (Mayr 1957, Briggs and Walters 1984). Also, populations of plants have frequently demonstrated selective change, forming ecotypes (Turesson 1922, 1930, Clausen et al. 1940), even in periods of time as short as 30 to 60 years (Antonovics et al. 1971, Bradshaw and McNeilly 1981). Consequently, despite the efforts of taxonomic botanists to move forward in categorizing highly variable species of plants, such as *E. elliptica*, or complexes of species, such as *E. tenuis*-*E. elliptica*-*E. compressa*, variation due to hybridization, natural selection pressures in the environment, and redistribution of species across the geographic landscape will continue to occur, blurring the lines between some species. Despite the recent release of the Flora of North America (Smith 2002) and its advances in taxonomic arrangement of *E. elliptica*, a certain level of uncertainty will remain. Botanists are likely more certain of this species now than they were 30 or 40 years ago, but the uncertainty is not gone, even today. Assigning a number or percentage to the uncertainty would not be appropriate. Just realizing that there is a level of uncertainty and keeping in mind some of the factors that will play into that uncertainty (e.g., hybridization, natural selection pressures in the environment, the potential for species to redistribute themselves in the local or regional geographic landscape) are more important.

Description

Eleocharis elliptica (**Figure 1**) is a perennial, mat-forming species with fairly long, evident rhizomes (underground stems) (Smith 2002). The rhizomes are 0.5 to 2.5 mm thick and have strongly overlapping scales on them. The mats may appear as dense clusters of stems, or the stems may be more scattered and diffuse. The vegetative characteristics are variable and very difficult to separate from *E. compressa* and *E. tenuis* (Smith 2002). The stems of *E. elliptica* are less than fully round (e.g., oval) to sometimes compressed or flattened, 5 to 90 cm tall, and 0.3 to 0.8 mm thick (Smith 2002). The stems of *E. compressa* tend to be much more flattened than those of *E. elliptica* (Rolfsmeier 1995, Mohlenbrock 1986, Smith 2002). According to Rolfsmeier (1995), true *E. compressa* have distinctly flattened stems whereas the Nebraska specimens have barely flattened stems that are wiry; the Nebraska specimens best fit the descriptions of typical *E. elliptica* plants collected in northeastern North America. The stems have five to ten ridges or angles on them (Smith 2002) and have previously been described

as six to eight-angled with a correspondingly similar number of vascular bundles (Deam 1940, Gleason and Cronquist 1963, Mohlenbrock 1986). *Eleocharis elliptica* var. *atrata* is specifically described as having up to eight prominent ridges (Smith 2001). The number of vascular bundles has been considered one of the most definitive distinguishing characteristics between *E. compressa* (nine to 14 bundles) and *E. elliptica* (four to eight bundles) (Mohlenbrock 1986, Gleason and Cronquist 1991, Catling 1994, Rolfsmeier 1995). The leaves are small, bladeless sheaths (tubular or sleeve-like), two in number, and found at the base of the stem. The bisexual flowers are very small and reduced (i.e., no petals or the petals occasionally exist only as one to three bristles) and are contained in inflorescences called spikelets (**Figure 3**). The scales of the spikelet have broad, rough tips that lack a green midvein (Dorn 2001). Each flower has three stamens and an ovary with three (sometimes two) style branches. The spikelets into which the flowers are grouped are generally oval in shape, measuring 3 to 8 mm high by 2 to 3 (or 4) mm wide. The seeds are contained in a one-seeded fruit called an achene. These may be lemon yellow, dark or golden yellow, or orange to medium brown in color (Deam 1940, Gleason and Cronquist 1963, Smith 2002). The achenes have a three-sided oval bottle shape (sometimes two-sided lens shape), have a roughened or ribbed surface, and are 0.7 to 1.2 mm long.

In Nebraska, *Eleocharis elliptica* could be most easily confused with *E. palustris* and *E. erythropoda* (Rolfsmeier 1995). *Eleocharis elliptica* has substantially stouter rhizomes with strongly overlapping scales; the other two have slender rhizomes with distinctly separated scales. Similarity to *E. erythropoda* is also discussed in Catling (1994). *Eleocharis erythropoda* also has elliptic-shaped stems, but they will vary from elliptic to round. *Eleocharis erythropoda* similarly has eight to ten vascular bundles. *Eleocharis erythropoda* has two-lobed styles instead of two to three-lobed styles, and the achenes are two-sided instead of two to three-sided. As already described, *E. compressa* var. *compressa* is supposed to have more distinctly flattened stems, with more vascular bundles than *E.*

Figure 3. Close-up of flowering structures of *Eleocharis compressa* (apparently misidentified as *E. elliptica* var. *compressa*). Source: Colorado State University Herbarium (2005) and USDA Natural Resources Conservation Service (1995) Midwestern Wetland Flora (http://plants.usda.gov). Used with permission. Correction supplied by Smith (personal communication 2006).

elliptica. Although *E. compressa* specimens in Ohio were considered distinctive, over its greater distribution it was considered to intergrade with *E. elliptica* in other states across its range (McCance and Burns 1984). *Eleocharis compressa* var. *acutisquamata* is supposed to have more rounded (less flattened) stems (Brown and Marcus 1998, Smith 2002), but some of these are intermediate with *E. elliptica* (Smith 2002). The stems of *E. tenuis* are usually four to five or sometimes six-angled (i.e., it has fewer angles than *E. elliptica*). *Eleocharis tenuis* stems tend to be round, but variety *pseudoptera* tends to have compressed stems. The achenes of *E. tenuis* may be greenish, a characteristic not generally seen in *E. elliptica*.

There are not many available photographs of *Eleocharis elliptica*. A readily accessible photograph (as used in this document) is available from the Freckmann Herbarium, University of Wisconsin (2004), but there is a possibility that it may be of *E. compressa* (Smith personal communication 2006). Another photograph is that on the Colorado State University Herbarium (2005) Web page, but the plant in this photograph appears to be of *E. compressa* (Smith personal communication 2006). There are a variety of sources on the description of *E. elliptica* in floras from across the continent. Those more readily available and/or reliable are listed as follows:

- Flora of North America Vol. 23 Magnoliophyta: Commelinidae (in part): Cyperaceae (Smith 2002).
- Flora of Wyoming (Dorn 2001).
- Flora of Colorado (Weber and Wittmann 2001a and 2001b).
- Nebraska Cyperaceae (Rolfsmeier 1995).
- Flora of the Great Plains (Great Plains Flora Association 1986).
- Flora of the Northeastern United States and Adjacent Canada (Gleason and Cronquist 1963 and 1991).

This does not mean there will not be discrepancies among these sources of information as to how *Eleocharis elliptica* is circumscribed. This taxon is difficult. Smith (2002) would be the most recent and authoritative account, but the taxon is still in need of taxonomic status review in USFS Region 2 states.

Distribution and abundance

Numerous sources report *Eleocharis elliptica* as having a wide distribution across North America. It occurs from the eastern United States and Canada, westward to British Columbia in Canada. In the United States, NatureServe (2004) indicates its presence in 24 states; these are mostly eastern and central states but include Wyoming within USFS Region 2. In Canada it is reported from nine provinces: Alberta, British Columbia, Manitoba, New Brunswick, Newfoundland, Nova Scotia, Ontario, Quebec, and Saskatchewan (NatureServe 2004). The USDA Natural Resources Conservation Service (2004) differs from NatureServe (2004) in that the former does not indicate *E. elliptica* in West Virginia but does include it in Idaho (still 24 states total, with just these two state variations). Smith (2002) presents a generally similar continental distribution (**Figure 2**), but due to the taxonomic revisions, different local and regional distributions have resulted. Consequently, using Smith (2002) in comparison to NatureServe (2004), *E. elliptica* has been removed from Rhode Island, Virginia, Georgia, Louisiana, Missouri, Ohio, Wyoming, and Washington in the United States, and from New Brunswick in Canada. It has been added to Tennessee, North Dakota, and Idaho in the United States, and to Labrador and the Northwest Territories in Canada (for a total of 19 U.S. states and 10 Canadian provinces). Whereas Smith (2002) is based on a careful examination of herbarium records, NatureServe (2004) and USDA Natural Resources Conservation Service (2004) are based on numerous local and regional reports and sources of information. Since specimen records in several major herbaria in USFS Region 2 have not yet been examined according to the recent Smith (2002) taxonomy (Smith personal communication 2006), it may be useful to include a wider potential circumscription (i.e., the *Eleocharis tenuis*-*E. elliptica*-*E. compressa* complex) for reviewing data and reports pertaining to or potentially pertaining to *E. elliptica*.

The specimens that typify the original descriptions of the species' characteristics for both *Eleocharis elliptica* and *E. tenuis* are from Pennsylvania (Svenson 1957). The type specimen for *E. compressa* is in Ohio (Svenson 1957, McCance and Burns 1984, Smith 2001). *Eleocharis elliptica*, *E. compressa*, and *E. tenuis* (and their synonyms) are frequently reported across the eastern and central United States (Deam 1940, Gleason and Cronquist 1963, Magee 1981, McCance and Burns 1984, Mohlenbrock 1986, New York Flora Atlas 2004, New York Botanical Garden 2005).

In Pennsylvania, where *Eleocharis elliptica* is listed as a state endangered species, it is reported to occur in eight or nine sites within five counties (Rhoads and Klein 1993). *Eleocharis compressa* var. *compressa* occurs in three or four sites in three counties, and *E. tenuis* var. *tenuis* occurs across most of the state. *Eleocharis tenuis* var. *pseudoptera* occurs

in more than 25 sites in 14 counties, and *E. tenuis* var. *verrucosa* occurs in six or seven sites in six counties in Pennsylvania.

In West Virginia, *Eleocharis tenuis* has been reported as being common across the state, perhaps in every county (Strausbaugh and Core 1970-77) while *E. compressa* is only known to occur in one county. *Eleocharis elliptica* was reported as a new collection for West Virginia in 1984 in a collection made from Greenbrier County (Brant 1987). The specimen came from emergent wetlands in the Meadow River area.

In Wisconsin, there was only one record of *Eleocharis elliptica* in the Freckmann Herbarium (Monroe Co. 1968; Freckmann Herbarium, University of Wisconsin 2004). From numerous other herbarium records, *E. elliptica* is known to occur in several counties across the state, especially the northern and eastern parts of the state. There are a total of 120 herbarium specimen records for *E. elliptica* across 20 of the 71 counties in Wisconsin (Wisconsin Botanical Information System 2005). It is considered common in shore fen habitats, an open peatland plant community along lake shores (Wisconsin Natural Heritage Inventory 2004).

Eleocharis elliptica does occur in Minnesota (Smith 2002). It was reported to have an occasional distribution along sandy beaches and lake shores in northeastern Minnesota (Lakela 1965). In a recent online Internet database search of the University of Minnesota Bell Herbarium (2005), there were no specimens currently labeled as *E. elliptica*. The related taxa, *E. tenuis*, had 10 specimens on file, and *E. compressa* had 92 specimens on file (University of Minnesota Bell Herbarium 2005). *Eleocharis compressa* was reported to occasionally occur in wet meadows and sedge mats in the Duluth area of Minnesota (Lakela 1965). *Eleocharis tenuis* was reported as rare in Iowa in 1898 when it was first reported for that state (Cratty 1898).

Eleocharis elliptica was not reported for the Great Plains states (Great Plains Flora Association 1986), and Smith (personal communication 2006) is currently unaware of any records (except for North Dakota). *Eleocharis compressa* has been reported in the Great Plains as occurring in low wet prairies, marshes, and sandy flood plains across the northern Great Plains and adjacent states (Great Plains Flora Association 1986); the listed states included Minnesota, Iowa, Missouri, North Dakota, South Dakota, Nebraska, Kansas, Oklahoma, Texas, and Colorado. *Eleocharis compressa* was reported as having a frequent distribution scattered across North Dakota, South Dakota, Nebraska, and the northeastern corner of Colorado (Larson 1993). It was considered a species very similar to *E. tenuis* var. *verrucosa*.

The taxonomic presence of *Eleocharis compressa* in Texas was questioned, and all Texas records were considered to be only of *E. acutisquamata* (Brown and Marcus 1998). *Eleocharis elliptica* var. *compressa* had been reported to occur in Oklahoma (Correll and Correll 1975). *Eleocharis tenuis* var. *verrucosa* was considered infrequent across the eastern United States, extending west to eastern Texas, Oklahoma, Missouri, and Illinois (Correll and Correll 1975). In Texas, the University of Texas Herbarium reports that there are 16 specimens of *E. compressa* on file (University of Texas Herbarium 2005). The variety is not specified except in only two specimens as variety *acutisquamata*. The distribution of the specimens ranges from eastern to central Texas. There are no records for *E. elliptica* in Texas. *Eleocharis tenuis* has seven records, all distributed in eastern Texas with no variety specified. There are nine records for *E. acutisquamata*, distributed from eastern to central Texas with no variety specified.

Eleocharis compressa has been identified as occurring in northern New Mexico from about 7,000 to 8,000 ft. in elevation on moist sandy ground (Martin and Hutchins 1980-81) and continues to be listed for New Mexico as *E. compressa* var. *acutisquamata* (Allred 2005). These accounts would be based on earlier findings such as those of Hartman (1973) who reported *E. compressa* from the Philmont Scout Ranch in 1968 in a wooded area along a trail by Clark's Fork Camp at 7,600 ft. Four species of *Eleocharis* are listed in the Handbook of Wetland Vegetation Communities of New Mexico (New Mexico Natural Heritage Program 1998, Muldavin el al. 2000), but none of these were synonymous with *E. elliptica* or part of its taxonomic complex.

In the Intermountain West (e.g., Utah, Nevada, southern Oregon, Idaho), 10 species of *Eleocharis* were listed (Cronquist et al. 1977), but none of these are synonymous with *E. elliptica* or part of its taxonomic complex. *Eleocharis tenuis* is reported as transcontinental across North America (Hitchcock and Cronquist 1973; *E. tenuis* being synonymous with *Scirpus capitatus* in this source. *Eleocharis compressa* was reported from the Northwest Territories, Canada, for the first time in the 1970's (Cody and Talbot 1978).

Using Smith (2002) to frame the above discussion into current context, *Eleocharis compressa* var. *compressa* is reported to occur from Colorado, Kansas,

Nebraska, and South Dakota eastward (**Figure 3**). *Eleocharis compressa* var. *acutisquamata* occurs from Colorado, Kansas, Nebraska, and South Dakota, south to New Mexico and Texas, east to Illinois, and north to Saskatchewan (some of the Canadian specimens are close to *E. elliptica*). *Eleocharis tenuis* (inclusive of all varieties) occurs from the central Great Plains eastward, as well as a disjunct location in California (variety *tenuis*). The distribution of *E. elliptica* makes an arc across the northern perimeter of USFS Region 2 by occurring in Idaho, Montana, North Dakota, Minnesota, Iowa, and extending into most states and provinces to the north and east of these (**Figure 2**). Thus, *E. elliptica* has a wide distribution across North America, with a more northerly distribution. It may be very common in localized areas but appears to be scattered widely about. A general conclusion is that USFS Region 2 appears to be situated on the southwest fringes of the natural distribution of this species. Whether *E. elliptica* actually has a distribution within USFS Region 2 will depend upon future research and examination of herbarium specimens in Region 2.

An historical account of *Eleocharis elliptica* or purported *E. elliptica* within USFS Region 2 is presented in the following paragraphs to frame what is currently known and will hopefully lead researchers towards future species circumscription work. A few points to keep in mind for this discussion: 1) thorough botanical field surveys of the western states have probably lagged behind those of eastern states, causing the "sudden" appearance of a species (such as *E. elliptica*) in states where it was historically never identified, and 2) the taxonomic flux that *E. elliptica* has been going through affects its reported distribution, particularly in USFS Region 2, an area considered peripheral to its main distribution.

Neither *Eleocharis elliptica* nor related taxa within the *E. tenuis*-*E.elliptica*-*E. compressa* complex were listed among the sedges and rushes of Colorado in Smith and Durrell (1944). Although Yellowstone National Park has recently been considered one of the key areas for protected populations of *E. elliptica* (Wyoming Natural Diversity Database 2004), none of the members of the *E. tenuis*-*E. elliptica*-*E. compressa* complex were listed for Yellowstone National Park in 1936 (McDougall and Baggley 1936). The species listed in this publication were *E. acicularis*, *E. palustris*, and *E. thermalis* (now *E. flavescens*) (Nelson and Hartman 1994,1997, Menapace 2002). In a newer version of the Yellowstone/Teton flora (Shaw 1981), the genus *Eleocharis* was not even addressed; this book focused more on showy flowering plants and had a less thorough species coverage than the 1936 version. The Information Center for the Environment (2006) does not currently identify Yellowstone National Park as a place of occurrence for *E. elliptica*. *Eleocharis elliptica* or currently related taxa continued to remain absent from the Colorado flora by Harrington in both 1954 and 1964 (Harrington 1954, 1964). This pattern remained similar with Dorn's Wyoming flora (Dorn 1977), in which six species of *Eleocharis* are included but none have any synonymy with *E. elliptica*. By the late 1990's, *E. elliptica* was appearing in floras and lists of floras for these states, apparently substantiated by specimens in herbaria. In a 1997 checklist of the flora of Wyoming (Nelson and Hartman 1997), *E. tenuis* var. *borealis* was listed. Dorn's revised Wyoming flora (Dorn 2001) reports *E. elliptica* (as *E. tenuis* var. *borealis*) growing in wet areas of Yellowstone National Park in the northwest part of the state and in Platte County in the southeast corner of the state (**Figure 4**). *Eleocharis elliptica* is one of the nine species of *Eleocharis* listed for Wyoming.

According to the Wyoming Natural Diversity Database (2004), *Eleocharis tenuis* var. *borealis* is considered a species with a peripheral distribution relative to the state, and it is reported to occur in the Laramie Mountain Range on the Medicine Bow National Forest (one site; Platte County) and on the Yellowstone Plateau in Yellowstone National Park (three sites; Teton County). These four records have all been collected since 1993, with 1997 being the most recent one (Wyoming Natural Diversity Database 2004). This report is contradictory to the specimen records on file at the University of Wyoming, which show specimens collected in Yellowstone National Park back in 1987 and 1988 (**Table 3**, **Figure 4**; University of Wyoming Rocky Mountain Herbarium 2005). It has been estimated that there are about 100 to 200 stems at one of the three sites in Yellowstone National Park. Finally, a recently collected (2005) juvenile specimen came from Crook County, Wyoming and was tentatively identified as *E. elliptica* (Burkhart personal communication 2006, Heidel personal communication 2006). The limited number of records at the University of Wyoming would appear to indicate a very limited distribution in Wyoming.

As happened in Wyoming, *Eleocharis elliptica* var. *compressa* was recently reported to occur in the Colorado flora, on eastern slope piedmont valleys and outwash mesas in Colorado (Weber and Wittmann 2001a). On Colorado's western slope, it was reported to occur in wet places of open pine forests (Weber and Wittmann 2001b). *Eleocharis compressa* was similarly listed for the east slope of Colorado (Hartman

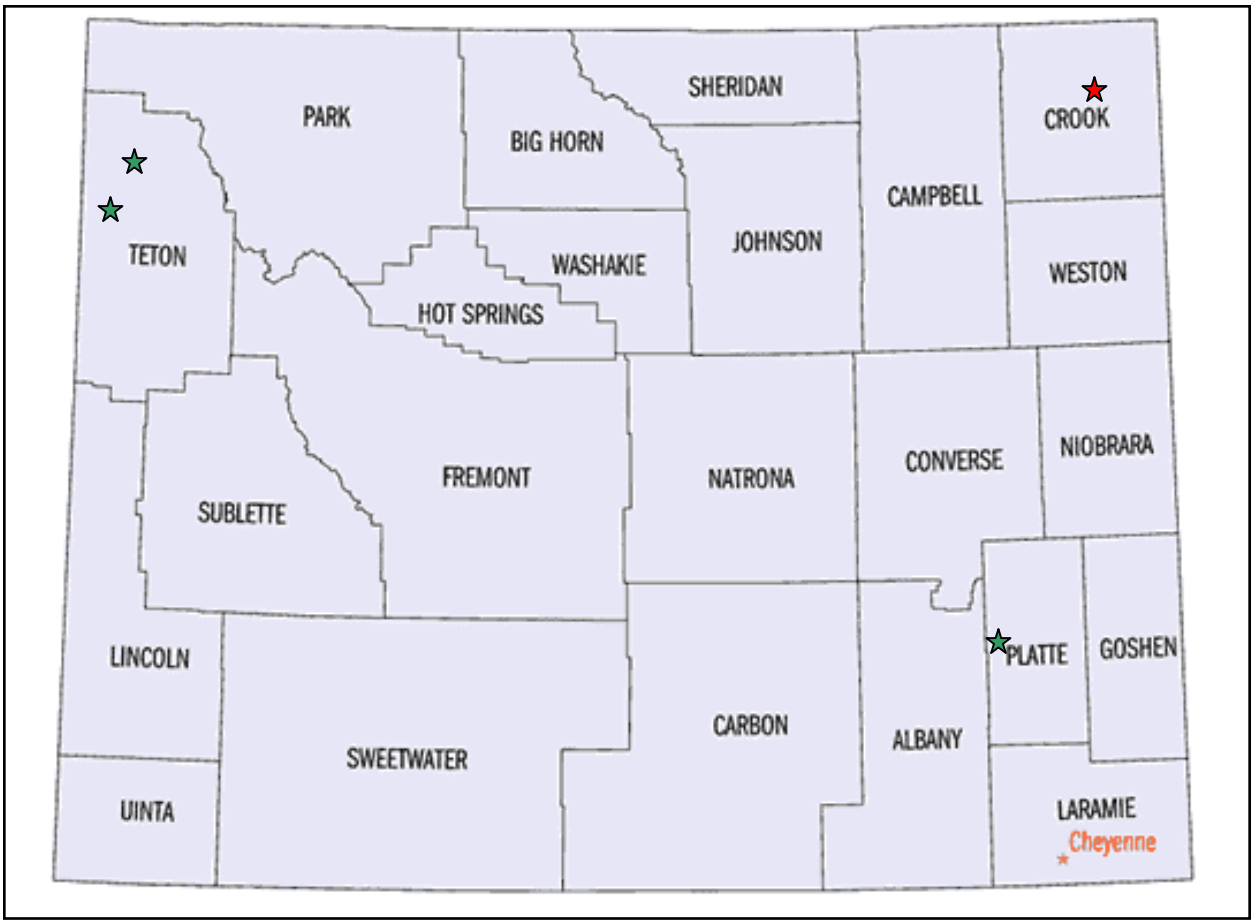

Figure 4. Distribution of purported *Eleocharis elliptica* sites in Wyoming. Green stars indicate approximate locations of known populations. The red star indicates a more recent (2005) tentative identification and collection. Source: University of Wyoming Herbarium (2004).

Table 3. Herbarium specimen records of *Eleocharis elliptica* in Wyoming (labeled, annotated, or filed under *E. elliptica* or its synonyms) at the University of Wyoming, Rocky Mountain Herbarium (RM).

County	Year of Collection	Notes on Location and Abundance	Notes on Habitat and Plant Community
Platte	1995	18 miles northwest of Wheatland, T26N, R70W, SE¼ Sec. 21	Seepage area with *Carex* and *Juncus*
Teton	1987	¼ mile southwest of Lone Star Geyser, along Firehole River, Yellowstone Plateau, Yellowstone National Park, T51N, R116W, Sec. 3	Along the Firehole River, in open wet areas adjacent to hot springs, 7,000 ft.
Teton	1988	¼ mile southwest of Lone Star Geyser, along Firehole River, Yellowstone Plateau, Yellowstone National Park, T51N, R116W, Sec. 3	Along the Firehole River, in open wet areas adjacent to warm-hot springs, dominant species are *Eleocharis rostellata*, *Scirpus americanus*, *Juncus balticus*, 7,600 ft.
Teton	1988	3 miles north of Cave Falls, along Old Marysville Road, Yellowstone Plateau, Falls River Basin, Yellowstone National Park, T49N, R117W, Sec. 30	In open seasonally wet areas with *Valeriana edulis*, *Juncus balticus*, *Carex nebraskensis*, 6,400 ft.

and Nelson 2001). Although no specimens of *E. compressa* are registered (using online data searches) at the Colorado State University Herbarium (2005), the species was not considered rare or endemic. The University of Colorado Herbarium has 12 specimens of *E. elliptica* var. *compressa* on record (University of Colorado Herbarium 2004; **Table 4**). These span five counties in Colorado: Boulder, El Paso, Jefferson, Logan, and Montezuma. Most are on the eastern slope of the Rocky Mountains, with the exception of the Montezuma County collection in the southwest corner (**Figure 5**). A few additional specimens labeled as *E. elliptica* var. *compressa*, but filed under *E. compressa* as a synonym, reside at the University of New Mexico Herbarium (2004; collections made by Weber and Wittmann). Based on specimen label information, **Table 4** indicates the county and year of collection for Colorado. Despite the absence of *E. elliptica* or its related taxa in earlier regional floras, collected specimens (**Table 4**) apparently date as far back as 1896. The abundance of *E. elliptica* at individual sites varies from infrequent, to frequent, to common. It has apparently persisted on the Rocky Flats Atomic Energy Site, an area now well known for its historical problems with environmental contamination (**Table 4**).

Table 5 lists University of Wyoming herbarium records for *Eleocharis elliptica* in Kansas, Nebraska, and South Dakota (University of Wyoming Rocky Mountain Herbarium 2005). At the present time, these records lend further support to the other reported occurrences of *E. elliptica* in Nebraska and indicate that there may be a limited distribution in both Kansas (**Figure 6**) and South Dakota (**Figure 7**). Considerable published information

Table 4. Herbarium specimen records of *Eleocharis elliptica* var. *compressa* for Colorado. All specimens reside at the University of Colorado Herbarium (COLO), except those marked with *, which reside at the University of Wyoming, Rocky Mountain Herbarium (RM) and **, which reside at the University of New Mexico Herbarium (UNM).

County	Year of Collection	Notes on Location and Abundance	Notes on Habitat and Plant Community
Boulder	1906	None	None
Boulder	1906	None	None
Boulder*	1907	Boulder	None
Boulder	1914	Infrequent in wet areas of dry grassland mesa	In wet areas of dry grassland mesa
Boulder	1914	Frequent in moist places of dry grassland mesa	In moist places of dry grassland mesa
El Paso*	1937	1 mile east of Monument	Dry woodland soil, 7,000 ft.
Boulder	1992	Woodland meadow area	Woodland meadow area
Boulder	1993	Open field area	Open field area
Boulder	1993	Common in low wet areas	In low wet areas
Boulder**	1993	City of Boulder open space wetland site	Wetland site, seasonally wet, associated with *Juncus dudleyi*
Boulder*	1993	City of Boulder open space	Seasonally wet wetland site (not permanently saturated) with *Juncus dudleyi*
Boulder**	1993	Top of Government Mesa, Boulder Mountain Park property	In low wet areas at a spring with *Juncus interior* and *Antennaria neglecta*
El Paso	1999	Paint Mines	In moist alkaline clay soil with *Scirpus*, *Typha*, and other *Eleocharis*
Jefferson	1973	Rocky Flats U.S. Atomic Energy Site	In level rocky soil
Jefferson	1992	Locally dominant in narrow zones around wet meadows	In wet meadow around depressions which accumulate water after rain, in a narrow zone with *Juncus bufonius* and *Veronica peregrinus*
Logan	1896	None	None
Montezuma	1997	Wet forested area on level mesatop	On level mesatop in shallow soil over potholed sandstone that is poorly drained, site very wet when collection made, *Pinus ponderosa-Quercus* forest

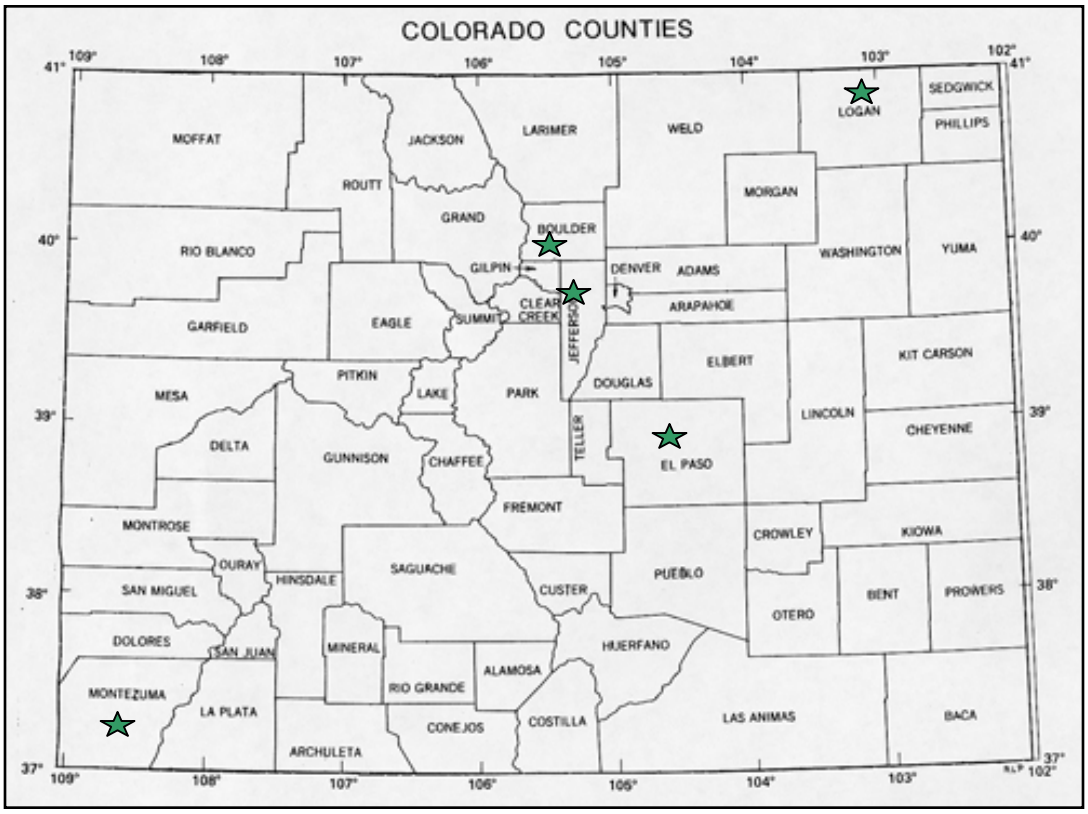

Figure 5. Distribution of purported *Eleocharis elliptica* sites in Colorado. Stars indicate the counties for which there are herbarium records (**Table 4**) housed at the University of Colorado Herbarium (COLO) (2004).

Table 5. Herbarium specimen records of *Eleocharis elliptica* in Kansas, Nebraska, and South Dakota (labeled, annotated, or filed under *E. elliptica* or its synonyms) located at the University of Wyoming, Rocky Mountain Herbarium (RM).

State	Year of Collection	Notes on Location and Abundance	Notes on Habitat and Plant Community
Kansas	1915	Casement pasture (specimen was originally on file with the USDA Forest Service Herbarium)	Pasture
Kansas	1983	Common in low areas in cemetery, ½ mile west of Reading, Lyon County	In low areas in relic prairie in cemetery
Kansas	1983	4.5 miles west of Sun City, Barber County, T31N, R15W, NE ¼ of SW ¼, Sec. 6	Sage prairie upland, sandy soil with a few areas of exposed sandstone
Kansas	1983	2 miles south, 1½ west of Ada, Ottawa County	Moist seepage area at base of prairie hillside, sandy soil
Nebraska	1897	Mindeu	None
Nebraska	1912	St. Libry	None
South Dakota	1922	Brookings	None
South Dakota	1922	Brookings	None

is available for *E. elliptica* in Nebraska. According to Rolfsmeier (1995), *E. elliptica* is considered widespread across Nebraska, but it is not as common in the far western part of the state. In fact, it is not considered common anywhere, but scattered as small populations. Rolfsmeier's (1995) treatment of the family Cyperaceae in Nebraska was the first since the Flora of the Great Plains (Great Plains Flora Association 1986), when *E. compressa* was the only species within the complex addressed within the region. Rolfsmeier reassigned all the *E. compressa* in Nebraska to *E. elliptica* and based his observations on the collected specimens

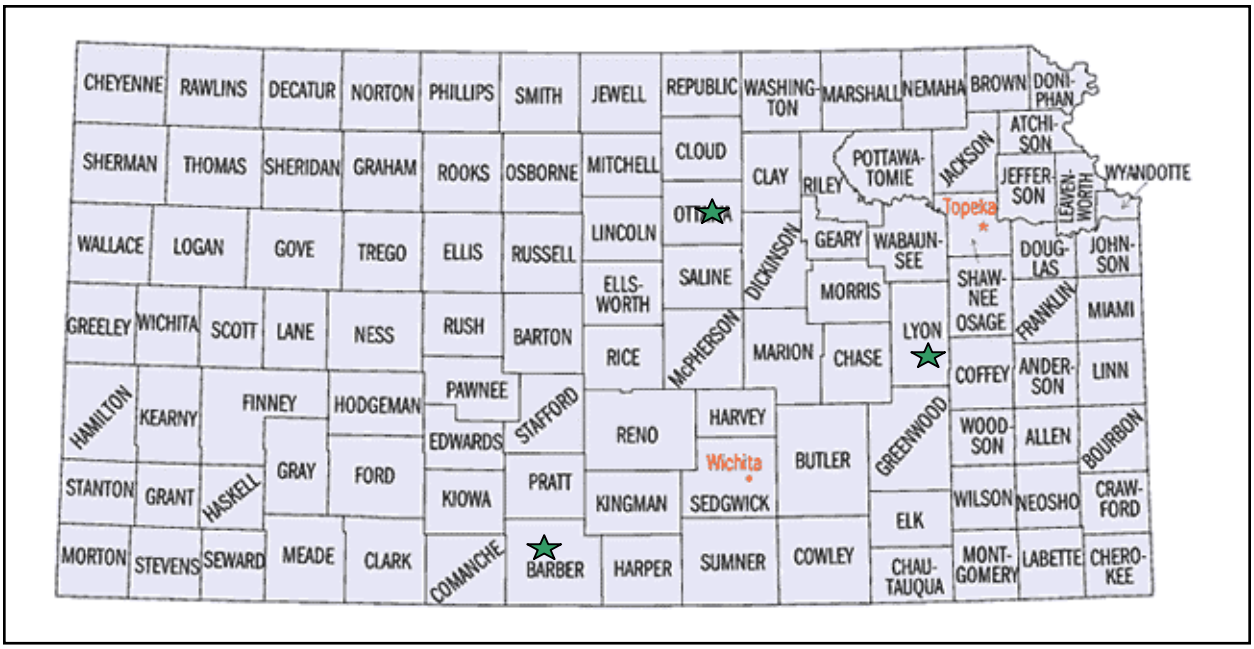

Figure 6. Distribution of purported *Eleocharis elliptica* sites in Kansas. The three green stars on this map are based on the specimen records (**Table 5**) at the University of Wyoming Rocky Mountain Herbarium (RM) (2005). The fourth specimen is from an undetermined location.

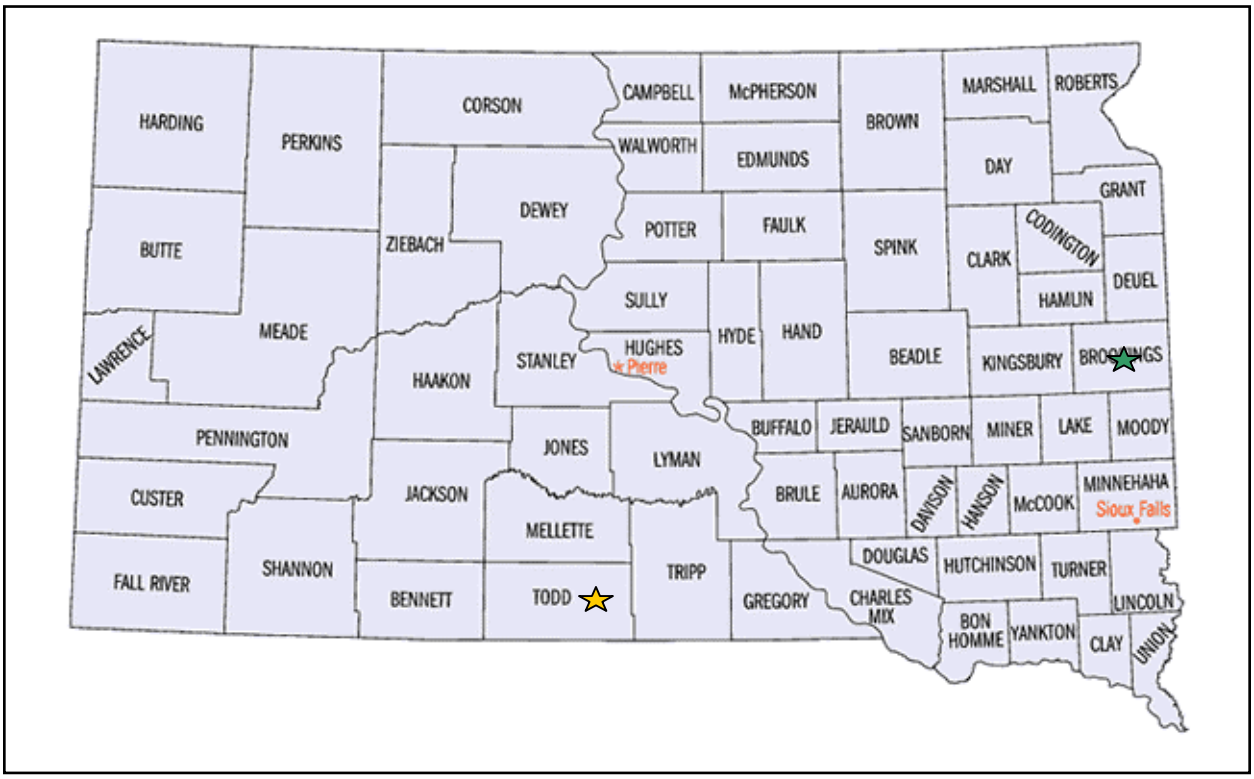

Figure 7. Distribution of purported *Eleocharis elliptica* sites in South Dakota. The yellow star is based on potential habitat (USDA Forest Service 2004). The green star in Brookings County is based on specimens (**Table 5**) at the University of Wyoming Rocky Mountain Herbarium (RM) (2005).

located in herbaria. His distribution shows *E. elliptica* in 26 counties, ranging from central to eastern Nebraska (**Figure 8**; Rolfsmeier 1995). Similarly, *E. elliptica* is listed as a species component in Sandhills Bluejoint Wet Prairie in Nebraska (USDA Forest Service 2004). This habitat occurs in the Sandhills area of Nebraska and may also occur in Kansas and North Dakota. In Nebraska, the sites are within the McKelvie National Forest. *Eleocharis elliptica* is also found in Sandhills Shrub Fen communities from north-central Nebraska to south-central South Dakota (e.g., Cherry and Grant Counties, Nebraska (yellow star in **Figure 8**) and Todd County, South Dakota (**Figure 7**)). However, there are no known sites on National Forest System lands in South Dakota. Finally, *E. elliptica* was listed as a species component in Almeria Meadows Wildlife Management Area in Loup County, Nebraska (Draft Environmental Assessment by Nebraska Game and Parks Commission 2002). The site is along the North Loup River in central Nebraska (purple star in **Figure 8**).

Table 6 lists University of Wyoming herbarium records for *Eleocharis elliptica* in Canadian provinces and in states outside of USFS Region 2 (University of Wyoming Rocky Mountain Herbarium 2005). These herbarium records also substantiate the widespread distribution of *E. elliptica* across central and eastern North America. At individual sites, it ranges in abundance from uncommon, to frequent, to extremely common.

Although *Eleocharis elliptica* has a wide distribution outside of USFS Region 2 (the northeastern United States to British Columbia, Canada), USFS Region 2 has previously stated that the only known occurrence is in Wyoming (i.e., the Laramie Range in the Medicine Bow National Forest and at sites very close to Region 2 in Yellowstone National Park) (USDA Forest Service 2002a). The numerous other sources of information, as discussed above, appear to contradict this conclusion. All of these USFS Region 2 observations and accounts will ultimately depend upon future investigations and verification of collected specimens across the region.

Population trend

There is essentially no available information on the population trend for *Eleocharis elliptica*. There are no scientifically based research reports studying population trends for this species at either a local or regional level to say whether this species is declining, increasing, or remaining stable. There are a few published papers on the community ecology and diversity of wetlands sites where *E. elliptica* (or purported *E. elliptica*) is a member of the community, but these focus on the overall community, not any plant species in particular.

Despite taxonomic confusion over the years, there appears to be enough information to say that *Eleocharis*

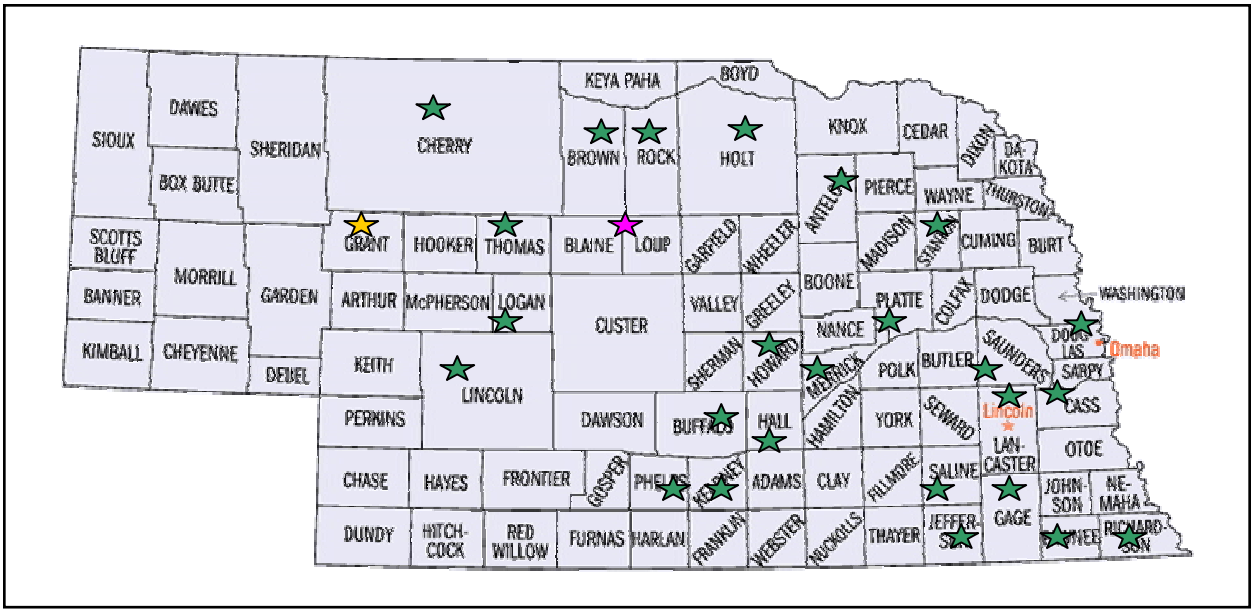

Figure 8. Distribution of purported *Eleocharis elliptica* sites in Nebraska. Green stars indicate the counties in which the species was reported and are based on information supplied in Rolfsmeier (1995). The purple star is the location in Almeria Meadows Wildlife Management Area in Loup County. The yellow star indicates a potential additional county based on potential habitat. Source: USDA Forest Service 2004.

Table 6. Herbarium specimen records of *Eleocharis elliptica* in U.S. states and Canadian Provinces outside of USFS Region 2 (labeled, annotated, or filed under *E. elliptica* or its synonyms) at the University of Wyoming Rocky Mountain Herbarium (RM).

State/Province	Year of Collection	Notes on Location and Abundance	Notes on Habitat and Plant Community
Delaware	1929	Along railroad track, Claymont, New Castle County	Low ground along railroad tracks
Illinois	1900	Stark County	Moist ditch
Illinois	1915	Macon County	Moist soil
Indiana	1932	Frequent near railroad tracks east of Goodland, Newton County, T27N, R8W, Sec. 25	Wet prairie, Marshall loam soil, deposition occurring, associated with *Asclepias* sp., *Carex* sp., *Steironema* (*Lysimachia*) sp.
Iowa	1897	Peru	None
Massachusetts	1900	Near Polpis, Nantucket	Swamps
Massachusetts	1917	Parker Mountain, Lanesboro	Swamp edge
Michigan	1898	Port Huron, St. Clair County	None
Michigan	1917	Emmet County	In bog
Michigan	1936	1 mile south of Lake Manganese, upper peninsula, Keweenaw County	Dry sandy upper beach of Lake Manganese
Minnesota	1962	4 miles northwest of Karlstad, Kittson County	Wet bushland
Minnesota	1963	Extremely common, often forming nearly pure stands, 5.6 miles north of Clearbrook, Clearwater County, T150N, R37W, SE¼ Sec. 30	In low meadow of old lakebed, in low spots, strongly rhizomatous, often forming nearly pure stands
Minnesota	1981	Frequent, 2½ miles south of Wright, Carlton County, T48N, R21W, Sec. 22	Minerotrophic water track dominated by *Carex lasiocarpa*
Missouri	1887	Jefferson County	Silica substrate
Montana	1894	Columbia Falls	None
Montana	2001	Uncommon along rivulet near spring, Bighorn Canyon National Recreation Area, Carbon County, T8S, R28E, SW¼ of NE¼, Sec. 27	Along rivulet near spring head on saturated peat, 15% east-north-east aspect, 5310 ft., on level ground of midslope escarpment, with *Carex lanuginosa* and *Juncus balticus*, in dense moss cover
New Hampshire	1893	Summer's Falls	None
New Hampshire	1936	Hillsboro County	Moist places
New Mexico	1968	Common in wooded area near Clarks Fork, Philmont Scout Ranch, Colfax County	In wooded area near trail with C*arex eleocharis*, *Pinus ponderosa*, and *Quercus gambelii*
North Dakota	1922	Lamour County	None
North Dakota	1922	Lamour County	None
North Dakota	1922	Lamour County	None
Canada, Newfoundland	1911	Valley of Exploits River, Bishop Falls	Springy spots in gravel or ledges, north bank of river below Bishop Falls
Canada, Ontario	1895	Near Sarnia, Lambton County	None
Canada, Ontario	1895	Near Sarnia, Lambton County	None

Table 6 (concluded).

State/Province	Year of Collection	Notes on Location and Abundance	Notes on Habitat and Plant Community
Canada, Ontario	1952	Abundant on sandy shore, Crowe Lake, 2½ northwest of Marmora, 44º 30'N, 77º 41'W	Sandy shore of Crowe Lake
Canada, Ontario	1969	Hastings County, Thurlow Township, Point Anne	Wet depression in pasture
Canada, Quebec	1926	De L'ile D'Antcosti, Jupiter River	Humid calcareous clays
Canada, Quebec	1929	At boundary with New Brunswick, junction of Restigouche and Matapedia Rivers	In flowing water at river junction
Canada, Quebec	1930	Boucherville County, De Chambly	Humid clays
Canada, Quebec	1941	Saint-Jean De L'ile D'Orleans	Rocky shore

elliptica as a whole across its entire range is stable, at least within its core area of distribution, the northeastern to central parts of the United States and Canada. The apparent recent "appearance" of the species in several western states, including those within USFS Region 2, within the past few decades, does not reflect a population trend, but is the result of taxonomic reports and revisions concerning *E. elliptica*. Such changes are not related to actual population trends, but may falsely appear as trends if all of the literature has not been properly assessed.

Ultimately, *Eleocharis elliptica* appears to be a species peripheral to USFS Region 2, but that with a few taxonomic uncertainties taken into consideration, it may be widely or narrowly distributed (and most likely sparsely) within Region 2. The information in the previous section generally indicates three scenarios. Either *E. elliptica* has 1) almost no occurrences or very few at most in USFS Region 2; 2) numerous occurrences, but a widely scattered distribution within USFS Region 2; or 3) numerous occurrences and a common distribution in USFS Region 2.

Given this gradation of uncertainty, and through stochastic properties of plant community dynamics and successional changes at individual wetland sites, populations at individual wetland sites may disappear (become locally extinct), appear at a new site (i.e., become dispersed and established elsewhere), or reappear at a site where it had previously disappeared (e.g., the mature vegetative plant may have died, but a long-lived seed bank could re-establish the species). Such local population trends would be more significant to Region 2 under the first scenario above, and much less significant under scenarios 2 or 3 above. Under the continental distribution of *Eleocharis elliptica*, such local population trends would have little overall meaning for the species as a whole, other than the potential loss of locally adapted ecotypes.

Habitat

Macrohabitat

As is characteristic with all members of the genus *Eleocharis*, *E. elliptica* is a wetland plant species, or minimally a species that requires moist to damp soil and a reliable water supply. The term wetland can encompass a wide variety of named habitats, but those that apply to USFS Region 2 would be bogs, fens, bottomlands, floodplains, marshes, playas, potholes, swamps, wet meadows, and wet prairies (Barbour and Billings 2000). How wetlands primarily receive their water (e.g., precipitation, surface flow, underground seepage) is important to their functioning and species composition. The wetting and drying cycles, water salinity, and water depth greatly influence the zonation patterns of the wetland vegetation.

As defined by the USFWS and used for inventory and mapping purposes for the National Wetlands Inventory, wetlands are lands that are transitional between terrestrial and aquatic systems where the water table is usually at or near the surface or the land is covered by shallow water, and they have one or more of the following three attributes:

- at least periodically the land supports predominantly hydrophytes,
- the substrate is predominantly undrained hydric soil, and
- the substrate is non-soil and is saturated with water or covered by shallow water at some

time during the growing season of each year (Cowardin et al. 1979).

This is the definition that is probably best used to circumscribe the generalized macrohabitat features for potential habitats for *Eleocharis elliptica*.

Wetlands have also been defined in regulatory terms (Wetland Training Institute 2001) as lowland areas that are inundated or saturated with water for a sufficient time to allow a prevalence of hydrophytic vegetation to develop. Jurisdictional wetlands, those protected from unauthorized dredge-and-fill activities under Section 404 of the Clean Water Act and implemented by the USACE, have three essential characteristics:

- dominance by hydrophytic vegetation
- hydric soils
- wetland hydrology.

Hydrophytic vegetation requires inundated or saturated soils. Hydric soils are ponded or flooded for a sufficient time during the growing season to develop anaerobic conditions. Wetland hydrology is the availability of surface water or groundwater to create a wetland environment. These regulatory definitions, although they reflect those of the USFWS, are narrower in scope than those of the USFWS.

The USFWS has classified numerous species across the United States for their tendency to be wetland plants. The related taxa *Eleocharis compressa* and *E. tenuis* are both listed as FACW plant species on the USFWS national and regional lists of wetland plants (U.S. Fish and Wildlife Service 1988, U.S. Fish and Wildlife Service 1996). FACW stands for a facultative wetland plant, meaning more specifically that it usually (over 67 to 99 percent frequency) occurs within wetlands, but sometimes (1 to 33 percent frequency) occurs in non-wetlands. It should be pointed out that the USFWS does not officially list every species that could occur in wetlands, and *E. elliptica* is not one of the species on USFWS lists. Based on experience, however, it can be assumed that *E. elliptica* would have a wetland rating very similar to that of *E. compressa* and *E. tenuis*.

Using the synonymies previously discussed (**Table 2**), *Eleocharis elliptica* is almost always reported as a species of wet areas across the eastern and central portions of the United States and Canada (Britton and Brown 1913, Gleason and Cronquist 1963); is a component in a sedge-rush swale area adjacent to a pond in Ontario Province, Canada (Nakashima 1973); occurs in moist sandy flats and sandy swales where it is classified as FACW+ in Pennsylvania (Rhoads and Klein 1993); is found along the borders of lakes and ponds and in moist prairie habitats in Indiana (Deam 1940); occurs in low wet areas of Illinois (Mohlenbrock 1986), in wet soil in West Virginia (Strausbaugh 1970-77), in emergent wetlands in West Virginia (Brant 1987), along sandy beaches and lake shores in northeastern Minnesota (Lakela 1965), and in the shore fen habitat (an open peatland plant community along lake shores) in Wisconsin (Wisconsin Natural Heritage Inventory 2004). It is also found in calcareous fens and prairies in Wisconsin (Smith personal communication 2006).

For eastern sources of information that specifically separated *Eleocharis elliptica* from *E. compressa* or *E. tenuis*, the following comments supply some additional information regarding the habitat of other members of the *E. tenuis-E. elliptica-E. compressa* complex. *Eleocharis compressa* occurs in marshes and along shores (Gleason and Cronquist 1963). In Pennsylvania, where they are both classified as FACW+, *E. compressa* var. *compressa* occurs on wet sandy ground, and river banks, and *E. tenuis* var. *tenuis* occurs in moist fields, swamps, bogs, and wet ditches (Rhoads and Klein 1993). *Eleocharis tenuis* var. *pseudoptera* occurs in moist meadows, hayfields, and damp areas of serpentine, and *E. tenuis* var. *verrucosa* occurs on moist open ground (Rhoads and Klein 1993). In the Duluth area of Minnesota, *E. compressa* occurs in wet meadows and sedge mats (Lakela 1965). It has its best development in prairies, and the limestone glades of Ohio and Tennessee where it grades into *E. elliptica* (Svenson 1957). In glaciated portions of the midwestern United States, *E. elliptica* has been identified as a species common to fens across Ohio, Indiana, Illinois, Iowa, and Wisconsin (Amon et al. 2002). Fens in this region of the country were defined as wetlands that

- have high botanical diversity
- are supported by groundwater with circumneutral pH and moderate electrical conductivities
- have water in the root zone for much of the growing season
- accumulate carbonate and/or organic substrates.

For the Great Plains and mountain states, where the taxonomic status of *Eleocharis elliptica* is yet to be fully determined according to Smith (2002), the macrohabitat for all three taxa (*E. elliptica*, *E. compressa*, and *E. tenuis*) will be briefly reviewed. *Eleocharis elliptica* var. *compressa* was reported for loamy moist soils and shallow waters of ponds in Oklahoma, eastern Texas, and Georgia, while *E. tenuis* was reported for moist or wet sandy areas, wet forested areas, ditches and sloughs across the eastern United States (Correll and Correll 1975). *Eleocharis compressa* was reported to occur in low wet prairies, marshes, and sandy flood plains across the northern Great Plains (Great Plains Flora Association 1986), and it was described for areas of wet seeps and wet prairies in the northern Great Plains (Larson 1993). *Eleocharis compressa* was reported to occur in northern New Mexico from about 7,000 to 8,000 ft. in elevation on moist, sandy ground (Martin and Hutchins 1980-81), and it was described as a species of some of the most xeric wetland conditions in western and Midwestern regions where it occurs on sites with shallow soil (Catling 1994). *Eleocharis elliptica* is listed as a wetland plant of Jefferson County, Colorado (Jefferson County 2004). *Eleocharis elliptica* var. *compressa* is reported to occur on eastern slope piedmont valleys and outwash mesas in Colorado (Weber and Wittmann 2001a). On Colorado's western slope, it occurs in wet places of open pine forests (Weber and Wittmann 2001b). *Eleocharis tenuis* var. *borealis* grows in wet areas of Yellowstone National Park and Platte County, Wyoming (Dorn 2001). *Eleocharis elliptica* typically occurs in wet meadows and seeps, sometimes in upland prairie sites in Nebraska (Rolfsmeier 1995).

Table 4 supplies notes from herbarium collections of *Eleocharis elliptica* in Colorado (University of Colorado Herbarium 2004). Some of these herbarium sheet comments concern more specific microhabitat characteristics and consequently will serve as a lead into the next section on microhabitat. The brief habitat notes supplied with **Table 4** herbarium specimens from Colorado suggest that the wetland habitats in which *E. elliptica* is found tend to be ephemeral, with drying and wetting cycles. It also appears that at least some sites have alkaline or calcareous substrate conditions. The plants may also be limited to narrow zones within the local community.

Table 3 presents habitat notes from herbarium collections of *Eleocharis elliptica* in Wyoming (University of Wyoming Rocky Mountain Herbarium 2005). The Teton County records in Yellowstone National Park indicate that some of the occurrences are associated with hot springs. Such sites might be classified as stressful sites (because of heated water, increased mineral levels, perhaps localized increases in sulfur dioxide gas, etc.), with conditions that are generally outside of the normal range of environmental variation experienced by most plants. However, this conclusion will depend upon exactly where in the hot springs habitat the plants occur. Collective knowledge in ecological research would indicate a general adaptive selection pressure that would cause some local ecotypic differentiation to have occurred in plant populations in such habitats. The other Yellowstone record indicates another seasonally wet habitat. The site in Platte County (**Table 3**, **Figure 4**) is described as a seepage site, which may also be seasonal depending on annual and short term precipitation conditions.

Table 5 lists records for other states within USFS Region 2 (University of Wyoming Rocky Mountain Herbarium 2005). A couple of the described sites appear to have been relatively dry when the collections were made. Seasonally wet conditions again appear as a descriptor. Prairie sites are among those where *Eleocharis elliptica* is reported. Many of the older specimens have no habitat comments associated with them.

Table 6 lists records for other states, and Canadian provinces, outside of USFS Region 2 (University of Wyoming Rocky Mountain Herbarium 2005). The observed habitats across the full range of *Eleocharis elliptica* are quite varied, from low wet areas along railroad tracks, wet ditches, swamps, bogs, wet prairies, sandy beaches, wet brushlands, at spring seeps, and along rivers. Substrates vary from rocky, to sandy, to clayey; the clays may be calcareous. Water sources may be mineral rich. In order for a species to have such a continent-wide distribution, it would have needed to go through a natural selection process in becoming adapted to such a wide variety of local conditions. This is not uncommon for wide ranging species. In the current Flora of North America (Smith 2002), *E. elliptica* is described as occurring on wet, calcareous or brackish shores, pools, fens, meadows, and prairies.

Microhabitat

There are considerably fewer observations and comments about the microhabitat conditions concerning *Eleocharis elliptica*, and the following discussion will summarize these. In Ohio, *E. elliptica* var. *compressa* was reported to occur in dry to moist calcareous openings, prairies, seeps, fens, even in old quarries (McCance and Burns 1984). Sites were often only seasonally moist,

and the species was considered the most adapted to drier sites of any spikerush. In Indiana, *E. elliptica* was reported to be associated with the strongly marl areas along lake borders and moist prairie habitats while the related *E. tenuis* was reported associated with hard clay soils along the edges of ponds and wet woods (Deam 1940). In West Virginia, *E. elliptica* was reported for emergent wetlands in circumneutral open minerotrophic spring waters (Brant 1987). In Wisconsin, *E. elliptica* was reported to be common in an open peatland plant community along lake shores in circumneutral waters that are nutrient rich (Wisconsin Natural Heritage Inventory 2004). A microhabitat observation pertaining to *E. tenuis* included it in an *Andropogon scoparius* grass association, which include three species of *Juncus* and one species of *Carex*, on serpentine barrens at Soldier's Delight, Maryland, about 15 km (9.4 miles) west of Baltimore. The site was about 324 hectares (800 acres) of serpentine barrens and forest where there were a few old chrome mines (Brooks 1987).

In Wyoming, *Eleocharis tenuis* var. *borealis* (i.e., *E. elliptica*) is mainly associated with thermally affected seeps and springs (Yellowstone National Park), but it is also found on non-thermal sites at 6,200 to 7,250 ft. in the Medicine Bow National Forest (Wyoming Natural Diversity Database 2004). In Smith (2002), *E. elliptica* var. *elliptica* is reported as adapted to microhabitats where the surface soil is permanently saturated with water from springs (e.g., ground supply only) whereas *E. compressa* var. *compressa* is adapted to prairie depressions with limestone substrates and dry summers. Although *E. elliptica* and *E. compressa* may occur within the same wetland, *E. elliptica* would be found in the wetter portions of the wetland and *E. compressa* in the drier portions (Smith personal communication 2006). *Eleocharis elliptica* var. *atrata* has been considered to occur in habitats intermediate in characteristics between *E. elliptica* var. *elliptica* and *E. compressa* var. *compressa* (Smith 2001). Whether these observations would remain consistent in USFS Region 2 may be another uncertainty factor in the regional and local distribution of *E. elliptica*. A wide ranging species would be expected to have numerous local ecotypes, populations adapted to particular local conditions. Consequently, microhabitat conditions associated with this species in northeastern North America may be slightly different than in the Great Plains or Rocky Mountain Region.

Vegetation associations and plant community

Based on herbarium records from the University of Wyoming Rocky Mountain Herbarium (2005) from specimens collected outside of USFS Region 2 (**Table 6**), associates of *Eleocharis elliptica* include *Carex* spp. (sedges), *Juncus* spp. (rushes), *Asclepias* spp. (milkweeds), and *Lysimachia* spp. (loosestrife). From herbarium records of states within USFS Region 2 (**Table 3**, **Table 4**, and **Table 5**), associates are *Carex* spp. (*C. nebraskensis*), *Juncus* spp. (*J. dudleyi*, *J. balticus*, *J. interior*), *E. rostellata*, *Scirpus americanus*, *Valeriana edulis*, *Antennaria neglecta*, *Typha* spp., and other *Eleocharis* spp. There are essentially no scientifically based research reports about the plant community associates of *E. elliptica*, using *E. elliptica* as a focal species of research. There are a few observations and reports about wetland plant communities in which *E. elliptica* (or purported *E. elliptica*) is one of the observed members of the community. These reports and papers are summarized in the Community Ecology section below. There is not enough known about the ecology of *E. elliptica*, either locally or over its entire geographic extent, to adequately assess the availability of habitat relative to occupied habitat.

Reproductive biology and autecology

There is very little published information about the reproductive biology and autecology of *Eleocharis elliptica* other than what is generally known about the genus as a whole. The flowers are very small and bisexual (i.e., contain both male and female parts). Such plants are referred to as perfect. As with most grasses and sedges with such small inconspicuous flowers, pollination is entirely by the wind (or by self-pollination). Outcrossing distances in *E. elliptica* are unknown. Although some members of the genus are annual, *E. elliptica* and its close taxonomic relatives are rhizomatous perennials. The rhizomatous growth habit would allow for substantial vegetative reproduction and population spread laterally or horizontally across the localized site. This growth habit would also greatly add to overall species longevity, but this is unknown for this species. For comparative purposes, rhizomatous clonal species of the genus *Carex* (sedges) are reported to range in age from 17 to 154 years for one species and 2,000 to 3,000 years for two other species (Steinger et al. 1996, Jonsdottir et al. 2000). Although there are no specific reports on which to classify its overall life history, based on the accumulated floras and literature, *E. elliptica* would probably be best classified as a "K" species, a species with a relatively lower reproductive rate, a longer lived species of stable to semi-stable habitats. Semi-stable meaning that some level of disturbance, such as wetting and drying cycles, are common aspects of some wetland habitats, especially those located in the plains and western mountain zones.

Based on some of the accounts, *E. elliptica* may also have some characteristics of a "stress tolerator" (Grime 1979). A potential example is its possible presence in the vicinity of thermal seeps in Yellowstone National Park, habitats with local conditions that could be considered different than what most plants experience (although the localized warming of water may also be favorable by extending growing seasons).

The following discussion summarizes some of the observations and comments made about the reproduction and autecology of *Eleocharis elliptica* or those of other species in the *E. tenuis*-*E. elliptica*-*E. compressa* complex that would likely apply to *E. elliptica*. In Illinois, *E. elliptica* blooms from May to July (Mohlenbrock 1986). In Indiana, *E. elliptica* blooms from May to August, peaking in June to July, while *E. tenuis* blooms from May to July with a June peak (Deam 1940). In Ohio, *E. elliptica* var. *compressa* fruits in June to July (McCance and Burns 1984). In West Virginia, the related *E. tenuis* blooms from May to July (Strausbaugh and Core 1970-77). Across the northeastern United States, *E. tenuis* blooms from May to July (Britton and Brown 1913). In Wyoming, *E. tenuis* var. *borealis* blooms and fruits from June to August (Wyoming Natural Diversity Database 2004). In the current Flora of North America, *E. elliptica* is listed as fruiting from late spring to summer (Smith 2002).

Seed distribution of *Eleocharis* species has long been known to occur by water and in mud that becomes attached to wetland birds and other animal life (Cratty 1898). These observations remain consistent today as *Eleocharis* seeds are reported to be dispersed by water, birds, and other animals that inhabit and feed on sedges (reviewed in Middleton 1999). Waterfowl can be important local and long distance distributors of *Eleocharis* seed (reviewed in Green et al. 2002). *Eleocharis* seeds may be moved locally as well as both northwards and southwards during migrations, and they tend to be consumed more in spring than other wetland species, thus resulting in greater potential southward movement than other wetland species (Green et al. 2002). Blue-winged teal (*Anas discors*), green-winged teal (*A. carolinensis*), mallard (*A. platyrhynchos*), and pintail (*A. acuta*) have all been reported to feed on and/or transport *Eleocharis* seeds. Water as a dispersal agent in lakes, ponds, swamps, etc. would not necessarily move seeds great distances, unless seeds were able to float, or become attached to floating debris. Plants growing in riparian settings are expected to experience greater distances of seed dispersal (at least in a linear direction), due to the flow through movement of the water, than plants in pond or lake habitats. Since birds and other waterfowl are important distributors of seed and can travel great distances, especially during migrations, there is a tremendous potential for long distance transport of *E. elliptica*. This may ultimately contribute to the taxonomic blending of *E. elliptica* with *E. compressa* and *E. tenuis*, by bringing them into close proximity within a wetland habitat. Seeds of the genus *Eleocharis* store well at 3 ºC in water (Baskin and Baskin 2001). Several species in the genus *Eleocharis* exhibit a greater percent germination under flooded conditions than under non-flooded conditions. Most species tested (*E. elliptica* is not one of the specifically tested species) require cold stratification (although one species requires warm stratification) and germinate at 15 to 30 ºC. Sediment depths greater than 1 cm are inhibitory to germination. Water pH and hardness can also affect germination (Baskin and Baskin 2001). Most species of *Eleocharis* appear to germinate best in moist, unflooded conditions, but some species do germinate under water (e.g., *E. palustris*) (reviewed in Middleton 1999). Bell and Clarke (2004) report that steadily increasing water depths (from 0 to 78 cm) results in substantial inhibitory effects upon seed germination for four species of *Eleocharis* in New South Wales, Australia. Seed viability remained high (83 to 94 percent) after 33 months of burial in sediments. Bell and Clarke (2004) estimated that seed longevity (expressed as half-life) was approximately 50 years for two of the four species and as much as 400 years for the other two species of *Eleocharis*.

Harms (1972) reported on making successful artificial crosses or hybrids between *Eleocharis elliptica* and other species in the *E. tenuis* complex. Successful crosses were made between *E. elliptica* and *E. compressa*, *E. elliptica* var. *elliptica* and *E. elliptica* var. *pseudoptera*, and *E. tenuis* and *E. compressa* (Harms 1972). The source material used for this study came from several northeastern states (*E. tenuis* and *E. elliptica*) and several midwestern states (E. elliptic and *E. compressa*). Harms (1972) thought that variety *pseudoptera* was best placed in *E. elliptica*, but most recently this variety has been placed in *E. tenuis* (Smith 2002). Smith (2002) stated that there are no voucher specimens of the taxa and crosses from the Harms (1972) study. Additional hybridization work on species in this complex was conducted by Catling (1994). Catling (1994) reports sterile hybrids from Ontario, Canada, between *E. compressa* and *E. erythropoda*. There was also some question as to whether *E. elliptica* could have been a parent in the hybrids. In a dichotomous key, Catling separates the *E. compressa* x *E. erythropoda* hybrid from *E. elliptica* by the number of stem angles and vascular bundles, five to nine in *E. elliptica*, and

nine to ten in the *E. compressa* x *E. erythropoda* hybrid. All of this information further emphasizes the apparent extensive hybridization and taxonomic confusion for the whole complex.

Demography

A simple life cycle diagram for *Eleocharis elliptica* based on the limited information in this section and in the previous section is shown in **Figure 9**. There are no studies in the literature discussing the demographic life history characteristics of *E. elliptica*. As a species reproducing vegetatively by rhizomes, it is expected to have a relatively long life span, especially in a stable local wetland habitat. Observations on 100 to 200 stems of *E. elliptica* populations at some of the Yellowstone National Park sites may represent a single clone. It may be possible to determine age classes of tillers (i.e., stems) in rhizomatous tillering species such as *Eleocharis*. In the rhizomatous *Carex bigelovii*

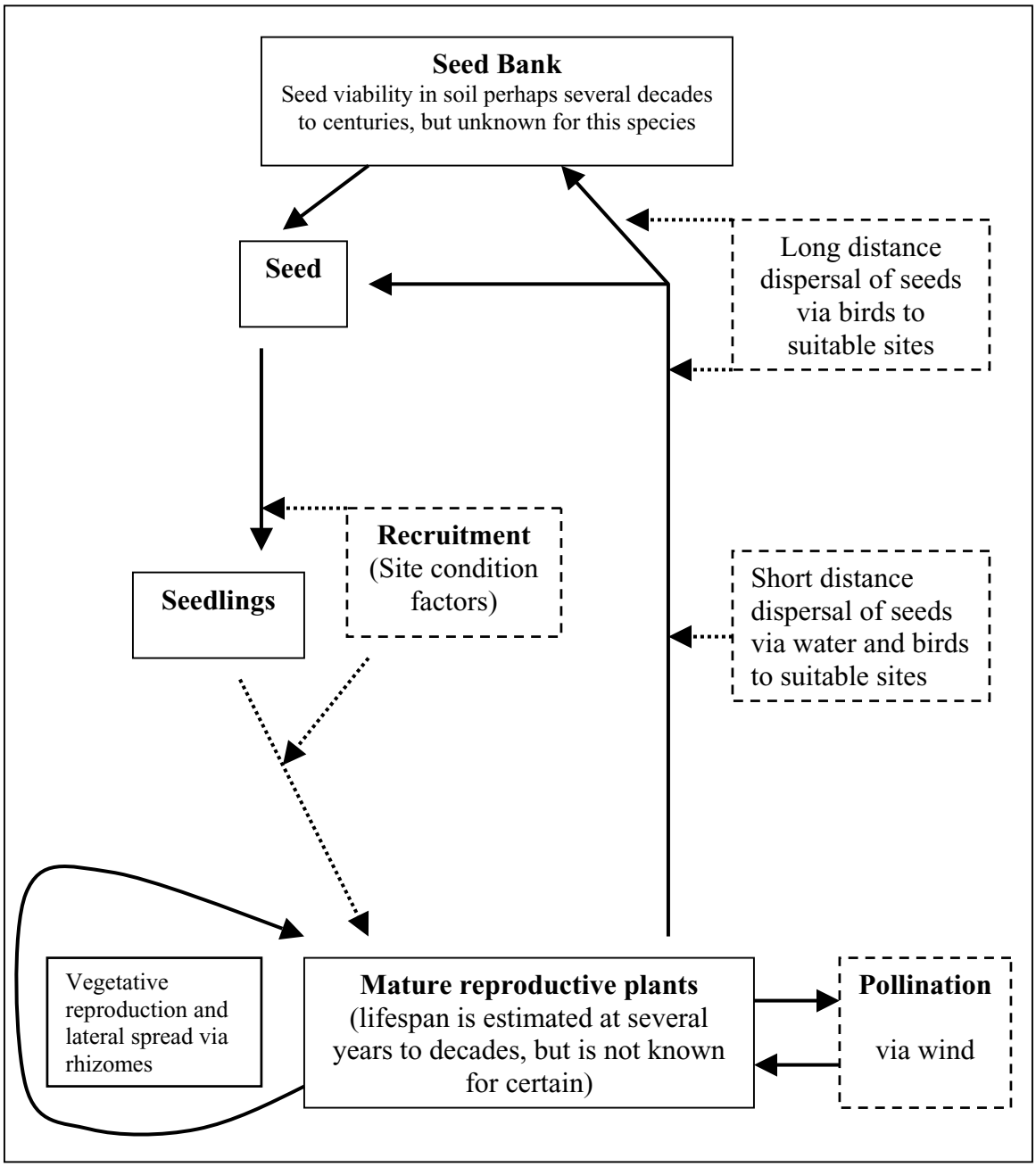

Figure 9. Life cycle diagram for *Eleocharis elliptica*.

(also in the Cyperaceae family with *Eleocharis*), it was possible through careful examination to determine four "age" classes (probably better termed size classes or growth stages) of aerial stems based on their size, apparent health, and ratio of dead to dead and living stems (Silvertown 1982). A matrix was used to predict stem density over time as stem density at a particular point in time could affect future stem density. The pattern of rhizome growth will affect a plant's apparent incremental spread across the habitat, whether that spread is linear or in multiple directions (Silvertown 1982).

Water depth can be important in seedling survival for many species of *Eleocharis* (reviewed in Middleton 1999). The depth that seed may become buried in soil and wetland sediments would likewise be a factor. The depth of buried viable seed for species of *Carex* declined dramatically from the surface down to 3 cm (Harper 1977).

Population viability analyses have not been performed on *Eleocharis elliptica*. Estimating minimum viable population sizes can become a risky extrapolation when the concrete field studies relating specifically to the taxon in question (and its site specific conditions) have not been performed. Extrapolating from one species with documented information to another species with little information (such as *E. elliptica*) may not be completely appropriate. Several authors have discussed effective, minimum, or viable population sizes in general (or broad) terms that have been extensively discussed, debated, and applied by other scientists (Franklin 1980, Soulé 1980, Lande and Barrowclough 1987, Soulé 1987, Menges 1991, Lande 1995, Nelson 1999). The general rule of thumb model from these authors has been the 50/500 rule; isolated populations will need an effective population size of 50 individuals for short term persistence while 500 individuals will be needed for long-term survival. Some of the more recent authors listed above have increased these numbers. Hickler (2003) attempted to address minimum viable population size for *E. quadrangulata* in New England by recommending a target of 5000 fertile stems for a stable population, but gave little direct experimental data support for this figure, and also indicated that the species has always been rare in New England, yet the species has good dispersal ability and is easily introduced into diverse settings. Considering the numerous environmental factors potentially affecting any particular plant population, locality specific and site specific research can be critical towards determining what a minimum viable population size is.

Eleocharis elliptica has the highest number of chromosomes reported for the *E. tenuis* complex (Harms 1972). It has a 2n (diploid) chromosome value of 38 with 19 bivalents common in meiosis although sometimes anywhere from 17 to 21 bivalents will be present. The *E. elliptica* source material used for this study came from Connecticut, Delaware, New York, Illinois, and Missouri. Many intercrosses were tested, numerous ones exhibiting success: *E. elliptica* (2n = 38) x *E. compressa* (2n = 36 form); *E. elliptica* var. *elliptica* (2n = 38) x *E. elliptica* var. *pseudoptera* (2n = 38); and *E. tenuis* (2n = 24) x *E. compressa* (both 2n = 24 and 2n = 36 forms). *Eleocharis verrucosa* (2n = 20) was considered the most different taxon of the complex studied. Harms concluded there were two ancestral cytotypes: 1) 2n = 10 generating the *E. verrucosa* taxon (field samples from Illinois and Kansas); and 2) 2n = 12 generating *E. tenuis* (field samples from Connecticut, Massachusetts, and New Jersey), *E. compressa* (field samples from Arkansas, Missouri, Kansas, and North Dakota), and *E. elliptica* (field samples as already indicated above). In another study, chromosome counts were reported for *E. tenuis* var. *pseudoptera* as 2n = 39 (Schuyler 1977). Also in this study, *E. tenuis* var. *verrucosa* was reported at 2n = 20, *E. tenuis* var. *tenuis* was 2n = 24, and a possible hybrid between variety *tenuis* and variety *pseudoptera* was 2n = 34.

Community ecology

The ecological literature is very scant for *Eleocharis elliptica*. This discussion begins with some general observations from localities within the eastern half of North America, and it then reviews some more detailed reports and studies from Nebraska to the state of New York. *Eleocharis elliptica* was listed as a plant community component in a sedge-rush swale area adjacent to a pond in Norfolk County, Ontario Province, near Port Rowan, Canada (Nakashima 1973). *Eleocharis elliptica* collected from Greenbrier County, West Virginia (Brant 1987) was described as being sympatric with *E. tenuis*. *Eleocharis elliptica* is common in the shore fen habitat (an open peatland plant community along lake shores) (Wisconsin Natural Heritage Inventory 2004). Associated species are woolly sedge (*Carex lasiocarpa*), sweet gale (*Myrica gale*), bogbean (*Menyanthes trifoliata*), twigrush (*Cladium mariscoides*), marsh horsetail (*Equisetum fluviatile*), intermediate bladderwort (*Utricularia intermedia*), marsh bellflower (*Campanula aparinoides*), narrow-leaved willow-herb (*Epilobium leptophyllum*), water parsnip (*Sium suave*), and bog willow (*Salix pedicellaris*).

Some of the most well described plant community associations containing *Eleocharis elliptica* come from within USFS Region 2, in Nebraska. *Eleocharis elliptica* was listed as a species component in the Almeria Meadows Wildlife Management Area in Loup County, Nebraska (Nebraska Game and Parks Commission 2002). The site is along the North Loup River in central Nebraska (purple star in **Figure 8**). The area is described as a Sandhills wet-mesic tallgrass prairie, while the lower swales are more specifically classified as Northern Sedge Wet Meadows. The water table lies about 1 m below the surface; portions of the areas may flood from time to time. Some of the listed plant associates are most similar to that described for the Sandhills Bluejoint Wet Prairie described above (*Asclepias incarnata*, *Cicuta maculata*, *Mentha arvensis*, *Lycopus uniflorus*, *Scutellaria galericulata*, *Prunella vulgaris*, *Lythrum alatum*, *Carex brevior*, *Hypoxis hirsuta*, as well as the non-natives, *Agrostis gigantea* and *Phleum pratense*). The area is mowed for hay once per year. This action functions as a substitute for the lack of natural fire by keeping out woody vegetation, reducing thatch, and providing winter forage for a leased cow/calf operation.

Eleocharis elliptica is listed as a species component in Sandhills Bluejoint Wet Prairie in Nebraska (USDA Forest Service 2004). The plant association is identified as a *Calamagrostis canadensis-Juncus* spp.-*Carex* spp.- Sandhills herbaceous vegetation classification (using common names, a Canada bluejoint-Rush spp.-Sedge spp.- Sandhills community). It is a temporarily flooded temperate grassland. This habitat occurs in the Sandhills area of Nebraska and may also occur in Kansas and North Dakota. In Nebraska, the sites are within the McKelvie National Forest. The community habitat occurs on relatively level ground adjacent to streams and rivers and wet interdunal valleys. This community will also form borders around lakes, marshes, and fens. These areas may be temporarily flooded or saturated in the early part of the growing season. The soils are sandy loams and sands with a relatively high organic matter content (mucks or peats) and are poorly drained. These soils have formed in aeolian sand or alluvium. Other species found in association with *E. elliptica*, in addition to those already mentioned, include *Spartina pectinata*, *Salix exigua*, *S. lutea*, *Cicuta maculata*, and *Mentha arvensis*. This habitat has been placed at a conservation rank of G3/G4 (vulnerable to apparently secure) because of site impacts from ditching and seeding to non-native species.

Eleocharis elliptica is also found in Sandhills Shrub Fen communities (*Salix petiolaris/Carex interior-Thelypteris palustris* Shrubland (common names, Willow/Sedge sp. Marsh Fern Shrubland)) (USDA Forest Service 2004). This community type occurs from north-central Nebraska to south-central South Dakota (e.g., Cherry and Grant Counties, Nebraska [**Figure 8**] and Todd County, South Dakota [**Figure 7**]). There are no known sites on National Forest System lands. This community type is found at the inflow ends of lakes and marshes and at the headwaters of stream valleys within the Sandhills region. The soils are classified as Cutcomb mucky peats, resulting from decaying herbaceous vegetation and tend to have a low oxygen availability. Soils stay saturated most of the time, but they do not flood, at least not regularly. The water table is 15 to 30 cm below the surface. The peat deposits may range from 30 cm to more than 7 m deep. The sites are often dominated by *S. petiolaris*, reaching heights of 1 to 3 m. Herbaceous species that may also be dominant are *Phragmites communis*, *Scirpus acutus*, and *Typha latifolia*. The ferns *Onoclea sensibilis* and *Thelypteris palustris* are common understory species. Fires and flooding (apparently irregular flooding) are important historical disturbance factors. The habitat conservation ranking is G2 (imperiled), and as with many wetlands, these sites have been impacted by draining, seeding to non-natives, and the decomposition of the peat once they are drained. Restoration of natural water regimes and prevention of draining will conserve these sites. In Kansas, freshwater marshes and fens have been assigned habitat conservation rankings of S1 to S2; the ranking for fens, however, is apparently questionable (Kansas Natural Heritage Program 2005). No other wetland habitats in which *E. elliptica* or its taxonomic relatives could occur have any ranking in Kansas.

According to the Nature Conservancy (The Nature Conservancy 2001; on NatureServe 2004), *Eleocharis elliptica* is identified as a characteristic identifying species for Sandhills Fens. The vegetation type is listed as *Carex interior-Eleocharis elliptica-Thelypteris palustris*. This classification sounds very similar to the Sandhills Shrub Fen described above, is identified as occurring in South Dakota and Nebraska, but has some species overlap/similarity with the Sandhills Bluejoint Wet Prairie also described above. The habitat conservation ranking is G1/G2 (critically imperiled to imperiled). The habitat distribution similarly follows that as described above.

In a peatland habitat site in the state of New York, in which *Eleocharis elliptica* was one of the wetland species present, the objective of a study was to determine the impacts of nutrient loading on the plant diversity in the wetland communities. Excessive nutrient

loading, especially of nitrate-nitrogen in excess of 4 mg per m^2 per day, resulted in reduced plant diversity. That portion of the wetland closer to an adjacent farm field had lower diversity than the portion of the wetland more distant (Drexler and Bedford 2002). Those areas of the wetland with greater diversity were more directly in line with groundwater spring flow, had more constant water levels and more consistent levels of base cation fluxes (e.g., calcium).

Eleocharis elliptica is one of the species reported from what have been described and classified as "isolated wetlands" (Tiner 2003). Isolated wetlands are generally in depressions surrounded by upland and are usually connected to nearby non-isolated wetlands by intermittent overland flow or spillage, or through groundwater flow. These wetlands are considered to have high biodiversity value and contain many at-risk (i.e., critically imperiled, imperiled, and vulnerable) species (Comer et al. 2005). Isolated wetlands perform many of the same functions as non-isolated wetlands (Tiner 2003). The various types of isolated wetlands found in Great Plains and western mountain regions are prairie potholes, playas, rainwater basin wetlands, sandhills wetlands, salt flats and salt lake wetlands, desert spring wetlands, kettle-hole wetlands, sinkhole wetlands, woodland vernal pools, rock and pool wetlands, geysers, seepage slope wetlands, fens, inactive floodplain wetlands, and natural ponds (Tiner 2003). Although this report is a general overall account of isolated wetlands, a few species, including *E. elliptica*, are mentioned by name. Both *E. elliptica* and *E. compressa* are identified as being associated with Great Lakes alvar wetlands, which occur on relatively flat limestone/dolomite based bedrock substrates. Named associates include balsam ragwort (*Senecio pauperculus*), Crawe's sedge (*Carex crawei*), bulrush sedge (*C. scirpoidea*), tufted hairgrass (*Deschampsia cespitosa*), and mosses (*Bryum* spp. and *Drepanocladus* spp.). *Eleocharis compressa* is even called a rare species (in a general sense) but typical on alvar wetlands. Impacts to such wetland habitats may be similar to wetland habitats in numerous places across the continent and include subdivision development, off-road vehicle use, and invasive plant species.

Eleocharis elliptica was one of the species occurring in fens in an Iowa study (Nekola 2004). Fens are considered peatland habitats in which the groundwater source has been enriched in nutrients, and the substrate is saturated, but not inundated. The fens in this study were considered high quality habitat. The 217 plant taxa were grouped by ordination into compositional clusters. *Eleocharis elliptica* was placed in a plant species cluster requiring relatively high soil moisture levels and calcareous conditions. *Eleocharis elliptica* was considered one of the regionally rarer species, but it occurred within its particular species cluster at a 42 percent sampling rate (statistical proportion). Its species cluster tended to occur most frequently (80 percent of the time) on a glacial till substrate as opposed to bedrock, fluvial, basin, and aeolian substrates. There were a few occurrences on bedrock and fluvial substrates. Species compositional regions were identified by the proportion of calciphile (calcium-"loving") and hydrophile (moisture-"loving") species. *Eleocharis elliptica* would be considered both a calciphile and a hydrophile. The plant cluster in which *E. elliptica* occurred was a low mat vegetation type with high plant diversity and high substrate pH and cation levels, with limited solubility of phosphorus compounds (Nekola 2004). Maintaining a low available phosphorus level and stable water levels, and minimizing unnatural influxes of nitrogen will be important in maintaining such plant communities.

The Cyperaceae family, including *Eleocharis*, is an important food source for wildlife such as waterfowl, muskrats, and other marsh inhabiting animals (Rolfsmeier 1995). *Eleocharis tenuis* is called "kill cow" because it is bad forage for livestock (Britton and Brown 1913, Strausbaugh and Core 1970-77). *Eleocharis compressa* and *E. erythropoda* are similarly avoided by cattle and also called "kill cow" (Catling 1994). Because of the generally toxic and unpalatable nature of the genus as a whole, making the plants useless for domestic livestock, the members of the genus *Eleocharis* are often classified as aquatic and riparian weeds, including those in the western United States (DiTomaso and Healy 2003).

Several species in the genus *Eleocharis* are reported to have allelopathic (toxic) effects on other aquatic and wetland plants (Wooten and Elakovich 1991, Pedersen 2002). There are no studies about parasites, diseases, or symbiotic and mutualistic interactions specifically concerning *E. elliptica*. Mycorrhizal relationships on other members of the Cyperaceae are reviewed in Muthukumar et al. 2004.

To conclude this section and previous sections on Reproductive Biology and Autecology, an envirogram has been designed for *Eleocharis elliptica* (**Figure 10**). An envirogram is a graphic presentation of the various principal environmental components that influence a species' ability to reproduce and survive in the environment. Envirograms have traditionally been designed for animals (Andrewartha and Birch 1984), but they may also be applied to

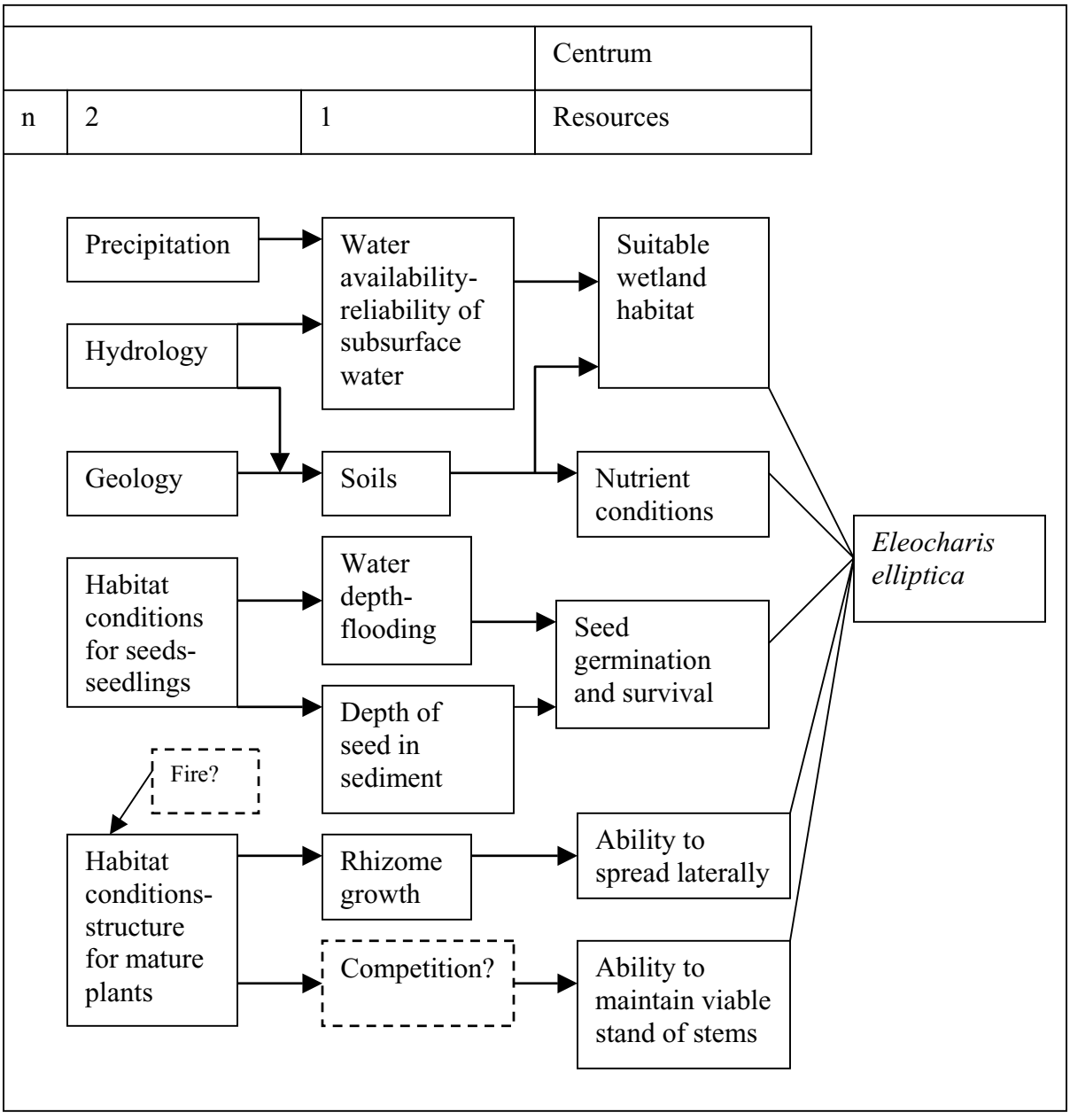

Figure 10. Envirogram outlining the resources of *Eleocharis elliptica*.

plants. Components that directly affect *E. elliptica* are part of the centrum. Although much information concerning this species is lacking, there was enough to construct a functional envirogram.

CONSERVATION

Threats

Wetlands

General loss and habitat impacts

Under current laws and regulations in the United States and Canada, there may not be any substantial rangewide threat to *Eleocharis elliptica*. A threat that would apply to *E. elliptica* regionally or locally would be impacts to wetlands, including the loss of wetlands. More than 50 percent of all wetlands have been lost in the conterminous United States since the time of European settlement (Barbour and Billings 2000, Dahl 2000). Of an estimated original 221 million acres, only 106 million remained in 1997. From 1950 to 1970, the annual loss rate was 450,000 acres; this then declined to 290,000 acres per year from 1975 to 1985 and to 58,000 acres per year from 1986 to 1997 (Dahl 2000). Most of this loss has been to inland freshwater wetlands, typical habitat of *E. elliptica* and its taxonomic relatives. The loss categories have been identified as follows: 30 percent to urban development, 26 percent to agriculture, 23 percent to silviculture, and 21 percent to rural development. Human and urban development has resulted in shifts of many clustered wetlands to many fewer and more isolated wetlands (Gibbs 2000). These processes may be referred to as habitat fragmentation, referring to geographic or physical separation. Fragmentation and connectivity, referring to ecological linkages, of populations and occurrences of a species are also relative, based on geographic and temporal scales and on the life history (life cycle) characteristics of the species. Although *E. elliptica* has a naturally fragmented distribution (i.e., wetlands in Region 2 do not occur as continuous habitat), fragmentation may still occur on smaller or local scales, within clusters or patches of existing wetland areas. Fragmentation on a local scale could be a potential threat by reducing connectivity of wind pollination and water distribution of seeds. Contrastingly, since waterfowl can be important distributors of seed both locally and through much greater migratory distances, *E. elliptica* populations and occurrences may still be connected at the seed distribution level.

In Nebraska, it was determined that approximately 64 percent of historical wetlands in the Rainwater Basin area of south-central Nebraska have been lost and that most of the remaining ones have been modified to some extent (U.S. Department of the Interior 1994). Although most of this loss was attributed to agriculture, some of the loss is due to road and ditch construction. Also in Nebraska, Sandhills Shrub Fen communities (reported to contain *Eleocharis elliptica*) have been impacted by draining, including the use of center pivot irrigation systems that could lower the water table just enough to impact these sites (USDA Forest Service 2004). Protection of these communities can occur through the restoration of natural water regimes by not draining wet meadows and prairies. The decomposition of the peat once a site is drained was identified as another threat to the original habitat.

In Colorado, there is an estimated 45,468 hectares (112,351 acres) of graminoid and forb dominated wetlands, which represents 0.17 percent of the state; 27.9 percent of this area contains roads, 2.9 percent was developed in 1990, and another 6.3 percent is at risk for development by the year 2020 (Theobald et al. 2001).

Degradation of wetland habitats was considered one of the main threats for *Eleocharis elliptica* populations in Wyoming, namely the population in the Laramie Mountain Range in the Medicine Bow National Forest, Platte County (Wyoming Natural Diversity Database 2004). On the other hand, the three Wyoming sites within Yellowstone National Park were considered protected. Other national parks (potentially "protected sites") outside of Region 2 where *E. elliptica* has been reported include Glacier National Park, Montana, and Isle Royale National Park, Michigan (Information Center for the Environment 2006). Contrastingly, even national parks are subject to processes that may cause local impacts. Events that affect landscape level drainages, such as large stand replacement forest fires (Meyer and Pierce 2003), may affect sites believed to be "protected." For example, heavy rains after stand replacement forest fires may cause long distance influx of upslope sediments and debris. "Protected" sites could also be subject to atmospheric impacts (e.g., acidic deposition, other air pollutants, aerial nutrient deposition) as the result of long distance transport (Duchelle et al. 1983, Skelly et al. 1983).

Water quality

In the state of New York, the portion of a wetland closer to an adjacent farm field had lower diversity

than the portion of the wetland more distant (Drexler and Bedford 2002). Those areas farther from the farm field and with greater diversity were more directly in line with groundwater spring flow, had more constant water levels, and had more consistent levels of base cation fluxes (e.g. calcium). *Eleocharis elliptica* was a member of the more diverse plant community farther from the farm. This study indicated that drainage from an adjacent farm field, which brought in higher levels of nutrients (such as nitrogen), reduced the diversity of the wetland that was closest to the farm.

In a similar study in Iowa, the plant cluster (sub-community) in which *Eleocharis elliptica* occurred was a low mat vegetation type with high plant diversity and high substrate pH and cation levels, with limited solubility of phosphorus compounds (Nekola 2004). Maintaining a low available phosphorus level and stable water levels, and minimizing unnatural influxes of nitrogen were identified as elements to manage in conserving the site. From these studies, it appears that *E. elliptica* and some of its associates may be sensitive to increased nutrient levels, especially nitrogen. This may not be a direct negative effect to *E. elliptica* plants, but rather it may alter its competitive interactions with other species. Some wetland plants such as cattails (*Typha* spp.) are known for responding favorably to greater nutrient influxes (e.g., nitrogen and phosphorus) and respond by increasing in quantity and density in the plant community (Newman et al. 1996). Even the runoff from roads can impact the community dynamics of a wetland adjacent to the road.

Invasive species

Concerning invasions of exotic species, there are very few reports specifically pertaining to *Eleocharis elliptica*. Invasive plants species were identified as a potential threat to the alvar wetland communities (of which *E. elliptica* was a component) surrounding the Great Lakes (Tiner 2003). In Ohio, plant succession and site invasion and overgrowth by woody species, along with soil compaction, were considered potential threats to *E. elliptica* var. *compressa* (McCance and Burns 1984). In Nebraska, Sandhills Shrub Fen communities are reported to be impacted by seeding to non-natives (USDA Forest Service 2004). Discontinuing mid-summer haying in these sites will allow for plant reproduction and reduce the tendency for non-native cool season exotics to expand. It is not unreasonable to speculate that invasive non-native species may impact *E. elliptica* and its habitat; such species would include musk thistle (*Carduus nutans*), bull thistle (*Cirsium vulgare*), Canada thistle (*C. arvense*), teasel (*Dipsacus fullonum*), Russian olive (*Elaeagnus angustifolia*), salt cedar (*Tamarix* spp.), poison hemlock (*Conium maculatum*), perennial pepperweed (*Lepidium latifolium*), hoary cress (*Cardaria draba*), purple loosestrife (*Lythrum salicaria*), hound's tongue (*Cynoglossum officinale*), and common tansy (*Tanacetum vulgare*) to name a few. Some native large-sized species that may also negatively interact with *E. elliptica* are *Typha* spp. (cattails), *Sparganium* spp. (bur-reeds), and woody species such as *Salix* spp. (willows). Some of these species tend to form large dense stands, especially cattails and some willows such as *S. exigua* (coyote willow), and these may overtop and out-compete relatively smaller plants like *E. elliptica*. Since cattails are known to respond favorably to increased nutrient influx, an increase in cattails could possibly be a sign of some change in local nutrient dynamics, depending on the site and its recent history.

Fire

Fire by itself is not considered to be a threat to *Eleocharis elliptica*, but it may indirectly affect the species by altering sediment influxes. Low intensity fires of relatively greater frequency may be beneficial to *E. elliptica* by keeping overhead woody plant species from encroaching upon wetlands. On the other hand, large catastrophic fires that result in considerable erosion and large sediment influxes into wetlands (Meyer and Pierce 2003) may negatively impact wetland plants. Water quality of wetlands within burned areas may be impacted for a period of time through reductions in pH, and increases in total phosphorus and nitrogen (Prepas et al. 2000). Agricultural activities may also result in increased levels of sedimentation to wetlands causing shifts in species composition; for example, a shift in *Carex stricta* dominated wetlands to dominance by *Phalaris arundinacea* (reed canary grass) and *Typha* spp. has been reported (Werner and Zedler 2002).

Grazing

Livestock grazing on National Forest System lands where wetlands are either known to contain *Eleocharis elliptica* or may potentially contain *E. elliptica* could be a threat. Livestock will often congregate around wetland areas and either overconsume or heavily trample the vegetation, causing localized catastrophic impacts to the plant community. Although members of the genus *Eleocharis* in general tend to be unpalatable to livestock, some may still be consumed. The primary threat from livestock grazing may actually be trampling of vegetation and disrupting important seed bed conditions. Excessive trampling by cattle may push

seeds of *E. elliptica* deep into the soil, thus removing them from the immediately available seed bank. The impacts and recovery of cattle grazing on sedge meadows in Wisconsin, which contained *E. elliptica*, have been reported (Middleton 2002). *Eleocharis elliptica* was one of several species in which recovery was most strongly correlated with both the amount of recovery time and with the frequency of cattle hoof prints (as a measure of intensity of grazing). *Eleocharis elliptica* was not one of the primary species consumed. In the area recovering from cattle grazing, the past grazing had apparently promoted the invasion of woody plants (primarily *Cornus sericea*). Over the 20-year recovery period, *E. elliptica* height recovery was very slight and non-significant (Middleton 2002). Contrastingly, the undisturbed reference area was going through some species compositional and structural changes as well, and the mean height of *E. elliptica* decreased over the same 20-year period, but not significantly. Perhaps this decrease was due to increases in certain other broad-leaved forbs and rhizomatous sedges.

Climate change

On a theoretical level, global climate change may be considered another threat to *Eleocharis elliptica*. Global climate change research over the past decade or so has demonstrated slight (1 to 2 °C) warming trends (reviewed in Weltzin et al. 2003). Although climate warming has been a controversial subject and difficult to determine, measure, and predict, most researchers have predicted warmer and drier conditions for much of central North America. There is no climate research specific to *E. elliptica*, but readers are referred to other published reports on climate change and its observed and potential effects to vegetation in USFS Region 2 (Grabherr et al. 1994, U.S. Environmental Protection Agency 1997, Lesica and McCune 2004).

Miscellaneous

Off-road vehicle use was an identified threat to the alvar wetland communities surrounding the Great Lakes (Tiner 2003). Under USFS land management practices of multiple use, off-road vehicle usage could be listed as a threat to *Eleocharis elliptica* in Region 2. For *E. elliptica* populations at the local level in Wyoming, road building was considered one of the potential threats to some of the currently known populations (i.e., the population in the Laramie Mountain Range in the Medicine Bow National Forest, Platte County). Road building increases accessibility, thus potentially leading to increased threat from off-road vehicle use, which was also considered to be of concern for the Platte County, Wyoming site. Invasive plant species could easily be brought in on vehicle tires, resulting in multiple threats affecting the species at the same time. Because the Wyoming site on the Medicine Bow National Forest is within an area subject to or potentially subject to a wider array of multiple uses, this site was considered more vulnerable (Wyoming Natural Diversity Database 2004).

Finally, at this time, over-utilization for commercial, recreational, scientific, or educational purposes does not appear to be a factor threatening the presence of *Eleocharis elliptica* within USFS Region 2. An envirogram outlining the threats and malentities to *E. elliptica* is included in **Figure 11**. The **Figure 11** diagram is similar to the one in **Figure 10**, but it focuses on the threats that may affect or influence the environmental resources important to *E. elliptica*. These threats are based on the limited number of scientific reports contained within the literature and infer pathways of potential impact to the species. The potential degree (severity) of impact along these various pathways remains an uncertainty and must be taken into consideration when making management decisions.

Conservation Status of Eleocharis elliptica in Region 2

USFS Region 2 has classified *Eleocharis elliptica* as a sensitive species, and within Region 2, the Wyoming Natural Heritage Program is the only agency or organization that has given the species any conservation status. This species is designated critically imperiled (S1) in Wyoming, but because it is considered a peripheral species in the state, it is given a low conservation priority (Wyoming Natural Diversity Database 2004).

Because of historical taxonomic ambiguities surrounding this species and the fact that Region 2 herbarium records have not been examined according to the most recent classification (i.e., Smith 2002), it is difficult to state whether the abundance of true *Eleocharis elliptica* (according to Smith 2002) is declining, increasing, or remaining stable across its entire range within USFS Region 2, or if it even occurs in Region 2. If true *E. elliptica* populations do occur in Region 2, they may be few and far between (e.g., if the Wyoming populations are the primary ones), or they may be much more common and widespread, (e.g., if the populations in Colorado, Nebraska, and potentially in South Dakota and Kansas are included). If in the first case they are few and far between, it may be possible for such small local populations (e.g., one Yellowstone

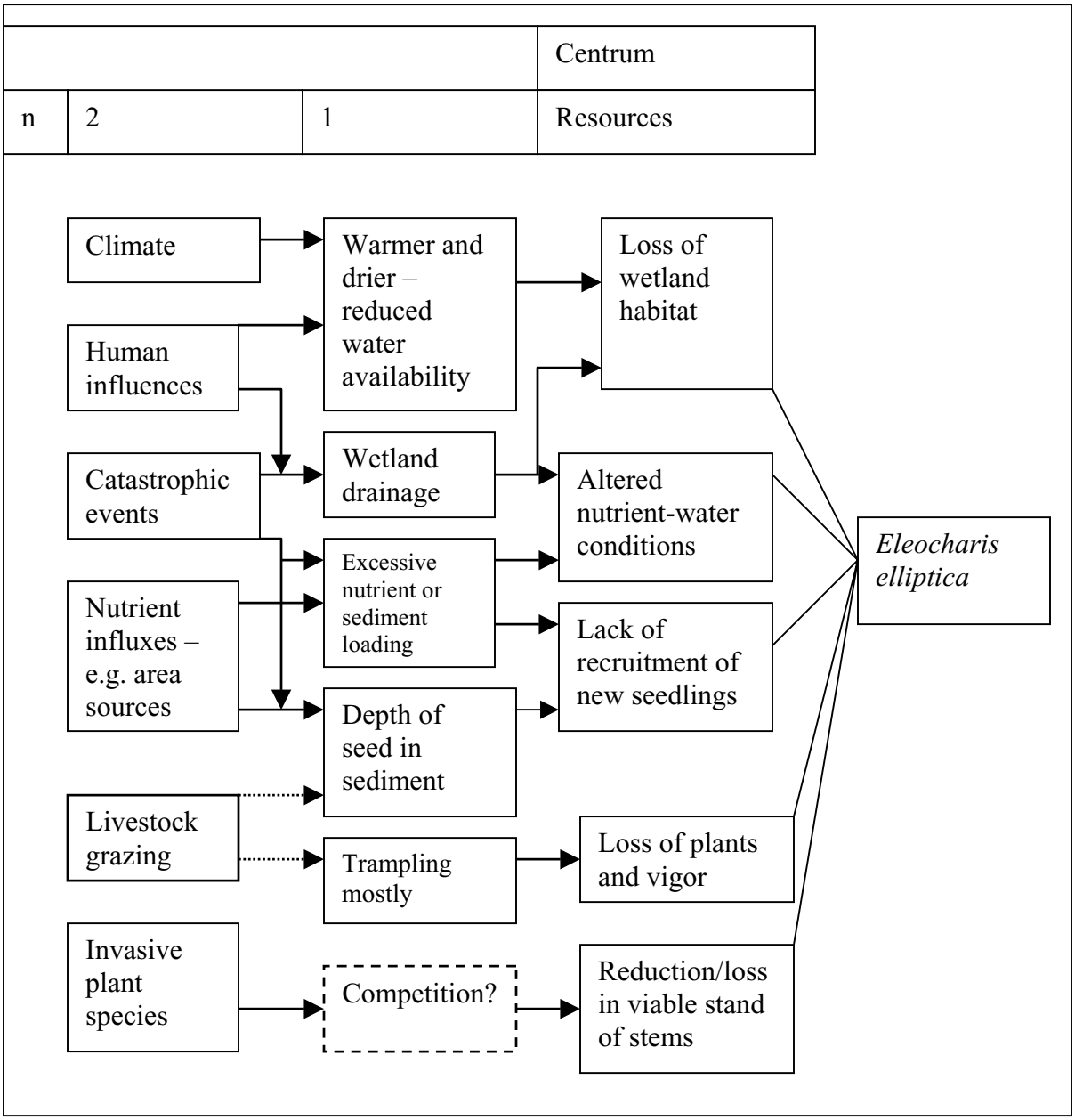

Figure 11. Envirogram outlining the malentities of *Eleocharis elliptica*.

site contains only 100 to 200 stems) to disappear due to local fluctuations in the plant community. On the other hand, the species could appear through dispersal and establishment to new sites. The observation from Ohio may indicate that the species can readily colonize new sites (McCance and Burns 1984). Such changes in small localized populations would be referred to as stochastic changes or subject to stochastic risk. Biologists have tried to deal with the concept of a minimum viable population (reviewed in Nelson 1999). Since *E. elliptica* is a rhizomatous species, unless someone has studied the site demographic aspects of seed dispersal, germination, survival and recruitment, rhizome connectedness and spread, it is not possible to determine what a minimum viable population size would be for *E. elliptica*. Because all collections in Wyoming have been made in relatively recent times (from 1987 to the present), it is possible that there are undiscovered sites. The most recently discovered potential sites are those in Platte County (from 1995) and Crook County (in 2005). The possibility of the species occurring on private lands or other lands not managed by the USFS is worth investigating.

Given the limited amount of ecological knowledge about this species, and given its presumed introgression tendencies with *Eleocharis compressa* and *E. tenuis*, not much can be said at this time about how wetland habitats across USFS Region 2 may vary in their capacity to support this species. Neither can much be said about whether *E. elliptica* is inherently vulnerable due to its life history characteristics. Smith (2002) and a few of the other accounts appear to indicate that the species prefers calcareous substrates. Other than this, the species could be searched region-wide to both better define its habitats and to define the species itself.

Management of Eleocharis elliptica in Region 2

Where applicable and appropriate, one of the management considerations that will be useful towards managing sites with *Eleocharis elliptica* in USFS Region 2 will involve the regulatory mechanisms under Section 404 of the Clean Water Act implemented by the USACE (Wetland Training Institute 2001). In addition, the USFS at various administrative levels has policy, guidelines, and management plans for wetlands. For example, within the Medicine Bow National Forest Revised Resources Management Plan (USDA Forest Service 2003), there are provisions to protect wet meadows, fens, bogs, and peatlands by:

- prohibiting concentrated livestock use.
- actively discouraging illegal motorized use.
- prohibiting peat or bog iron mining.
- prohibiting road construction (USDA Forest Service 2003).

Additional provisions, more specific for the protection of occurrences of *Eleocharis elliptica*, contained within the Medicine Bow National Forest Revised Resources Management Plan (USDA Forest Service 2003) include:

- implementing watershed conservation practices and assessing site-specific risks and strategies during project level planning and implementation
- including conservation measures for the species in the Fire Management Plan
- modifying allotment management plans to contain considerations such as exclosure construction to help maintain viable populations, closure of areas to recreation and other uses, and control of timing, extent, and intensity of livestock grazing agreements
- implementing the Region 2 weed free hay policy to limit the introduction of weeds from pack stock feed
- allowing the USFS discretion to modify projects and contracts if boreal spikerush is determined to occur within a project or contract area.

In Region 2, fen habitats and their obligate plants and animals have also received additional specialized conservation guidance to preserve and enhance these habitats (USDA Forest Service 2002b). Such policies and guidelines on wetlands, in combination with the listing of *Eleocharis elliptica* as a sensitive species in Region 2, add layers of protection onto existing federal CWA Section 404 regulations. Such measures are comparable to actions taken by the State of Pennsylvania, where a layer of management and conservation has been added by listing the species as endangered.

Implications and potential conservation elements

The combination of existing management activities protecting wetlands under: 1) applicable and appropriate use of Section 404 of the CWA, and 2) implementation of USFS policies and guidelines on wetlands protection will continue to be important conservation elements for populations of *Eleocharis elliptica*. Approaching wetland management with a "no net loss" (U.S. Army Corps of Engineers 2005) consideration is important. On December 26, 2002, a multi-agency task force issued the National Wetlands Mitigation Action Plan (National Wetlands Mitigation Action Plan 2005). The USDA, of which the USFS is a part, was a signatory to this plan. The USACE and U.S. Environmental Protection Agency have been issuing guidance for the use of on-site versus off-site and in-kind versus out-of-kind compensatory mitigation, the use of vegetated buffers, the implementation of preservation, compensation within a watershed, mitigating impacts to streams, the use of biological indicators, and functional assessments towards protecting and mitigating impacts to wetlands. Protecting (conserving) wetlands and mitigating impacts to wetlands and riparian areas will be an important conservation element.

Wetlands should not necessarily be viewed as static environments, but rather as environments subject to a certain amount of disturbance from which they may easily recover and regenerate (Middleton 1999). Changing water levels and flood pulsing can be important factors in wetland ecosystem dynamics, especially in riparian systems. Ephemeral pools, playas, and prairie pothole habitats can likewise experience flood pulsing and drying cycles. Flood pulsing may be expected as a more important feature of wetland habitats in arid western lands. From the scattered accumulated accounts in floras and herbarium records, *Eleocharis elliptica* sites appear to be subject to seasonal wetting and drying cycles. Seeds, seedlings, and mature plants within a single species will have varying environmental requirements. As previously mentioned, *Eleocharis* seeds are dispersed by water, birds, and other animals that inhabit wetlands and feed on sedges. Most species of *Eleocharis* appear to germinate best in moist and unflooded conditions, but some species do germinate under water (e.g., *E. palustris*). Water depth can be important in seedling survival. These factors need to be taken into consideration when managing *E. elliptica* populations.

Eleocharis elliptica may be limited to habitats of particular microhabitat conditions (i.e., discreet, patchy habitats, especially descriptive of wetlands in the plains states and western states). For example, calcareous, alkaline, or semi-alkaline substrates may characterize its microhabitat. Defining *E. elliptica* in the broadest sense, by including the numerous reports across all states within the boundaries of USFS Region 2, this wide distribution does appear to have a relatively spotty and widely scattered distribution. Because small sites are influenced and modified by the greater matrix of habitats (including upland habitats) surrounding them, protecting a localized site all by itself may not be enough. Protecting the greater habitat matrix surrounding a particular site may be just as important as protecting the site itself (reviewed in Nelson 1999).

Ecological knowledge (confounded with taxonomic uncertainties) about *Eleocharis elliptica* is minimal at best, making inferences about whether it is a matrix species or gap-phase species difficult. Matrix habitats are those that form extensive and contiguous cover (Corner et al. 2003). Gap-phase species are those that respond to gaps or localized transitional zones in a larger habitat matrix. Wetlands in the Great Plains and the Rocky Mountains would generally not be considered matrix habitat. Apparently being a species of localized wetland habitats, it can be concluded that *E. elliptica* is not a matrix species, at least not in the West. The best conclusion based on what is known is that it is a species of potentially patchy, semi-specialized microhabitats, at least concerning wetland habitats on the fringes of its range in the plains and western states.

In Nebraska, at the Almeria Meadows Wildlife Management Area, part of the area is mowed for hay once per year. This action acts as a substitute for the lack of natural fire by keeping out woody vegetation and reducing thatch, and it acts to provide for winter forage for a leased livestock operation (Nebraska Games and Parks Commission 2002). Such management activities may help to prevent woody species from colonizing wetland sites where *Eleocharis elliptica* resides.

Also in Nebraska, the frequently used center pivot irrigation systems near wetlands in the Sandhills country may lower the water table just enough to impact wetland sites that may contain *Eleocharis elliptica*. Protection of these wetland community sites can occur through the restoration of natural water regimes by not draining wet meadows and prairies (USDA Forest Service 2004). Discontinuing mid-summer haying in these sites will allow for plant reproduction and reduce the tendency for non-native cool season exotics to expand. Restoring natural water regimes and the preventing drainage will protect these wetland sites in which *E. elliptica* occurs.

In the state of New York, *Eleocharis elliptica* occurred in areas of the wetland with greater diversity and that were more directly in line with groundwater spring flow, had more constant water levels and more consistent levels of base cation fluxes (e.g., calcium) (Drexler and Bedford 2002). In Iowa, *E. elliptica* was likewise associated with an area of the wetland with a high diversity of plants. Such areas also had high substrate pH, high cation levels, and a limited solubility of phosphorus compounds (Nekola 2004). Maintaining a low available phosphorus level and water levels, and minimizing unnatural influxes of nitrogen could be important in maintaining such plant communities.

Finally, in Ohio, *Eleocharis elliptica* var. *compressa* was considered to have a good recovery potential since the species was reported colonizing abandoned quarry sites that accumulated water (McCance and Burns 1984). Such observations would indicate that *E. elliptica* is a potentially adaptable species and able to colonize new sites, even sites that could potentially differ from those normally experienced in the natural environment (e.g., old quarries).

Tools and practice

Inventory and monitoring protocol

There is nothing particular about the biology, life history, distribution, or ecology that would necessarily place any constraints on monitoring known sites containing *Eleocharis elliptica*, at least not any constraints that would be any different from monitoring many other plant species. For example, monitoring of flowering time and seed productivity of just about any plant species is going to have the constraint of being prepared to conduct the field work at the appropriate flowering and seed set time periods.

Species and habitat inventory

Probably the first and most important element or priority for the conservation of *Eleocharis elliptica* would be to employ the services of more professional botanists and plant ecologists for more field surveys. Such surveys would need to include not only Region 2 National Forest System lands, but also lands under other ownership and management oversight within the boundaries of USFS Region 2. A region-wide inventory would increase knowledge about this species' abundance and distribution within Region 2, which would substantially help managers to make decisions concerning *E. elliptica*. Some of this work will need to involve taxonomic research. Are the Region 2 herbarium records truly *E. elliptica*? Once this question is asked, it must be kept in mind that there may be differences in scientific professional opinions. Ultimately, one may need to be content with a blurred picture, *species do intergrade*, and the natural environment is not static.

Species distribution and habitat surveys could probably begin by radiating out in concentric circles around existing recorded sites. All wetland habitats should be considered potential habitats although the surveys could initially focus on sites that may have more calcareous or alkaline substrates. Since fens are also potentially identified habitats in Region 2, these could be targeted for field investigations using existing Region 2 habitat inventories. Topographic maps, soils maps, wetlands maps (National Wetlands Inventory), aerial photos, and remotely sensed data sets and images can all be employed to focus in on potential wetland habitats. Once several more sites are found within a several mile radius around an original focal site, inventory at that location could stop. Was *Eleocharis elliptica* re-identified or relocated from the original focal collection site? When new occurrences (i.e. new populations or individuals) are discovered, at least one voucher specimen must be collected and submitted to a university or museum herbarium; this is an important step in documenting and verifying an occurrence. It may be best if one particular university herbarium is selected to house all the collected specimens, but at least one specimen from each new site should also go to the nearest local university herbarium. Extensive collection may be important because based on herbarium records and reports summarized in this document, currently there are only two counties in Wyoming, five counties in Colorado, 26 counties in Nebraska, and probably many fewer counties in Kansas and South Dakota that contain occurrences.

Population monitoring – methods and techniques

The following monitoring techniques can be used at existing *Eleocharis elliptica* sites. First, determine the approximate full extent of the area currently occupied by the species at a site. Next, determine the extent of potential habitat, including portions of the wetland that do not appear to currently contain the species. If these areas coincide fairly closely that is fine since the objective of this exercise, before laying out transects or quadrats, is to avoid biasing the sample by purposely placing a quadrat over *E. elliptica*. Once the full potential habitat area is determined, this will be the sample area. Depending on the overall size of the area, it can be divided up into gridded sections. Once grids are established, then they can be selected at random for sampling. Grids do not have to be used. Transects can be spaced at regular intervals across the habitat.

There are numerous sampling methods used in field plant ecology (Barbour et al. 1980, Magurran 1988, Bonham 1989, Smith 1996, Scheiner and Gurevitch 2001). Within a quadrat, simply record presence/absence, use cover classes, estimate cover without using classes, use point-intercept, or determine density. Probably the simplest method would be determining presence and absence. This information can then be used to determine the frequency or percent of all grids sampled. Another approach is the quadrat method, in which general cover categories such as the Daubenmire method or the Braun-Blanquet method can be employed. These methods use cover class ranges (e.g., 5 to 25 percent).

Along transects, quadrats may be placed, or other techniques such as the point-line intercept method may be performed. This method is quick and very robust (Mitchell et al. 1994). Frequency is how many of the samples in which the species appeared (whether one is

sampling via quadrats, point, or line intercept, etc.). The species' productivity can be determined by harvesting some of the plants and by taking air dry weights. Although this is more intensive and destructive, it will give biomass produced annually and is best done in late summer to fall. Measuring productivity is probably not needed for assessing general population change, as the latter will be a function of cover and density. For monitoring population changes in *Eleocharis elliptica*, cover and density may be good indictors that will not require extensive amounts of field time. These methods only need to be employed once per year, but they should be employed on an annual basis to monitor for trends and should be conducted at about the same time each year.

Arriving at an understanding of demographic patterns and cycles at a particular site would entail more precise sampling that would involve observations on the numbers of fertile versus sterile stems (see p. 15 Le Blanc [2003] for more information). Determining flowering time, collecting and harvesting seed for productivity, placing seed traps for dispersal distance, watching and marking seedlings with toothpicks or other markers for seedling recruitment and survival, and carefully marking stems for survival and longevity would all be part of such a monitoring program. Being an extensive rhizomatous species, one may need to find the terminus of a rhizome, and then monitor its spread carefully. Once finding a rhizome terminus, one may be able to do this by observing for new tiller (stem) production within the immediate area.

Monitoring the overall habitat will be important too. Regularly recording the plant associates of *Eleocharis elliptica* would be a part of such a program. Monitoring cover of *E. elliptica* may be difficult because of the narrow, leafless stems, so stem density may be a better parameter to monitor. The use of a laser device may be the best technique for measuring cover. Cover and/or density of other species could be collected simultaneously and will help to determine whether the cover relationships between species are changing. Making note of new species appearing in the habitat could be important. Observing the depth of surface water or measuring the depth to free water by digging pits could be important to where *E. elliptica* resides in the habitat. Soil samples could be collected from both directly below *E. elliptica* plants and from other areas in the habitat where there are no *E. elliptica* plants. These could be analyzed for minerals and nutrients to possibly help determine microhabitat preferences for the species. Finally, photo point monitoring is another monitoring technique, but this usually works best for general landscape monitoring and would not supply much information specific to *E. elliptica*.

Beneficial management actions and approaches

Beneficial management actions and approaches are corollaries to many of the conservation elements discussed earlier and listed in the Summary section. The following lists of beneficial management actions are not in a prioritized order. Land managers are encouraged to carefully evaluate the situation at each *Eleocharis elliptica* site and to make their own determination on which approaches and actions are most appropriate for a particular site at a particular point in time. General management actions that will benefit the species include:

- protect and preserve wetlands, and mitigate impacts to wetlands according to existing USFS Region 2 policy and guidance; apply USACE regulations and mitigation guidance where applicable and appropriate; consider whether wetlands as defined by the USFWS can be used to improve upon existing policies and guidelines

- protect the greater habitat matrix, including upland habitat, surrounding a small isolated wetland site containing *E. elliptica*

- implement prescribed fire and mowing of surrounding uplands to prevent the colonization of wetland sites by woody species, thereby helping to maintain *E. elliptica* populations

- avoid mid-summer mowing in and around wetlands with *E. elliptica* as this may prevent the plants from flowering thus eliminating or reducing seed production

- prevent or minimize the overuse of livestock in a wetland area where *E. elliptica* may reside; overgrazing by livestock in a wetland may substantially alter the local habitat conditions

- prevent the use of off-road vehicles in wetland areas

- avoid the draining and ditching of wetland areas with *E. elliptica* as this is expected to have a negative impact

- ❖ maintain natural water regimes at *E. elliptica* sites in order to maintain the populations

- ❖ prevent alterations of the surrounding upland habitat since they may change the influx of nutrients, especially nitrogen; maintain a low available phosphorus level at a site.

The following is a list of additional tools and beneficial management actions that are within direct control and responsibility of the USFS (Roche personal communication 2005):

- ❖ continue to list *E. elliptica* as a sensitive species

- ❖ regulate occupancy and use of National Forest System lands, including ditches and water diversions, area closures to recreation and/or other uses, and stock exclosures

- ❖ implement, change, and improve standards and guidelines in Land Resource Management Plans

- ❖ change management area allocation to one with more protection

- ❖ implement other management directions such as watershed conservation practices

- ❖ identify the potential for land exchanges or purchases

- ❖ propose land exchanges or purchases with willing partners

- ❖ provide opportunities to collect and store seed or other propagules

- ❖ provide opportunities to establish off-site populations for conservation purposes

- ❖ file for water rights on wetlands that support rare species

- ❖ designate limited operating periods or areas (buffers) as part of project planning and implementation.

Seed banking

There are probably no offsite, human-managed seed banks for this species, but it is very likely that one or more habitat restoration or wetland restoration companies that grow plants from seed may be propagating this species and its taxonomic relatives. If *Eleocharis elliptica* (or purported *E. elliptica*) is used in wetland restoration activities in USFS Region 2, it may be best to obtain seed from existing Region 2 sites, rather than from a commercial supplier, where the true taxonomic identity may not be certain.

Information Needs

The information needs for *Eleocharis elliptica* are extensive. The taxonomic classification of existing herbarium specimens and the subsequent potential distribution of the species in USFS Region 2 are not understood well enough to know whether management elements discussed above will be conserving *E. elliptica* populations or other related taxa of *Eleocharis*. Considerably more work on the taxonomy, distribution, ecology, demography, and habitat requirements of this species by professional botanists and plant ecologists is needed. There needs to be thorough and careful examination of herbarium records from major universities in Region 2, such as the University of Wyoming (RM), Utah State University (UTC), University of Colorado (COLO), and Nebraska State Museum (NEB). These specimens should be examined by S.G. Smith or other botanists competent with the genus *Eleocharis*.

The species' life cycle is generally understood, but its local habitat and population trends are not well understood or not understood at all. The species' responses to fine and broad scale changes in natural disturbance are similarly not well understood or perhaps not understood at all. Metapopulation dynamics are not understood at all. Reproduction methods of the genus and related taxa are probably understood enough to know the basic reproductive capability of *Eleocharis elliptica*, but how that capability relates to whether *E. elliptica* will persist at a site is not known.

There are numerous reliable methods to monitor population trends at existing sites. Reliable restoration methods are likewise available. Wetland restoration has advanced considerably over the past several decades. Some of the particular local habitat and environmental requirements of *Eleocharis elliptica* are not understood very well. *Eleocharis elliptica* as a focal species of research is almost completely ignored in ecological literature. This is why so little is known about it.

Research priorities could focus on tasks in the following order:

1) Conducting thorough examinations of existing herbarium collections located within USFS Region 2 states to verify whether populations currently identified as being *Eleocharis elliptica* match the classification scheme given in the recent Flora of North America (Smith 2002).

2) Assessing the distribution throughout USFS Region 2 by conducting numerous additional field surveys and making specimen collections.

3) Monitoring populations identified as *E. elliptica*.

At this time, there are not much additional currently available research and data potentially useful that were not incorporated into this report. There was not time to include specimen records from all herbaria in the region. Many herbaria do not have on-line Internet systems through which to conduct a search. Nebraska has been identified as a potentially significant state containing *Eleocharis elliptica*. Herbarium records from herbaria in this state were not included, except published reports that are expected to be based on those herbarium records. There are many wetland restoration practitioners across the United States, and it is very possible that some of these practitioners may have some actual field experience with *E. elliptica* in restoration projects that is not generally published or available.

Definitions

Achene: one-seeded fruits produced by members of the family Cyperaceae.

Aeolian: wind-deposited sediments and soils.

Alluvium: sediments and soil materials deposited by streams.

Alvar wetlands: wetlands that occur on relatively flat limestone/dolomite based bedrock substrates.

Aneuploidy: an abnormality where certain chromosomes are present in extra copies or are deficient in number.

Bivalent: having two homologous chromosomes or two sets of homologous chromosomes.

Cation: element or mineral in solution that has a positive charge.

Circumneutral: water near or at a neutral pH of 7.0.

Cytotypes: cells with different numbers of chromosomes.

Diploid: having a homologous pair of chromosomes for each characteristic except sex; having one chromosome from each parent.

Ecotype: a population within a species that has undergone a natural selection process and become adapted to a particular set of local environmental conditions.

Fen: a peatland community dominated by grasses, sedges, and forbs; it lacks or has minimal woody vegetation cover.

Frequency: how often, or how many times, something is encountered in a sampling design.

Inflorescence: the structure produced by plants that bears flowers.

Intercrosses: breeding of different species or taxa.

Introgression: the spread of genes of one species into the gene pool of another by hybridization and backcrossing.

Meiosis: the cell division in sexually reproducing organisms that reduces the number of chromosomes in reproductive cells (gametes) by half.

Minerotrophic: a site that receives most of its water from a ground water source, e.g. seeps.

Occurrences: sites or locations in the environment where individuals of a species are located.

Ordination: a mathematical and graphing technique used to describe features or characteristics of ecological units, such as plant communities.

pH: refers to the hydrogen ion concentration in solution, how acidic or basic a solution is.

Polyploidy: having more than two sets of chromosomes.

Population: a group of interbreeding individuals.

Rhizome: an underground horizontal stem.

Shore fen: an open peatland plant community along lake shores.

Spikelet: the specialized structure of an inflorescence, bearing flowers in sedges and grasses.

Vascular bundle: the tissues within a plant that conduct water and food, e.g. xylem and phloem.

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