Schoenoplectus hallii (Gray) S.G. Sm. (Hall's bulrush): A Technical Conservation Assessment

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

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Schoenophectus hallii (Hall's bulrush). Photo by Paige Mettler. Reprinted with permission from the photographer.

SUMMARY OF KEY COMPONENTS FOR CONSERVATION OF *SCHOENOPLECTUS HALLII*

Status

Schoenoplectus hallii (Hall's bulrush) is a geographically widespread but rare sedge species occurring in damp, sparsely vegetated areas at the edges of ephemeral and shallow wetlands in the eastern and midwestern United States. Within USDA Forest Service (USFS) Rocky Mountain Region (Region 2), *S. hallii* has not been identified on any National Forest System lands, but it is known from approximately 36 occurrences on non-USFS lands in the sandhill prairie region of Kansas and Nebraska (Kansas Natural Heritage Inventory 2002, Nebraska Natural Heritage Program 2002, NatureServe 2003).

The Global Heritage Status Rank for *Schoenoplectus hallii* is G2, globally imperiled (NatureServe 2003). State Natural Heritage Programs in Kansas and Nebraska both rank this species as S1, critically imperiled (Kansas Natural Heritage Inventory 2002, Nebraska Natural Heritage Program 2002). This species is on the USFS Rocky Mountain Region sensitive species list (USDA Forest Service 2003).

Primary Threats

Schoenoplectus hallii is a species of concern because of its small number of documented occurrences, widely fluctuating abundance, and vulnerability to human-related and environmental threats. The full distribution and abundance of this species in USFS Region 2 is not known. Human-related threats to *S. hallii* include hydrologic changes (e.g., irrigation), habitat loss and alteration (e.g., residential development, agriculture), livestock grazing and other agricultural activities, off-highway vehicle use, pollution, road maintenance, and landscape fragmentation. Biological vulnerabilities and environmental threats to populations of *S. hallii* include succession/competition, extreme environmental fluctuations (e.g., drought or storm events), non-native plant invasions, hybridization, genetic isolation, global climate changes, excessive herbivory, and changes to the natural disturbance regime that would affect habitat creation.

Primary Conservation Elements, Management Implications and Considerations

The lack of information regarding the current distribution and abundance, seedbank status, dispersal ability, adaptability to changing environmental conditions, reproductive potential, and genetic variability of *Schoenoplectus hallii* makes it difficult to predict its vulnerability. Features of *S. hallii* biology that may be important to consider when addressing the conservation of this species (i.e., key conservation elements) include its reliance on specific hydrologic conditions for germination and growth (e.g., spring flooding followed by drawdown and adequate soil moisture throughout the growing season), dependence on early successional wetlands, possible requirements for certain soil qualities, apparent preference for barren substrates and areas with low interspecific competition, mostly annual habits with a reliance on seedbank additions for population replenishment, long-lived seedbank, ability to adapt to environmental stochasticity, potential hybridization with *S. saximontanus* and *S. erectus*, production of both basal and terminal achenes, seed dispersal by water movements or animal activities, and potential for reintroduction in restoration efforts. Priority conservation tools for *S. hallii* may include monitoring existing populations and population trends, documenting the effects of current land-use practices and management activities within the region, reducing any human-related threats to existing high-risk populations (e.g., use of monocot-specific herbicides), maintaining suitable habitat (e.g., early successional wetlands) and minimizing changes to hydrologic regimes, and assessing the density and extent of the seedbank. Additional key conservation tools may include surveying high probability habitat (e.g., lands in the Samuel R. McKelvie and Halsey national forests in USFS Region 2) for new populations, preventing non-native plant invasions and livestock overgrazing, studying demographic parameters of populations in the region, establishing a private land owner contact program to provide technical assistance, acquiring lands with extant populations or creating easements for protection of populations on private lands, supporting development of long-term monitoring and research, and assessing the effects of future management activities or changes in management direction. Studying the distribution and abundance of *S. hallii*, its microhabitat requirements, the effects of hydrologic events and water availability on its germination and growth, its seedbank dynamics and other demographic factors, imminent threats (e.g., non-native plant invasion) to the species, and the effects of land management activities are of primary importance to further the understanding of this species in USFS Region 2.

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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), U.S. Department of Agriculture (USDA) Forest Service (USFS). *Schoenoplectus hallii* is the focus of an assessment because it is designated a sensitive species in USFS Region 2 (USDA Forest Service 2003). Within the National Forest System, a sensitive species is a plant or and animal whose population viability is identified as a concern by a regional forester because of significant current or predicted downward trends in population numbers, density, or habitat capability that would reduce the species' existing distribution (USDA Forest Service 1995). A sensitive species may require special management, so knowledge of its biology and ecology is critical. This introduction defines the goal of the assessment, outlines its scope, and describes the process used in its production.

Goal

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

Scope and Information Sources

The *Schoenoplectus hallii* species assessment examines the distribution, biology, ecology, conservation status, and management of this species with specific reference to the geographic and ecological characteristics of USFS Region 2. Although there are no known occurrences of this species on National Forest System lands within Region 2, our analysis includes potential threats and management of this species if populations are discovered on USFS lands. Although some of the literature on the species originates from field investigations outside the region, this document places that literature in the geographic, ecological, and social context of Region 2. Similarly, this assessment is concerned with the reproductive behavior, population dynamics, and other characteristics of *S. hallii* 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.

In producing the assessment, we performed an extensive literature to obtain all material focusing on *Schoenoplectus hallii* within USFS Region 2. We reviewed refereed literature (e.g., published journal articles), non-refereed publications (e.g., unpublished status reports), theses and dissertations, data accumulated by resources management agencies (e.g., Natural Heritage Program [NHP] element occurrence records), and regulatory guidelines (e.g., USDA Forest Service Manual). Visits were not made to every herbarium with specimens of this species, but specimen label information provided by herbarium staff and available in NHP element occurrence records was included. Additionally, we incorporated information from studies of *S. hallii* from outside USFS Region 2, as well as information about related *Schoenoplectus* or *Scirpus* species with similar ranges and habitat. We summarized results of recent field studies if unpublished reports were available (e.g., M. Smith 2001, 2002, 2003) and cited if data are otherwise in preparation, in review, or in publication. While the assessment emphasizes refereed literature because this is the accepted standard in science, non-refereed publications and reports are used extensively in this assessment because they provide information unavailable elsewhere. All information was treated with appropriate uncertainty.

Treatment of Uncertainty

Science represents a rigorous, synthetic approach to obtaining knowledge. Competing ideas regarding how the world works are measured against observations. However, because our descriptions of the world are always incomplete and our observations are limited, science focuses on approaches for dealing with uncertainty. A commonly accepted approach to science is based on a progression of critical experiments to develop strong inference (Platt 1964). However, it is difficult to conduct critical experiments that produce clean results in the ecological sciences, and often observations, inference, good thinking, and models must be relied on to guide the understanding of ecological relations. While well-executed experiments represent the strongest approach to developing knowledge, alternative methods (modeling, critical assessment of observations, and inference) are accepted approaches to understanding features of biology. In this assessment, the strength of evidence for particular ideas is noted and alternative explanations are described when appropriate.

Much of the knowledge about the status, biology, ecology, and conservation of *Schoenoplectus hallii* is summarized in unpublished status reports prepared by Robertson et al. (1993), McKenzie (1998), Magrath (2000), Steinauer (2001), and M. Smith (2001, 2002, 2003). Because of a lack of experimental research of this species in USFS Region 2, this assessment relies heavily on personal observations and communications with USFS rangeland management specialists, U.S. Fish and Wildlife Service (USFWS) biologists, NHP botanists, university researchers, and independent scientists from throughout the species' range. When information presented in the assessment is based on our personal communications with a specialist, we cite those sources as "personal communication" The unpublished reports mentioned above also rely heavily on personal communications with species experts. This assessment summarizes and cites the information from unpublished reports (e.g., McKenzie 1998), without stating the original source of the personal communication in every case. Other unpublished data (e.g., NHP element occurrence records) were important in estimating the geographic distribution and in describing habitat. These data required special attention because of the diversity of persons and the variety of methods used to collect the data, and because of unverified historical information. Due to the paucity of experimental research specific to this rare plant species in USFS Region 2, we also incorporated information on studies of *S. hallii* from outside USFS Region 2 to formulate this assessment. For example, recent studies by M. Smith and colleagues (e.g., M. Smith 2001, 2002, 2003) on *S. hallii* populations in Illinois, Kentucky, and Missouri provide important insights for understanding *S. hallii* biology and ecology. However, all of the results may not directly apply to populations of *S. hallii* within USFS Region 2. Personal communications with M. Croxen, rangeland management specialist in the Nebraska National Forest, were important in estimating potential threats to *S. hallii*, if populations of this species are discovered on USFS Region 2 lands in the future. However, because there are no known populations of this species on National Forest System lands in Region 2, our conclusions are associated with considerable uncertainty.

As a result, conclusions about threats to *Schoenoplectus hallii* and conservation considerations in USFS Region 2 are based on inference from these published and unpublished sources. We clearly noted when we were making inferences based on the available knowledge to augment or to enhance our understanding of *S. hallii*.

Publication of Assessment on the World Wide Web

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

Peer Review

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

Management Status and Natural History

Schoenoplectus hallii is a geographically widespread but rare species known from the eastern and midwestern United States. Although this species is known from approximately 36 occurrences in Kansas and Nebraska, none of these populations are on National Forest System lands (**Figure 1**; Kansas Natural Heritage Inventory 2002, Nebraska Natural Heritage Program 2002, NatureServe 2003). This section discusses the special management status, existing regulatory mechanisms, and biological characteristics of this species.

Management and Conservation Status

Global rank

The Global Heritage Status Rank for *Schoenoplectus hallii* is G2, globally imperiled, as a result of its limited abundance and distribution (NatureServe 2003).

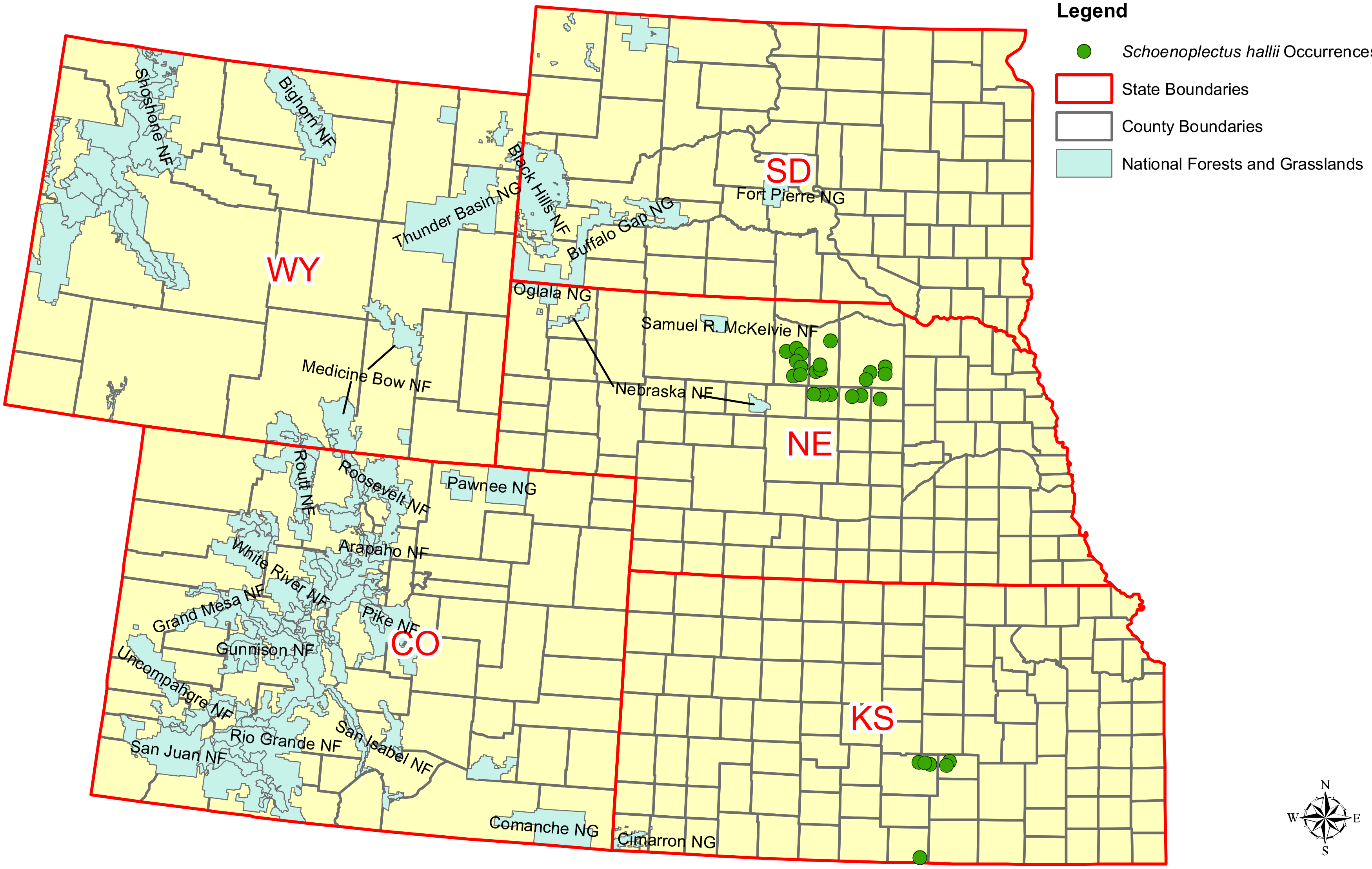


Figure 1. Map of U.S. Forest Service (USFS) Region 2 illustrating *Schoenoplectus hallii* occurrences in Nebraska (General locations in Brown, Garfield, Holt, Loup, Rock, and Wheeler Counties depicted) and Kansas (Harper, Harvey, and Reno Counties). The distribution of this species also includes states outside USFS Region 2. Refer to document abundance information. Sources: Kansas Natural Heritage Inventory. 2002. Biological Conservation Database. Kansas Natural Heritage Inventory, Kansas Biological Survey, Lawrence, KS; Nebraska Natural Heritage Program. 2002. Biological Conservation Database. Nebraska Natural Heritage Program, Nebraska Game and Parks Commission, Lincoln, NE.

Federal rank

The Endangered Species Act (ESA) of 1973 was passed to protect plant and animal species placed on the threatened or endangered list (U.S. Congress 1973). The listing process is based on population data and is maintained and enforced by the USFWS. In 1993, *Schoenoplectus hallii* was ranked as a Category 2 species (a taxa for which proposal as endangered or threatened is appropriate, but conclusive data on biological vulnerability and threats are not currently available) (U.S. Fish and Wildlife Service 1993). Although the USFWS eliminated the category list in 1996, species on the list are still being tracked through various sources (U.S. Fish and Wildlife Service 1996, P. McKenzie personal communication 2003). Species that meet any of the five listing factors under Section 4 of the ESA are elevated to candidate status after review and approval. Species added to the candidate list are given a listing priority number and then listed as threatened or endangered species, pending available funds and completion of actions taken on higher priority species (P. McKenzie personal communication 2003). Thus, the USFWS solicits information from agencies (e.g., state NHPs) that continue to monitor *S. hallii* to determine if there are any changes in the species' current abundance and distribution or if there are any significant threats that would warrant elevation to official candidate status (P. McKenzie personal communication 2003).

Regional rank

Schoenoplectus hallii is listed as a sensitive species by USFS Region 2 (USDA Forest Service 2003).

State rank

State NHPs collect information about the biological diversity of their respective states and maintain databases of plant species of concern. *Schoenoplectus hallii* has been ranked by the Nebraska NHP and Kansas NHI to be S1, or critically imperiled in the state because of extreme rarity or because of some factor(s) making it especially vulnerable to extirpation from the state (typically five or fewer occurrences or very few remaining individuals or acres) (Kansas Natural Heritage Inventory 2002, Nebraska Natural Heritage Program 2002). This species is not known from the other states of USFS Region 2 (i.e., Colorado, South Dakota, or Wyoming) and is thus not currently listed or ranked in those states (Colorado Natural Heritage Program 2002, Fertig and Heidel 2002, South Dakota Natural Heritage Program 2002).

Existing Regulatory Mechanisms, Management Plans, and Conservation Practices

Although *Schoenoplectus hallii* has been identified as a species of special concern, there are few specific regulatory mechanisms at the federal or state level to regulate its conservation. Of the known populations of *S. hallii* in USFS Region 2 and throughout its range, only a handful occur in areas under public ownership; most populations occur on private land (Robertson et al. 1993, McKenzie 1998, Steinauer 2001). Populations of *S. hallii* on private land generally do not receive protection (McKenzie 1998, T. Smith personal communication 2002). Only one *S. hallii* population in USFS Region 2 occurs on public land, the South Pine Wildlife Management Area in Brown County, NE, managed by the State of Nebraska. *Schoenoplectus hallii* has not been identified on any National Forest System lands in Region 2. Morse (2001) lists Samuel R. McKelvie and Halsey national forests in Region 2 as possible locations for *S. hallii*, but the species has not yet been discovered in those forests.

Schoenoplectus hallii was previously on the USFWS Category 2 list, but there is currently no legal protection for this species under the ESA. USFWS Region 3 (Illinois, Indiana, Iowa, Michigan, Missouri, Ohio, Wisconsin) has placed *S. hallii* on its list of conservation priorities (species that require utmost attention) and has outlined strategies to overcome obstacles in species conservation (U.S. Fish and Wildlife Service 2002). Strategies identified for the conservation of *S. hallii* in USFWS Region 3 include: (1) acquisition of biological information to support conservation actions; (2) conservation of habitat through protection, restoration, and management; (3) provision of technical assistance to initiate, augment, or redirect conservation actions; and (4) education, outreach, and public involvement in species conservation, planning, and activities.

If *Schoenoplectus hallii* is discovered on National Forest System lands within Region 2, then it may obtain protection from USFS policies. *Schoenoplectus hallii* is designated a USFS Region 2 sensitive species. The USFS is directed to develop and implement management practices to ensure that sensitive species do not become threatened and endangered (USDA Forest Service 1995). The National Environmental Policy Act requires an assessment of impacts from proposed federal projects to the environment (U.S. Congress 1982), and USFS policies require Biological Evaluations to determine the impacts of USFS projects to sensitive species (USDA Forest Service 1995). In addition, the USFS prohibits the collection of any sensitive plants without a permit (USDA Forest Service 1995). A new travel management plan is currently being developed for the Nebraska National Forest, and it may protect some rare species by restricting motorized vehicle access to certain designated areas (M. Croxen personal communication 2004, Nebraska Off Highway Vehicle Association 2004).

The Nebraska NHP and Kansas NHI have classified *Schoenoplectus hallii* as a species of special concern due to its rarity (Kansas Natural Heritage Inventory 2002, Nebraska Natural Heritage Program 2002). Natural Heritage Program databases draw attention to species potentially requiring conservation strategies for future success. However, these lists are not associated with specific legal constraints, such as limiting plant harvesting or restricting damage to critical habitats.

Existing regulations are not adequate to conserve *Schoenoplectus hallii* in USFS Region 2 over the long term, considering that the current abundance and distribution of this species are not well known and that specific populations may be threatened by a wide range of human-related and ecological disturbances.

Biology and Ecology

Classification and description

Systematics and synonymy

Schoenoplectus hallii (A. Gray) S.G. Smith is a member of the genus *Schoenoplectus* and section *Supini* (Chermezon) Raynal of the family Cyperaceae (sedges) in group Monocotyledonae (monocots) of phylum Anthophyta (flowering plants) (McKenzie 1998, Natural Resources Conservation Service 2002, S.G. Smith 2002). The taxonomy of the Cyperaceae family is complex and has been the subject of much discussion, but taxonomists appear to be in agreement about the modern treatment of these species (Penskar and Higman 2002). Refer to McKenzie (1998) for an historical overview of *S. hallii* taxonomy.

Schoenoplectus hallii was included in the genus *Scirpus* L. sensu latu until recent investigations (Smith 1995, Smith and Yatskievych 1996, S.G. Smith 2002, Smith and Hayasaka 2002). In the most recent treatment, *Scirpus* L. sensu latu is divided into nine segregate genera, including *Schoenoplectus*, based on spikelet morphology, vegetative features, embryology, and DNA evidence (S.G. Smith 2002, Smith and Hayasaka 2002). *Schoenoplectus* is the largest of these genera in North America with about 17 species (77 species worldwide) (S.G. Smith 2002). McKenzie (1998) verified that, "*S. hallii* is a valid, distinct species with no outstanding challenges to its taxonomic validity," based on testimony from species experts.

Historical treatments have considered this species as *Scirpus hallii* A. Gray, *Scirpus supinus* L. var. *hallii* (A. Gray) A. Gray, *Scirpus uninodis* (Delile) Boissier var. *hallii* A. Beetle, and *Schoenoplectus erectus* (Poiret) Palla ex J. Raynal (Beetle 1942, Koyama 1962, Schuyler 1969, Raynal 1976, Smith 1995, McKenzie 1998). Common names include Hall's bulrush, Hall's twine-bulrush, Hall's club-rush, and Hall's tule.

History of species

Asa Gray originally described this sedge in 1863 as *Scirpus hallii* based on specimens collected in Illinois, and S.G. Smith placed it in the genus *Schoenoplectus* (Smith 1995). The holotype specimen is housed at the Gray Herbarium (Cambridge, MA), and isotype specimens are at the New York Botanical Garden (Bronx, NY) and the U.S. National Herbarium (Washington, D.C.). As discussed above, the taxonomy of *S. hallii* and other members of family Cyperaceae has been a subject of discussion from 1942 through the present (Beetle 1942, Koyama 1962, Mohlenbrock 1963, Schuyler 1969, Raynal 1976, Smith 1995, McKenzie 1998, S.G. Smith 2002).

Schoenoplectus hallii was listed as a Category 2 species with the USFWS in 1993, and the category program was eliminated in 1996. Robertson et al. (1993) (Illinois), Steinauer (2001) (Nebraska), Penskar and Higman (2002) (Michigan), and Magrath (2002) (Wichita Mountain Wildlife Refuge Survey, Oklahoma) prepared state- or area-specific status reports, and McKenzie (1998) produced a rangewide status report. Achene morphology, germination, and demography of *S. hallii* have been the subject of recent research by botanists, researchers, and students (S. Ammann, C. Baskin, J. Baskin, E. Chester, K. Havens, J. Houpis, R. Johnson, J. Knolhoff, P. McKenzie, B. Meinardi, N. Parker, E. Schuyler, C. Shaffer, M. Smith, S. Smith, S. Williams), funded in part by the USFWS (C. Baskin personal communication 2003, M. Smith personal communication 2003). Some of the work is summarized in Transactions of the Illinois State Academy of Science (Shaffer et al.. 2001, Meinardi et al. 2002, Mettler and Smith 2002), American Journal of Botany (Baskin et al. 2003), and unpublished status reports (M. Smith 2001, 2002, 2003). Results of recent work are also being prepared for publication or are in publication review in peer-reviewed journals (P. McKenzie personal communication 2003, M. Smith personal communication 2003, Smith and Houpis 2003, M. Smith et al. 2003). Additional germination and seed storage research has been performed at the Chicago Botanic Garden (K. Havens personal communication 2003). Previous to these studies, no detailed demographic, ecological, or biological studies of this species had been undertaken.

Morphological characteristics

Members of the family Cyperaceae are sedges with three-sided stems, spikelets, solid internodes, linear leaves with a closed sheath, and fibrous roots, growing in damp or marshy habitats (Zomlefer 1994).

Schoenoplectus hallii is a slender, caespitose sedge from 5 to 80 centimeters (cm) tall with short, slender rhizomes (**Figure 2**; Mohlenbrock 1976, McKenzie 1998, S.G. Smith 2002). This species has been described as an annual, but experts on the species suggest that *S. hallii* is a weak perennial with "slender rhizomes", at least in some circumstances (P. McKenzie personal communication 2003). The stems are stiff to flaccid and terete to subterete in cross section. The leaf blades are 0.1 to 20 cm long, have smooth or spinulose margins, and are clustered near the base.

Schoenoplectus hallii is amphicarpic in that it produces terminal inflorescences as well as basal flowers. The terminal inflorescence is comprised of one to seven sessile spikelets in a head-like cluster (rarely with one or two short branches) at the tip of the stem (i.e., aerial). The involucral bract is 3 to 15 cm long (about half as long as the culm), appears as a continuation of the stem, and surpasses the spikelets. The spikelets are ovoid-cylindric, ovate, or lance ovate, 5 to 20 millimeters (mm) long and 2.0 to 3.5 mm wide. The spikelet scales are ovate, acuminate, 2.5 to 4.0 mm long, greenish-brown, tan or orangish-brown, with a green or straw-colored midrib that projects past the body of the scale. The flowers have two stigmas and lack perianth bristles. The achenes are obovoid, flat on one side and broadly rounded on the other, 1.3 to 2.0 mm long, transversely rugose (corrugate), and dark brown to black at maturity.

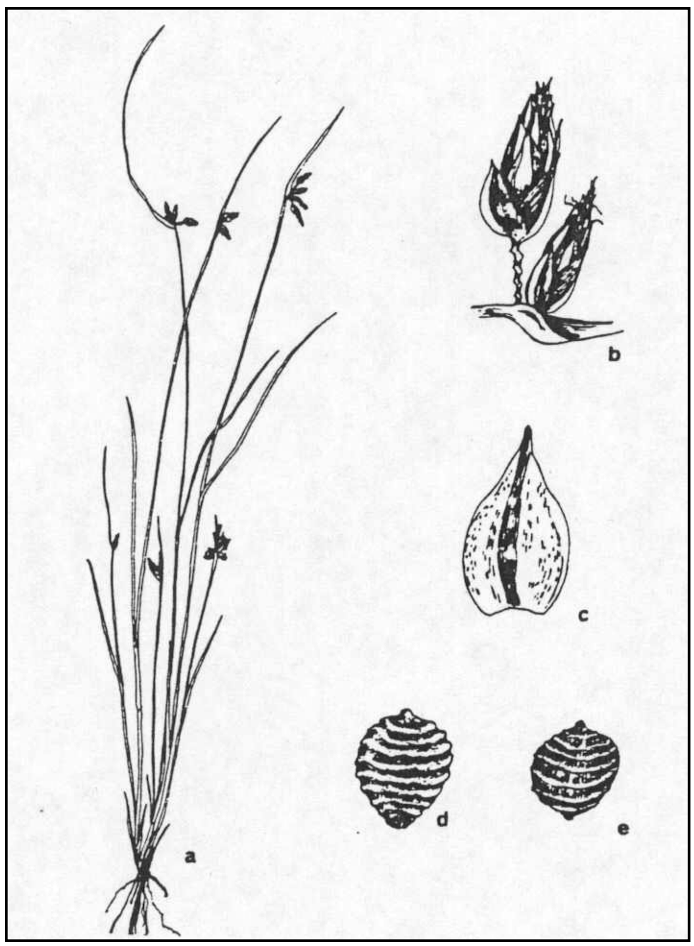
Schoenoplectus hallii can also produce short basal culms, usually seen later in the season, that are only 1 cm in length and are often enclosed within the encircling leaf sheath (Penskar and Higman 2002). These short stems can produce solitary pistillate flowers and achenes. The basal flowers can have three stigmas, and the basal achenes are usually larger than those produced by aerial stems and unequally three-angled (Mohlenbrock 1976, McKenzie 1998, M. Smith 2001, S.G. Smith 2002). The basal achenes have obvious vertical grooves and lack the prominent horizontal ridges that are characteristic of the terminal achenes (M. Smith 2001). Amphicarpy is a characteristic shared by other species of the section *Supini*, and having basal fruits available is helpful when identifying individuals without aerial fruits (C. Freeman personal communication 2003). Refer to M. Smith (2001) for a quantification of differences between the terminal and basal achenes of *S. hallii* and for descriptions on how these achenes can be sorted and identified from seedbank samples.

Schoenoplectus hallii can be confused with other *Schoenoplectus* species in the sections *Supini* (e.g., *S. erectus* and *S. saximontanus*) and *Actaeogeton* (e.g., *S. smithii*, *S. purshianus*, and *S. mucronatus*) in terms of vegetative and reproductive structures (Mohlenbrock 1976, McKenzie 1998). However, the black, ornamented achenes of *S. hallii* are a distinct feature and enable this species to be distinguished from all others (Penskar and Higman 2002). Members of *Schoenoplectus* section *Actaeogeton* differ from those in section *Supini* because they lack the presence of a node above the basal leaves and they do not exhibit amphicarpy, as seen in the latter group (Smith and Hayasaka 2002). *Schoenoplectus purshianus* has biconvex, pitted achenes with stout bristles, and obtuse scales (Mohlenbrock 1976). *Schoenoplectus smithii* has smooth, plano-convex achenes with slender or no bristles, and obtuse or mucronulate scales (Mohlenbrock 1976). *Schoenoplectus hallii* specimens have also been misidentified as the closely related *S. erectus* and *S. saximontanus* in some cases (McKenzie 1998). *Schoenoplectus erectus* is more southern in its distribution (known from Alabama, Florida, Georgia, South Carolina, Texas, and Mexico) and has reddish spikelet scales and achenes with a flat or bulged ventral surface. *Schoenoplectus saximontanus* tends to be more western in its distribution (known from British Columbia, California, Colorado, Illinois, Kansas, Missouri, Nebraska, Ohio, Oklahoma, South Dakota, Texas, Utah, Wyoming, and Mexico) and has three-branched styles and three-sided achenes. Magrath (2002) also noted that the transverse ridges of *S. saximontanus* are mostly rounded with narrow wings, compared to the rounded transverse ridges of *S. hallii*'s

A

Photographs by Paige Mettler. Reprinted with permission from the photographer.

B



Adapted from Mohlenbrock, R.H. 1976. The Illustrated Flora of Illinois: Sedges - Cyperus to Scleria. Southern Illinois University Press: Carbondale and Edwardsville, IL.

Figure 2. *Schoenoplectus hallii* **(A)** photographs in its natural habitat in Scott County, Missouri, and **(B)** illustration of the vegetative and reproductive structures, a. Habit x 0.225, b. Spikelets x 2.25, c. Scale x 6.75, d. and e. Achenes x 9.

achenes. M. Smith is currently using scanning electron microscopy to further describe these characteristics (Magrath 2002).

A technical description and an illustration of *Schoenoplectus hallii* are presented in Mohlenbrock (1976) and S.G. Smith (2002). The most recent key to *Schoenoplectus* is available in S.G. Smith (2002).

Distribution and abundance

Estimating distribution and abundance

Describing the range and abundance of *Schoenoplectus hallii* is complex because (1) the locations of some historical accounts are unclear, (2) the historic and current distributions differ significantly (i.e., *S. hallii* appears to be extirpated from several states), (3) specimens have been misidentified or confused with similar species (e.g., *S. saximontanus*, *S. erectus*), (4) the abundance and presence of *S. hallii* at sites varies widely from year to year depending on hydrologic fluctuations and habitat availability, (5) *S. hallii* can maintain a seedbank for many years (The Nature Conservancy considers populations observed within last 25 years to be extant), and (6) extensive surveying has not occurred (McKenzie 1998, Ormes 1998, NatureServe 2003). Researchers have also stated that estimating abundance is difficult because it is easy to mistake a clustered group of plants to be one individual (Nebraska Natural Heritage Program 2002). Thus, the full distribution and abundance of this species are not known.

Global distribution

Schoenoplectus hallii is widely distributed but rare throughout eastern and midwestern United States. For the 1998 status report, P. McKenzie extensively researched historical records, consulted species experts (A.E. Schuyler and S.G. Smith) about their reviews of herbarium specimens, and corresponded with state botanists to ascertain the previous and current distribution of *S. hallii*. Refer to McKenzie (1998) for a complete discussion, including a state-by-state treatment. The current distribution reported in S.G. Smith (2002) includes the following states: Georgia, Illinois, Indiana, Kansas, Kentucky, Michigan, Missouri, Nebraska, Oklahoma, and Wisconsin. This bulrush is probably extirpated from Massachusetts and Iowa (McKenzie 1998, S.G. Smith 2002).

Historical accounts of *Schoenoplectus hallii* from Alabama, Colorado, Florida, Georgia (Baker and Decatur counties), Oregon, South Carolina, South Dakota, and Texas are based on misidentifications of *S. saximontanus* or *S. erectus* (McKenzie 1998, S.G. Smith 2002).

USFS Region 2 distribution

Schoenoplectus hallii occurs in the sandhills region of north-central Nebraska (Brown, Garfield, Holt, Loup, Rock, and Wheeler counties) and central Kansas (Harper, Harvey, and Reno counties) (Steinauer 2001, Kansas Natural Heritage Inventory 2002, Nebraska Natural Heritage Program 2002). None of the known populations are located on USFS lands. Morse (2001) identified the Samuel McKelvie National Forest and the Halsey National Forest, associated units of the Nebraska National Forest, as likely locations for this species.

Based on the most current verified records obtained from NHPs within USFS Region 2, *Schoenoplectus hallii* is known from 30 populations in Nebraska and 6 populations in Kansas (**Figure 1**, **Table 1**). **Figure 1** depicts 29 *S. hallii* populations with available location information (Steinauer 2001, Kansas Natural Heritage Inventory 2002, Nebraska Natural Heritage Program 2002). The locations of seven populations discovered in 2001 in Nebraska are not included on the map because of sensitive location information; the Nebraska NHP should be contacted for further information (R. Schneider personal communication 2003). Distributional records in Kolstad (1991) overestimated the range of *S. hallii* in USFS Region 2 based on misidentified *S. saximontanus* specimens (Rolfsmeier 1995, McKenzie 1998, Steinauer 2001). *Schoenoplectus hallii* has not been observed in Kansas since 1997, despite revisiting sites and surveying sandhill prairie communities (McKenzie 1998).

Schoenoplectus hallii does not occur in the other USFS Region 2 states (i.e., Colorado, South Dakota, or Wyoming) and is thus not currently listed or ranked in those states (Colorado Natural Heritage Program 2002, Fertig and Heidel 2002, South Dakota Natural Heritage Program 2002). Previously published accounts of *S. hallii* in Colorado (Harrington 1954, Rydberg 1969, Small 1972, U.S. Fish and Wildlife Service 1993) and South Dakota are based on misdeterminations of *S. saximontanus* (McKenzie 1998). W. Weber (Weber and Wittmann 1992, 2001) retained both names as synonymous after re-identifying a *S. hallii* specimen as *S. saximontanus*. However, these species are distinct and separable (S.G. Smith 2002), and thus there are no documented occurrences of *S. hallii* in Colorado.

Table 1. *Schoenoplectus hallii* site information for USFS Region 2, as of 2002. Includes state, county, date the site was last observed, and estimated abundance. All occurrences at these sites have been verified by species experts. No occurrences are currently known from National Forest System lands. Sources: Kansas Natural Heritage Inventory. 2002. Biological Conservation Database. Kansas Natural Heritage Inventory, Kansas Biological Survey, Lawrence, KS; Nebraska Natural Heritage Program. 2002. Biological Conservation Database. Nebraska Natural Heritage Program, Nebraska Game and Parks Commission, Lincoln, NE.

State	County	Number of Sites	Date Last Observed	Estimated Abundance
Kansas (6 occurrences)	Harper	1	1997	Not Available (NA)
	Harvey	2	1963	NA
			1969	NA
	Reno	3	1949	NA
			1978	NA
			1993	NA
Nebraska (30 occurences)	Brown	10	1999	500 or more (+)
			2000	100
			2000	5,000+
			2000	20
			2000	1,000+
			2000	5,000+
			2000	119
			2000	3
			2000	20
			2001	50
	Garfield	2	2000	1,500+
			2000	4
	Holt	6	1941	NA
			1971	NA
			1999	10 to 15
			2000	50 to 100
			2001	100+
			2001	NA
	Loup	3	2000	200+
			2000	20+
			2000	2
	Rock	7	before 1997	NA
			2000	100+
			2000	3,000+
			2000	50 to 100
			2001	100
			2001	100
			2001	10 to 20
	Wheeler	2	2000	10 to 20
			2001	1,000+

Global abundance

Schoenoplectus hallii has a widespread geographic distribution, but it is rare within its range. In some states within its range, *S. hallii* is found at only one site. The number of *S. hallii* individuals varies drastically from year to year and from site to site as a result of habitat availability and environmental fluctuations (McKenzie 1998, Ormes 1998). This species could number in the thousands (or millions) at one site in one year and be visually absent from that site for the next 20 years (NatureServe 2003). At a site in Illinois, researchers estimated hundreds of thousands of plants covering several acres during a year with optimal conditions and found no plants at the same site two years later. Thus, estimating the global abundance of this species is difficult. As of 1998, there were fewer than 50 occurrences of *S. hallii* worldwide (McKenzie 1998). Ostlie (1998) assigned ranks indicating high concern relative to the global abundance of this species because populations disappear in some years and the number of occurrences is poorly known.

In 1998, P. McKenzie tabulated the historical and current number of known *Schoenoplectus hallii* sites throughout its range as a rough estimate of distribution and abundance (McKenzie 1998). The total number of sites appeared to fluctuate from approximately 29 sites prior to 1973, to approximately 46 sites recorded from 1973 to 1993, to approximately 37 sites recorded from 1993 to 1997. These fluctuations likely reflect changes in survey intensity, environmental conditions, and/or reductions in available habitat, rather than actual population sizes or seedbank sizes (McKenzie 1998). Outside USFS Region 2, the numbers of sites by state known from 1993 to 1997 include Illinois (30 sites), Indiana (1 site), Kentucky (1 site), Missouri (3 sites), and Wisconsin (1 site) (McKenzie 1998). Historical populations are known from Georgia, Iowa, Massachusetts, but they have not been seen since 1973 (McKenzie 1998). Michigan did not have any extant populations as of 1997, but sites have been discovered since that time (P. McKenzie personal communication 2003). This assessment does not provide a further analysis on the abundance of this species outside USFS Region 2.

The most updated records for USFS Region 2 states include Kansas (6 sites) and Nebraska (30 sites) (Steinauer 2001, Kansas Natural Heritage Inventory 2002, Nebraska Natural Heritage Program 2002). However, *Schoenoplectus hallii* has not been identified on any National Forest System lands within Region 2. Refer to the following section for details on *S. hallii* abundance on non-USFS lands in Region 2 states.

USFS Region 2 abundance

Any population of any size is considered an occurrence under global element occurrence specifications (Ostlie 1998). The current estimated number of *Schoenoplectus hallii* populations on non-USFS lands in Region 2 includes 30 sites for Nebraska and 6 sites for Kansas (**Table 1**; Steinauer 2001, Kansas Natural Heritage Inventory 2002, Nebraska Natural Heritage Program 2002). *Schoenoplectus hallii* has not been identified on any USFS lands within Region 2, and thus there is zero abundance of this species with respect to National Forest System lands. Abundance estimates for the Nebraska populations ranged from under 10 individuals to hundreds and thousands of individuals per site (**Table 1**; Steinauer 2001, Nebraska Natural Heritage Program 2002). There was no specific abundance information available for the Kansas records; two occurrences described the population as "abundant," one occurrence described the population as "scattered," and one occurrence reported "species not found" (Kansas Natural Heritage Inventory 2002). *Schoenoplectus hallii* has not been observed in Kansas since 1997, despite revisiting sites and surveying sandhill prairie communities (McKenzie 1998).

Occurrences of *Schoenoplectus hallii* in Nebraska are associated with an element occurrence rank based on population abundance, perceived habitat quality, and potential threats (Ostlie 1998). Of 30 ranked occurrences in Nebraska, three were ranked as "A" (1,000 or more individuals; occurs in a large, high-quality environment; habitat is free of human-induced disturbance), two were ranked as "AB", two were ranked as "B" (100 to 999 individuals; occurs in a moderate-sized, good quality environment; habitat has little human-induced disturbance), six were ranked as "BC", 13 were ranked as "C" (10 to 99 individuals; occurs in small, adequate quality environment; habitat has moderate human-induced disturbance), four were ranked as "CD", and none were ranked as "D" (1 to 9 individuals; occurs within a highly degraded environment; habitat has significant human-induced disturbance). Occurrence ranks were not provided for any Kansas records (Kansas Natural Heritage Inventory 2002).

Population trends

Population trends for *Schoenoplectus hallii* are difficult to estimate due to fluctuating population sizes and a lack of information, especially for newly discovered populations and historical locations. The Nature Conservancy describes *S. hallii* as declining due to habitat destruction (Ormes 1998). As an annual or weak perennial species, populations fluctuate greatly from year to year, depending on hydrologic fluctuations and habitat availability. Although population sizes have been estimated in some cases, multi-year population or demographic monitoring has not been initiated for any site in Kansas or Nebraska. *Schoenoplectus hallii* has not been identified on any USFS lands in Region 2, and thus, no population trend data exist specifically with respect to National Forest System lands.

The recorded abundance of *Schoenoplectus hallii* populations on non-USFS lands in Kansas and Nebraska has increased dramatically since 1997 as a result of newly discovered locations. For example, 27 new *S. hallii* populations have been discovered during 1999 and 2001 inventories of native plant communities in the Nebraska sandhills (Steinauer 2001). It is very likely that additional populations exist in other sandhill areas that have not been thoroughly surveyed (Robertson et al. 1993, McKenzie 1998, Steinauer 2001, NatureServe 2003). Thus, the abundance could be overestimated or underestimated, depending on the full spatial extent of the species, undiscovered populations, potentially misidentified occurrences, effects of environmental fluctuations, and threats from habitat destruction.

Habitat characteristics

General habitat characteristics

Schoenoplectus hallii is an obligate wetland species that colonizes damp areas such as shores and bottoms of shallow ephemeral pools, sinkhole ponds, coastal plain marshes, roadside ditches, small lakes, sandy swales, stock ponds, depressions in cultivated fields, and sand pits from 70 to 855 meters (m) (230 to 2805 feet [ft]) in elevation (**Figure 2**; Robertson et al. 1993, McKenzie 1998, S.G. Smith 2002). Soils tend to be sandy, but silty, muddy flats, sandy-peaty substrates, and cobbly, rocky habitats have also been recorded (McKenzie 1998, Penskar and Higman 2002). These habitats are characterized by widely fluctuating water levels and are generally free of competing vegetation (Robertson et al. 1993, McKenzie 1998, NatureServe 2003). Seeds germinate in moist sand that is exposed as water levels recede in dry summer conditions (Penskar and Higman 2002). The amount and distribution of habitat can be affected by the amount and timing of precipitation (Robertson et al. 1993). In wet years, habitat can be created in usually dry depressions of cultivated fields, habitat can be expanded over a larger area at the margins of ponds, or existing habitat can be decreased through flooding (Robertson et al. 1993).

Based on a variety of reports throughout the range, species and genera commonly associated with *Schoenoplectus hallii* on lands outside USFS Region 2 include *Agrostis* spp., *Alisma* spp., *Ammania coccinea*, *Bacopa* spp., *Cyperus* spp., *Echinochloa* spp., *Eleocharis* spp., *Fimbristylis autumnalis*, *Heterantha* spp., *Hypericum* spp., *Isoetes* spp., *Juncus* spp., *Leersia* spp., *Lindernia* spp., *Lipocarpha micrantha*, *Ludwigia* spp., *Lycopus* spp., *Polygonum* spp., *Rhexia* spp., *Rhynchospora* spp., *Rorippa* spp., *Rotala ramosior*, *Sagittaria* spp., *Schoenoplectus* spp., *Scirpus* spp., *Typha* spp., and *Xyris* spp. (McKenzie 1998). Other rare plants are often associated with the same habitats as *S. hallii* (e.g., *Echinodorus tenellus* var. *parvulus*) (P. McKenzie personal communication 2003). Refer to NatureServe (2003) and state NHP element occurrence records for descriptions of associated species in states outside USFS Region 2.

USFS Region 2 habitat characteristics

Within Region 2, *Schoenoplectus hallii* has only been identified on non-USFS lands in Kansas and Nebraska. All *S. hallii* occurrences in Kansas and Nebraska occur in sandhill prairie habitat on bare, wet, sandy substrates with sparse vegetation (Steinauer 2001, Kansas Natural Heritage Inventory 2002, Nebraska Natural Heritage Program 2002). In Nebraska, *S. hallii* is known from (1) the margins of deep- and shallow-water marshes, ponds, and lakes; (2) roadside ditches; and (3) cattle trails that lead through shallow-water wetlands and other depressions. Elevations range from 634 to 853 m (2080 to 2800 ft). In Kansas, *S. hallii* colonizes (1) shorelines of small, shallow, sandhill ponds; (2) roadside ditches; and (3) wet-mesic to mesic swales among sand dunes and hummocky sands. Elevations range from 387 to 519 m (1270 to 1700 ft).

The sandhills prairie region is the largest stabilized dune field in the western hemisphere, and wetlands tend to form in interdunal valleys, usually fed by groundwater rather than surface runoff (Ostlie et al. 1997). Water levels are generally highest in winter and spring and decrease throughout the growing season. Soils tend to be poorly drained sandy loams, fine sands, or gravel derived from aeolian and alluvial deposits, often with an impermeable or semi-permeable silt or clay layer (Ostlie et al. 1997).

Under the wetland classification system defined by Cowardin et al. (1979), many of the ephemeral wetlands with *Schoenoplectus hallii* would be classified in the Class Unconsolidated Shore (Subclass Vegetated) of the Palustrine System. The Class Unconsolidated Shore (Subclass Vegetated) is characterized by temporary, intermittent, or seasonal wetland habitats with sparse vegetation cover, except for pioneer plants that become established in brief periods when conditions are favorable. The water regime modifier in these non-tidal wetlands would be described as Seasonally Flooded (surface water present early in growing season, but absent by end of season), Temporarily Flooded (surface water present for brief periods during growing season), or Intermittently Flooded (substrate usually exposed, with surface water present at some times). More permanent wetlands would be classified in the Class Emergent Wetland, with persistent vegetation such as *Spartina* spp. and *Typha* spp. or non-persistent vegetation such as *Sagittaria* spp. The water regime modifier for these wetlands would likely be Permanently Flooded (surface water present throughout year), Intermittently Exposed (surface water present except during drought), or Semi-permanently Flooded (surface water persists through growing season in most years). The water chemistry or soil modifiers for *S. hallii* habitats in USFS Region 2 have not been recorded. Special modifiers would apply to *S. hallii* habitat in cases where the wetlands have been altered by human activities, such as Excavated, Partly Drained, Farmed, or Artificial.

Schoenoplectus hallii generally grows in areas with sparse vegetation and in plant communities with low species diversity (Mettler and Smith 2002, M. Smith 2003). It is difficult to classify the vegetation in these habitats because annual and seasonal water fluctuations result in dynamic vegetation communities (Ostlie et al. 1997). M. Smith (2003) discovered that the characteristics of vegetation communities (identity of species, percentage obligate wetland species, diversity, richness, and evenness) at *S. hallii* sites in Missouri changed from year to year depending on the climatic and hydrologic conditions. Vegetation communities in these habitats are most likely classified within Formation Temporarily flooded temperate grassland (V.A. 5.N.j.), Formation Semipermanently flooded temperate grassland (V.A.5.N.l.), or Formation Saturated temperate grassland (V.A.5.N.m.) (Grossman et al. 1998).

Schoenoplectus hallii appears to rely on a growing season drawdown to expose moist substrate free of competing vegetation, as it tends to grow as a terrestrial or emergent plant in the ecotone between the high water and low water marks (Schuyler 1969). Steinauer (2001) occasionally observed *S. hallii* amid dense concentrations of *Eleocharis acicularis* (needle spike rush), the most common associated species with *S. hallii* in Nebraska. More often though, dense mats of the spike rush appeared to exclude *S. hallii* from otherwise suitable habitat (Steinauer 2001). *Rotala ramosior*, *Eleocharis obtusa*, *E. palustris*, *Alisma subcordatum*, and *Sagittaria cuneata* were also commonly found with *Schoenoplectus hallii* in Nebraska (Steinauer 2001). Refer to **Table 2** for a complete list of associated species in Nebraska. There were no records of associated species from Kansas.

Specific microhabitat requirements for *Schoenoplectus hallii* populations in Kansas and Nebraska have not been studied. Steinauer (2001) surveyed several sites in Nebraska with "extensive areas of sparsely vegetated wet sand" in a good year for the species at other sites, but he did not discover any new *S. hallii* populations. M. Smith and colleagues are currently studying habitat characteristics, such as soil type, soil moisture, groundwater fluctuation, and vegetation patterns where *S. hallii* flourishes in Missouri, Illinois, and Kentucky (M. Smith 2001, Mettler and Smith 2002, M. Smith 2002, M. Smith 2003). Preliminary results from these sites suggest that *S. hallii* does not survive below 14 percent soil moisture, establishes in low diversity communities, and inhabits soils with a range of organic matter from 0.3 to 2.6 percent (M. Smith 2001, Mettler and Smith 2002). The full ecological amplitude of this species is not known.

Reproductive biology and autecology

Reproduction

Details concerning the breeding system of *Schoenoplectus hallii* are largely unknown. This bulrush produces non-fleshy, indehiscent achenes from terminal and basal structures. *Schoenoplectus hallii* flowers and fruits from early July through mid-October, depending on temperature and moisture conditions throughout the growing season (M. Smith 2001, 2002, 2003). Refer to subsequent sections for further information regarding life history, pollination, dispersal, hybridization, and demography.

The hypothesized life cycle of *Schoenoplectus hallii* is depicted in **Figure 3**. The life cycle diagram is based mainly on the results of demographic monitoring at one site in Missouri by M. Smith and colleagues (M. Smith 2001, 2002, 2003). *Schoenoplectus hallii* is an annual or weak perennial species, so plants tend to germinate, grow, reproduce, and die in one or a few growing seasons. This species is thought to be a weak perennial under some circumstances (P. McKenzie

Table 2. Plant species associated with *Schoenoplectus hallii* at Nebraska (USFS Region 2) sites. Sources: Steinauer, R.F. 2001. 2000 Survey for Hall's Bulrush *Schoenoplectus hallii* (Gray) S.G. Sm. in the Eastern Sandhills of Nebraska: Final Report. Unpublished report prepared for the Nebraska Game and Parks Commission, Lincoln, NE, and Nebraska Natural Heritage Program. 2002. Biological Conservation Database (Element Occurrence Records) for *Schoenoplectus hallii*. Nebraska Natural Heritage Program, Nebraska Game and Parks Commission, Lincoln, NE.

Alisma plantago-aquatica	*Juncus marginatus*
Alisma subcordatum	*Juncus nodosus*
Anagallis minima	*Juncus scirpoides*
Arumaria robusta	*Leersia* spp.
Aster lancelata	*Lindernia dubia*
Bidens spp.	*Lipocarpha drummondii*
Bulbostylis capillaris	*Ludwigia palustris*
Carex pellita	*Panicum acuminatum*
Cyperus acuminatus	*Panicum virgatum*
Cyperus squarrosus	*Polygonum* spp.
Cyperus strigosus	*Potamogeton* spp.
Drepanocladus aduacus	*Rotala racemosa*
Eleocharis acicularis	*Rotala ramosior*
Eleocharis atropurpurea	*Sagittaria calycina*
Eleocharis erythropoda	*Sagittaria cuneata*
Eleocharis obtusa	*Sagittaria graminea*
Eleocharis ovata	*Sagittaria latifolia*
Eleocharis palustris	*Sagittaria rigida*
Eragrostis spp.	*Salix eriocephala*
Euthamia gymnospermoides	*Salix humilis*
Juncus alpinoarticulatus	*Schoenoplectus acutus*
Juncus alpinus	*Spartina pectinata*
Juncus bufonius	*Typha* spp.
Juncus canadensis	*Veronica peregrina*

personal communication 2003), but perennial habits have not been identified during work in Missouri (M. Smith 2003) and are not considered to be prevalent. Rates of dispersal, dormancy, germination, and establishment are unknown. Survival of young plants to flowering plants and the fecundity of large and small flowering plants have been measured at one site in Missouri (M. Smith 2003), and details of this work are summarized in the Demography section.

The effect of amphicarpy (producing both terminal and basal fruits) on the reproductive success of *Schoenoplectus hallii* has not been studied. Amphicarpy in the genus *Schoenoplectus* appears to be environmentally induced with a decrease in water levels of the microhabitat (Browning 1992). Hypotheses on the adaptive significance of producing basal fruits include placement of the fruits in a favorable site for future re-colonization and/or protection of fruits from changes in microclimate, predation/herbivory, or perturbations (i.e., fire or flooding) (Bruhl 1994). Some amphicarpic species produce cleistogamous basal flowers (versus chasmogamous aerial flowers) that presumably aid in the protection of the basal flowers. However, Bruhl (1994) noted that amphicarpic *Schoenoplectus* species do not produce cleistogamous basal flowers. Despite a presumed lack of cleistogamy in *S. hallii*, producing basal fruits will likely ensure reproductive success even when aerial fruits are grazed or otherwise damaged (P. McKenzie personal communication 2003).

Recruitment relies on germination from an extensive seedbank and thus depends on reproductive success from previous years as well as current conditions. Observations of *Schoenoplectus hallii* in USFS Region 2 indicate that most populations showed evidence of flowering and/or fruiting individuals (Nebraska Natural Heritage Program 2002). Even one

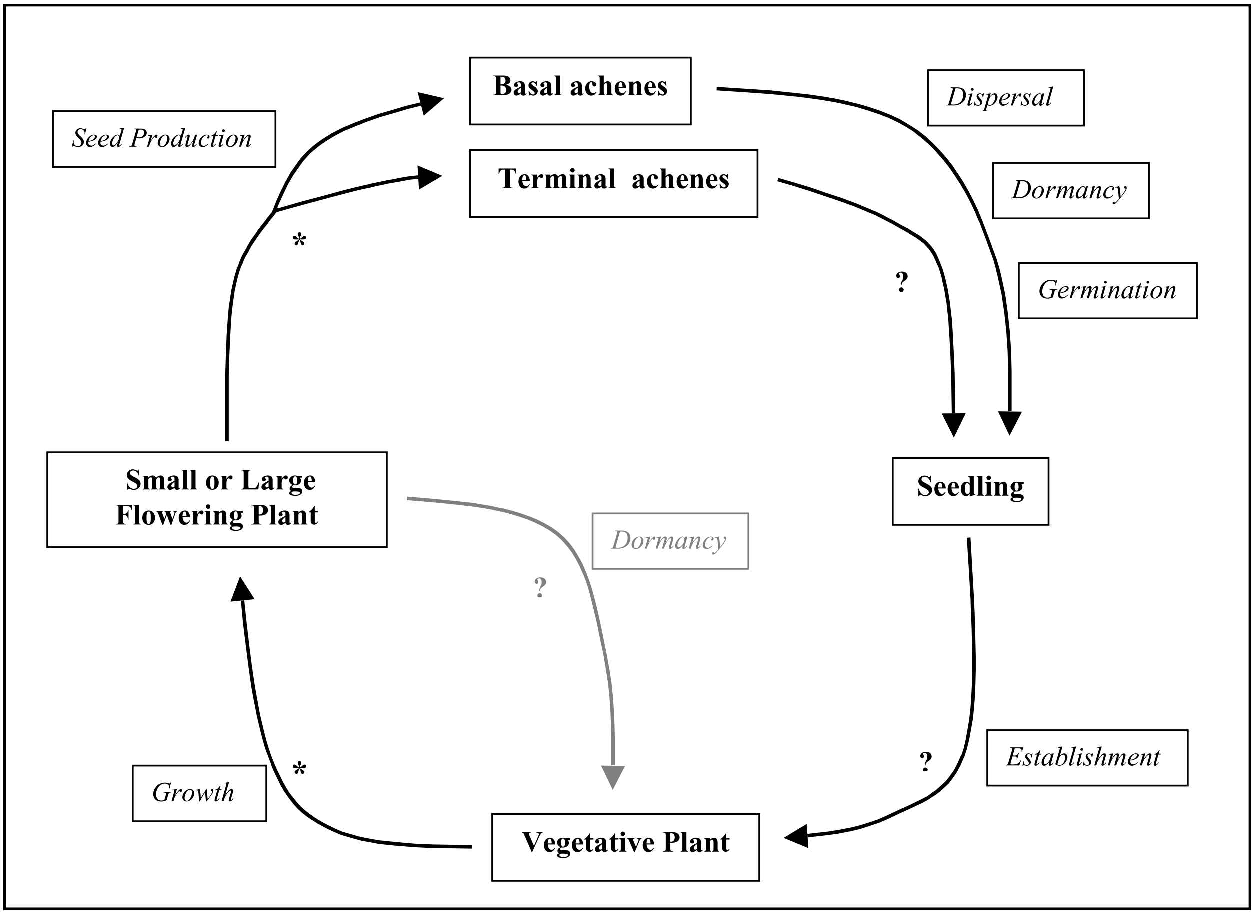


Figure 3. Schematic representation of the life cycle of *Schoenoplectus hallii*. Figure is adapted from Grime (1979) and based on preliminary demographic monitoring at one site in Missouri by M. Smith and colleagues (M. Smith 2001, 2002, 2003). Plants taller than 5 cm are considered to be large flowering plants. Amphicarpy in this species is indicated by the production of both basal and terminal achenes. This species is thought to be a weak perennial under some circumstances (P. McKenzie personal communication 2003), but perennial habits are not considered to be prevalent (M. Smith 2003) and this portion of the life cycle is indicated in gray font. Rates of dispersal, dormancy, germination, and establishment are unknown (indicated by "?"). Survival of young plants to flowering plants and the fecundity of large and small flowering plants (indicated by "*") have been measured at one site in Missouri (M. Smith 2003), and details of this work are summarized in the text.

population impacted by cattle grazing was producing flowers and fruits (Steinauer 2001). The presence of current fruiting populations in USFS Region 2 suggests that past populations have been successful and that new propagules are being added to the seedbank for future populations.

Life history and strategy

Schoenoplectus hallii is a small, short-lived sedge that flourishes during favorable conditions, takes advantage of ephemeral wetland habitats, and maximizes reproductive success by developing an extensive seedbank. Based on vegetation strategies described by Grime (1979), *S. hallii* would be considered a ruderal, or r-selected, species. A ruderal species can exploit unpredictable environments by minimizing vegetative growth and maximizing reproductive output during a short life span (Grime 1979, Barbour et al. 1987). Annual ephemeral species have an advantage in environments with temporally and spatially unpredictable resources because the probability that a seed will establish exceeds the probability that an adult plant will survive to another growing season (Barbour et al. 1987). The environment inhabited by *S. hallii* in USFS Region 2 is unpredictable or ephemeral because available water fluctuates throughout a growing season and thus alters the distribution and extent of habitat. Marshland ruderals generally colonize bare areas that become available as water levels fall during drying periods or where excess water creates ephemeral wetlands. The substrates in these areas generally support rapid plant growth because they are rich in readily available nutrients and moisture and free of competing perennial vegetation disturbed by fluctuating water levels (Grime 1979, Barbour et al. 1987).

Pollinators and pollination ecology

The specific pollination mechanisms for *Schoenoplectus hallii* have not been described, but members of the family Cyperaceae are generally adapted for wind pollination (anemophily) (Zomlefer 1994). Wind-pollinated flowers are usually unisexual, have exposed anthers and stigmas, an insignificant perianth, no insect attractants, and copious small-grained pollen (Richards 1987). Important issues related to the pollination of rare plants that have yet to be researched for *S. hallii* include pollination efficiency, the role of plant density on pollination, and genetic implications of pollination.

Dispersal mechanisms

Details of seed dispersal mechanisms in *Schoenoplectus hallii* are not known. *Schoenoplectus hallii*'s short life cycle, the ephemeral nature of its populations, and its specialized habitat needs probably lead to limited dispersal capability (McKenzie 1998). The achenes of *S. hallii* are small and appear to lack any adaptation that would facilitate wind or animal-mediated dispersal. Only the achenes produced by aerial spikelets are likely to disperse over a long distance; the basal achenes of amphicarpic *Schoenoplectus* species probably remain *in situ* (Browning 1992). Magrath (2002) also hypothesized that the less numerous, heavier seeds from basal achenes probably stay in presently occupied sites, while the more numerous, smaller seeds from terminal achenes can be dispersed farther distances to new sites. Other studies have found that the majority of sedge seeds remain close to the parent plant. Seedbank studies of an ephemeral wetland invader, *Scirpus cyperinus*, found that the sedge produces copious amounts of wind-dispersed seeds. The number of seeds in the soil near the parent plants (about 83,000 seeds per squared meter) was 32 times greater than the number of seeds found 35 meters away (Wilcox et al. 1985).

Schoenoplectus hallii seeds probably drop when jostled by wind or animals or when plants senesce and fall over. In addition, plants may be uprooted or inflorescences may be broken off by animal activity or storm events (Magrath 2002, M. Smith 2003). The seeds or inflorescences may be dispersed downslope or downwind by erosion, wind, or water. Seeds probably lie on the surface when soils dry out in the autumn, but then float and disperse when water levels rise in the spring. M. Smith (2001) found that *S. hallii* terminal achenes are capable of floating up to 60 days in gentle wave action in laboratory experiments, and thousands of achenes were seen floating in a pond. In addition, seeds may be transported by the activities of animals. Magrath (2002) hypothesized that mud containing seeds or inflorescences with seeds could adhere to the hooves, hair, or skin of animals' legs (e.g., bison, cattle). Several studies have documented that waterfowl (ducks and geese) are capable of transporting wetland seeds with hard seed coats (e.g., sedges) long distances (Kantrud 1996, McClain et al. 1997, NatureServe 2003). Migratory waterfowl use temporary ponds and feed on many wetland plants. Ducks could move seeds by collecting them on their feet or passing them through their digestive tracts. "Large numbers of [*Scirpus robustus*] achenes pass through the digestive systems of some waterbirds with increased viability and can be transported long distances" (Kantrud 1996). Dispersal by waterfowl is likely important for long-distance dispersal for *S. hallii*; this species was discovered at the edges of a man-made pond in Missouri, and researchers hypothesized that ducks brought seeds in from nearby ponds (NatureServe 2003).

Presumably, dispersal success of *Schoenoplectus hallii* depends on wind patterns, animal activity, topographic heterogeneity, precipitation amount and frequency, and availability of suitable "safe" sites for seed germination. For example, waterfowl migration patterns and the timing of seed feeding by waterfowl could affect whether seeds are generally transported south or north.

Seed viability and germination requirements

The fertility, seed viability, and germination requirements of *Schoenoplectus hallii* have been observed in both field and greenhouse environments (Ostlie 1998, Baskin et al. 2000, Shaffer et al. 2001, M. Smith 2001, Meinardi et al. 2002, M. Smith 2002, Baskin et al. 2003, K. Havens personal communication 2003, M. Smith 2003). Preliminary seedbank studies from *S. hallii* sites in Missouri and Illinois indicated that seed viability tends to be high, but varies significantly among different soil depths and sites. Seed number and proportion viable seeds decrease with soil depth (Shaffer et al. 2001, M. Smith 2001, Meinardi et al. 2002).

Ostlie (1998) noted that germination of *Schoenoplectus hallii* does not appear to be triggered mainly by water level changes, as it is with other sedges. B. Meyers-Croteau began seedbank studies while studying at Illinois State University (McKenzie 1998), but her work was not completed (R. Anderson personal communication 2003). Seed has been germinated at the Chicago Botanic Garden in wet sand under light at 25 ºC, after 12 weeks of cold moist stratification at 4 ºC (K. Havens personal communication 2003). Recent research on seeds of *S. hallii* from Kentucky, Missouri, and Illinois by Baskin et al. (2003) and M. Smith (2001, 2002, 2003) focused on dormancy-breaking and germination needs, experimenting with cold/warm stratification, flooding, light exposure, and chemical cues. The researchers concluded that seeds are dormant when they are mature and that dormant seeds require cold conditions in the winter or spring to break dormancy. Non-dormant seeds then germinated in the spring with appropriate temperature, light, moisture, and exposure to ethylene. Ethylene produced in anaerobic soils might be a "flood-detecting" mechanism and a signal for seeds that soils are sufficiently moist, competing species are absent, and appropriate temperatures are present (Baskin et al. 2003). The researchers also found that dormant seeds that were flooded in the fall or early winter (versus late winter or spring) remained dormant, despite appropriate temperature and exposure to ethylene. In addition, temperatures that fluctuated daily (e.g., 15º to 30 ºC), as might occur in shallow water or soils, promoted germination, in contrast to more constant, warmer temperatures (e.g., constant 20 ºC), as might occur in deeper water or deep in soils. Seeds could germinate in lowlight or dark conditions, depending on the presence and timing of other germination cues (e.g., exposure to ethylene, flooding, temperatures). Maximum germination of seeds occurred at a water depth of 3 cm (M. Smith 2002). Buried seeds undergo a conditional annual dormancy/non-dormancy cycle, depending on the timing of flooding and high temperatures (M. Smith 2003). A conceptual model for the germination of *S. hallii* seeds is presented in Baskin et al. (2003). Seeds are most likely to germinate if dormancy is broken by flooding in late winter or spring, the area is flooded in spring or summer (i.e., ethylene is produced in anaerobic soils), and seeds are on or near the surface (i.e., appropriate light and temperature) (Baskin et al. 2003).

Studies with the closely related *Schoenoplectus purshianus* found that germination cues were different for seeds that went through different conditions (e.g., flooding, temperature, burial) during dormancy (Baskin et al. 2000). Among other factors, *Scirpus robustus* seeds require light to germinate, perhaps to prevent the seeds from germinating in dense stands of marsh grasses instead of in newly exposed bare soil (Dietert and Shontz 1978).

Cryptic phases

Because *Schoenoplectus hallii* is an annual or weak perennial species, the only cryptic phase during the life cycle is the presumably long-lived and extensive seedbank. Seed dormancy can be an important adaptation for plant populations to avoid unfavorable conditions and to exploit favorable conditions in harsh or variable environments (Venable and Lawlor 1980, Kaye 1997). "Annuals, in unpredictable environments, tend to have effective dormancy mechanisms and extremely long seed life, forming persistent seed pools in the soil." (Barbour et al. 1987). Extensive seedbanks have also been reported for other sedge species, including *Scirpus mucronatus*, *S. validus*, *S. cyperinus*, and *S. setaceus* (Baskin et al. 2000).

Schoenoplectus hallii populations fluctuate greatly from year to year in response to habitat conditions. McKenzie (1998) noted that, "seeds apparently germinate sporadically from year to year depending on the availability of wet, exposed habitat…In some areas, the species can disappear for long periods only to reappear when conditions are favorable." Populations in Illinois can have hundreds to thousands of individuals covering an extensive area in one year, and then they can entirely disappear the next (McKenzie 1998). At one site in Illinois, researchers observed a population that appeared in 1996 during unusually high water levels, and they hypothesized that the seeds must have been dormant at that location since the last high groundwater levels in 1973 (McClain et al. 1997). In some areas, *Schoenoplectus hallii* relies on germinating from the seedbank when groundwater levels are high and agricultural production is suspended. *Schoenoplectus hallii* can be present at a population site in some wet years and then be absent at that site during other wet years (Baskin et al. 2003). Baskin et al. (2003) demonstrated that the presence and timing of certain environmental factors (e.g., ethylene exposure, temperature, light) affects dormancy cycles and germination. Any occurrence where *S. hallii* has been recorded within the last 25 years is considered to represent an extant population because of the potential for seeds to germinate from the seedbank (Ostlie 1998).

Preliminary research at sites in Missouri indicated that *Schoenoplectus hallii* seedbank density was generally high but varied significantly among different soil depths and sites. Seed number and proportion of viable seeds decreased with soil depth (Shaffer et al. 2001, M. Smith 2001, Meinardi et al. 2002). In addition, areas with intermediate water inundation regimes tended to have a greater number of seeds in the seedbank. Transects that were continuously under water or transects that were infrequently flooded had significantly fewer seeds (M. Smith 2001). However, seeds from drier transects were more likely to be viable, suggesting that dry conditions preserve seed viability better than wet conditions. The study also found that a cultivated field, which previously had a large population of *S. hallii*, had a large number of seeds, but the proportion of viable seed was lower than for a nearby pond site, perhaps as result of decay over time or mechanical damage from cultivation (M. Smith 2001). The Chicago Botanic Garden has stored *S. hallii* seeds for up to five years and successfully germinated and grew plants to reproductive maturity (K. Havens personal communication 2003). The percentage of the *S. hallii* seedbank that germinates in any given year at a site is unknown. Wienhold and van der Valk (1989) demonstrated that the number and density of seeds in a seedbank of a drained wetland decreases over time.

Phenotypic plasticity

Phenotypic plasticity is demonstrated when members of a species vary in morphology, phenology, or other attributes, with change in light intensity, latitude, elevation, or other macrosite or microsite characteristics. Observations of *Schoenoplectus hallii* suggest that its phenology can be affected by the timing of moisture fluctuations; germination and reproductive phenology of this species are affected by flooding and moisture conditions throughout the growing season (M. Smith 2001, M. Smith 2002, McKenzie personal communication 2003, M. Smith 2003). Sites in Nebraska that dried earlier typically had more mature individuals than wetter sites (Nebraska Natural Heritage Program 2002). Mature plants can develop as early as July and as late as October at different sites (P. McKenzie personal communication 2003). At one site, plants in Michigan emerged in late July instead of mid-August, as a result of suitable hydrologic conditions following several years of drought (Penskar and Higman 2002).

Observations also indicate that the stature of *Schoenoplectus hallii* individuals is variable. At sites in Nebraska and Wisconsin, the plants were very small ("dwarfed"), perhaps as a result of grazing or trampling from intense cattle activity (McKenzie 1998, Nebraska Natural Heritage Program 2002). At a roadside ditch site in Nebraska, the plants were unusually large, perhaps as the result of available resources and reduced intraspecific or interspecific competition (Nebraska Natural Heritage Program 2002). Penskar and Higman (2002) noted that plants in Michigan tend to be at the low end of the size range for the species. M. Smith (2003) observed that flowering plants can be small (less than 5 cm tall) or large (greater than 5 cm tall), depending on moisture conditions throughout the growing season. Small flowering plants that resulted from dry conditions during the growing season also had significantly fewer inflorescences and seeds than large flowering plants.

Mycorrhizal relationships

The existence of mycorrhizal relationships with *Schoenoplectus hallii* was not reported in the literature. Microbial organisms likely play an important role in the decomposition of organic material, in nutrient mineralization, and in the production of ethylene in anaerobic conditions (and in providing a cue for *S. hallii* germination) (Baskin et al. 2003, M. Smith 2003).

Hybridization

Schoenoplectus hallii has been documented to hybridize with *S. erectus* and *S. saximontanus* (Magrath 2002, S.G. Smith 2002, P. McKenzie personal communication 2003). S.G. Smith (2002) noted that, "I have identified a specimen from the Georgia coastal plain, where *S. hallii* and *S. erectus* are sympatric, as intermediate between the two." The first putative hybrid between *S. hallii* and *S. saximontanus* was collected in Oklahoma by P. McKenzie and independently verified by two species experts (Magrath 2002, P. McKenzie personal communication 2003). A manuscript authored by M. Smith, P. McKenzie, G. Smith, and E. Schuyler with more detailed information about this collection is currently in review in the journal *Sida* (P. McKenzie personal communication 2003).

Hybridization, whether natural or anthropogenic, can lead to rare species extinction when a more abundant congener genetically swamps the rare species, when hybrid offspring outcompete the rare parent species, or when the production of hybrid seed reduces reproductive success of the rare species (Day 1965, Grey 1982, Glenne 2003). *Schoenoplectus hallii* and *S. saximontanus* are known to occur together at four sites in the Wichita Mountain Wildlife Refuge (Oklahoma), but the extent of hybridization at other locations has not been studied. It is possible that these two *Schoenoplectus* species may become more sympatric in the future as man-made ponds are constructed to attract waterfowl (P. McKenzie personal communication 2003). The extent and effects of hybridization or existence of pre-zygotic or post-zygotic isolating mechanisms is an important area of research for this species.

Demography

Life history characteristics

The demography of *Schoenoplectus hallii* has been studied for three years (2001 to 2003) at one site in Missouri by M. Smith and colleagues (2001, 2002, 2003). The research, funded in part by the USFWS, involved marking and monitoring *S. hallii* individuals in order to determine life stages, to estimate survival probabilities, to develop a life cycle model, and to predict possible population growth rates (M. Smith 2001, 2002, 2003). Mettler and Smith (2002) suggested that this species may have "a more complex life cycle than previously considered." The life cycle of *Schoenoplectus hallii* based on the results of this work is depicted in **Figure 3**.

Life cycle diagram and demographic matrix. A life cycle diagram is a series of nodes that represent the different life stages connected by various arrows that symbolize rates (e.g., survival rate, fecundity, germination). Stage-based models based on population matrices and transition probabilities can also be created to assess population viability depending on adequate quantitative demographic data (Caswell 2001). Demographic parameters, such as rates of dispersal, dormancy, germination, and establishment are unknown for *Schoenoplectus hallii*. The effect of these vital rates on species fitness has not been quantitatively studied. The implications of amphicarpy on the long-term survival of *S. hallii* are also unknown. Survival of young *S. hallii* plants to flowering plants and the fecundity of large and small flowering plants have been measured at one site in Missouri, and the effects of these parameters on population growth rate have been estimated by M. Smith (2003).

The life cycle stages of *Schoenoplectus hallii* include seed, seedling, vegetative (immature) individuals, and reproductive (mature) individuals (**Figure 3**). As discussed, perennial growth habits have been identified in some areas, but the extent and role of perennial growth in the life history of this species have not been studied. *Schoenoplectus hallii* is known to have a long-lived seedbank (McKenzie 1998). Preliminary seedbank studies from *S. hallii* sites in Missouri and Illinois indicated that seed viability varies significantly among different soil depths and sites (Shaffer et al. 2001, M. Smith 2001, Meinardi et al. 2002). In any year, it is likely that only a portion of the seedbank is germinating (Penskar and Higman 2002). The probability of germination and subsequent establishment depends on the dormancy of these propagules and whether appropriate environmental conditions exist for germination and growth. As discussed previously, favorable conditions for germination of *S. hallii* seeds include dormancy break, exposure to ethylene, adequate moisture, and appropriate light and temperature regimes. These conditions can occur with cold temperatures in winter/early spring (i.e., dormancy break), and a period of spring flooding followed by adequate temperature and moisture conditions (M. Smith 2001, 2002, 2003). Seeds that germinate will grow into seedlings, assimilate resources, and become mature plants in one growing season, assuming that adequate moisture exists throughout the growing season. Survival and growth rates are likely influenced by the intensity and frequency of disturbance and the availability of resources, such as space, light, moisture, and nutrients. M. Smith (2002) recorded that only 36 percent of seedlings marked at a site in Missouri survived to a flowering stage due to drought conditions, and none of the flowering plants produced any seeds as a result of a significant rain event that uprooted and destroyed all of the plants. In 2003, 96 percent of the seedlings survived to the flowering stage, and all of the plants produced seeds. Successful seed set will depend on the rate of pollen and ovule formation, pollination, fertilization, and embryo development. Fecundity rates depend on the production of seeds and the percentage of those seeds that survive to germination in subsequent years. M. Smith (2003) discovered that small flowering plants (shorter than 5 cm) at a site in Missouri produced significantly fewer inflorescences and seeds compared to large flowering plants (taller than 5 cm). Eighty-nine large flowering plants produced at total of approximately 21,915 seeds in 2002 (M. Smith 2003).

Population viability analysis. In order to initiate a population viability analysis for *Schoenoplectus hallii*, the rates of germination, fecundity, survival, and other important parameters require additional study. With adequate data, matrix projection models can determine population growth trends and sensitive life history stages. M. Smith (2003) predicted population growth rates based on preliminary observations of fecundity rates at one site in Missouri from 2002 to 2003 and production of seeds by greenhouse populations. The researchers concluded from the modeling exercise that the difference in seeds produced by small flowering plants versus large flowering plants significantly affects predicted population growth rates, assuming that only a small proportion of seeds germinate every year. A population dominated by large flowering plants is more likely to have positive population growth compared to a population with small flowering plants with fewer seeds (M. Smith 2003). While this analysis was based on data from just one site over two years, it identified that seed production is a critical factor affecting future population growth rates. These research efforts provide the basis for future demographic monitoring and population viability assessments.

Ecological influences on survival and reproduction

The long-term persistence of *Schoenoplectus hallii* most likely depends on a range of ecological influences over many years, including climatic fluctuations, hydrology, microsite conditions (e.g., soil and water chemistry), microbial activities, herbivory levels, disturbance patterns, and interspecific competition. Refer to **Figure 4** and **Figure 5** for envirograms outlining the resources and malentities potentially important to *S. hallii*.

Schoenoplectus hallii clearly needs certain hydrological conditions to create a suitable environment for germination and growth. "The advance and retraction of groundwater appears to dictate the distribution and survival of *S. hallii*." (Mettler and Smith 2002). As discussed previously, favorable conditions for growth and germination of *S. hallii* seeds may be a period of spring flooding followed by adequate temperature and moisture conditions throughout the growing season (M. Smith 2001, 2002, 2003). Not only does this species require flooding, but it is necessary for the flood waters to subside and the soil moisture/groundwater levels to remain adequate for continued growth (M. Smith 2003). This species transpires continuously as a result of open stomata, and thus it needs a continuous source of water (Smith and Houpis 2003). M. Smith (2003) found that the number of *S. hallii* adults is positively correlated with growing season precipitation, and the distance of the groundwater from the surface is negatively correlated with the number of seedlings. In addition, *S. hallii* does not establish and grow in plots with extreme hydrologic conditions, such as persistent flooded conditions or less than 10 percent soil moisture. The researchers found that 33 to 84 percent soil moisture is optimal for growth throughout the season.

Schoenoplectus hallii may be absent during drought conditions and then reappear when more suitable hydrological conditions are created (Penskar and Higman 2002). The amount and distribution of habitat in any year can be affected by the amount and timing of precipitation, among other factors (Robertson et al. 1993). In wet years, habitat can be created in usually dry depressions of cultivated fields, habitat can be expanded over a larger area at the margins of ponds, or existing habitat can be flooded and destroyed (Robertson et al. 1993). In dry years, some of these areas, such as cultivated fields, do not have suitable habitat and are planted with crops. In addition, climatic conditions over several years can affect the creation of wetlands; Steinauer (2001) noted that many of the wetlands supporting populations were the result of elevated groundwater levels in the 1990s. Many of these wetlands were not present on aerial photos, and the presence of flooded cottonwood trees (up to 2 feet in diameter) at those sites also demonstrated that many of these wetlands were relatively new. Presumably, *S. hallii* seeds were deposited at locations by recent dispersal from nearby sites, or in the past when wetlands had existed there due to high water levels. Habitat availability can also change throughout a growing season. For example, *S. hallii* populations that flourished in the spring were flooded and overtopped when wetter conditions occurred in the summer (Steinauer 2001). Steinauer (2001) surveyed several sites with "extensive areas of sparsely vegetated wet sand" in a good year for the species at other sites, but he did not discover any new *S. hallii* populations. One location in Michigan has been observed for 25 years, and the *S. hallii* colonies have been located in slightly different areas each year, depending on microsite heterogeneity.

In addition to adequate temperature and moisture regimes, other key microhabitat factors that have been correlated with successful germination and growth of *Schoenoplectus hallii* include exposure to ethylene, presence of soil organic matter, low oxygen levels, and low interspecific competition. Exposure to ethylene is an important germination cue for *S. hallii*, and the production of ethylene may be affected by the availability of substrate for microbial activity (e.g., organic material), warm temperatures for high microbial activity, and low oxygen concentrations for metabolism in anaerobic organisms (M. Smith 2003). Production of ethylene by microbes may be inhibited by high nitrate levels in the soil (e.g., fertilizer runoff), which could consequently prevent seed germination (M. Smith 2003). Important microhabitat characteristics for the germination or growth of other wetland species also include soil and water sodium and pH (Lentz and Dunson 1999).

It is possible that *Schoenoplectus hallii* has a narrow range of environmental tolerances and that subtle differences in microhabitat conditions can affect germination and growth. Even subtle changes in water levels could potentially affect growth; a study

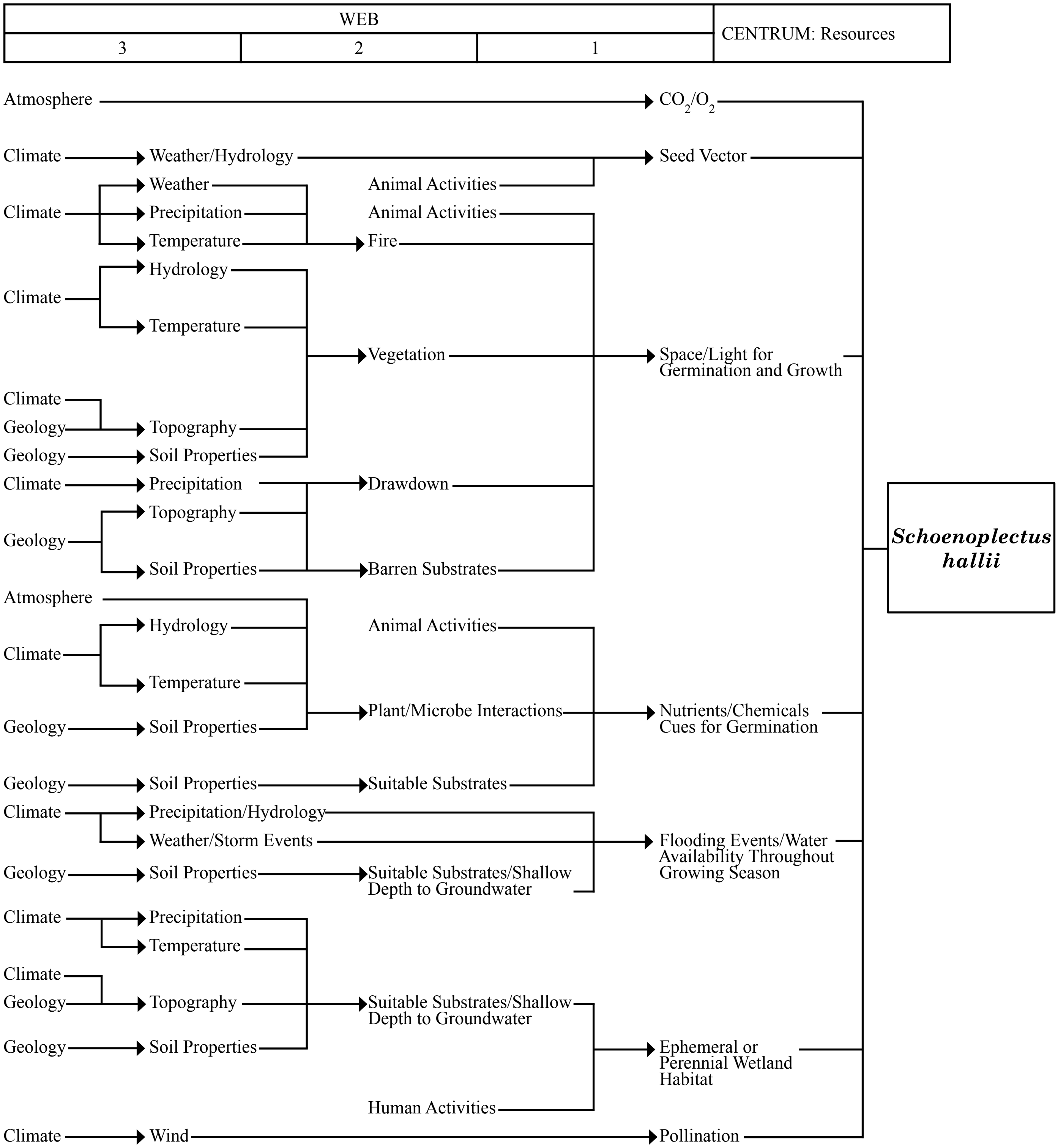


Figure 4. Envirogram outlining potential resources for *Schoenoplectus hallii*.

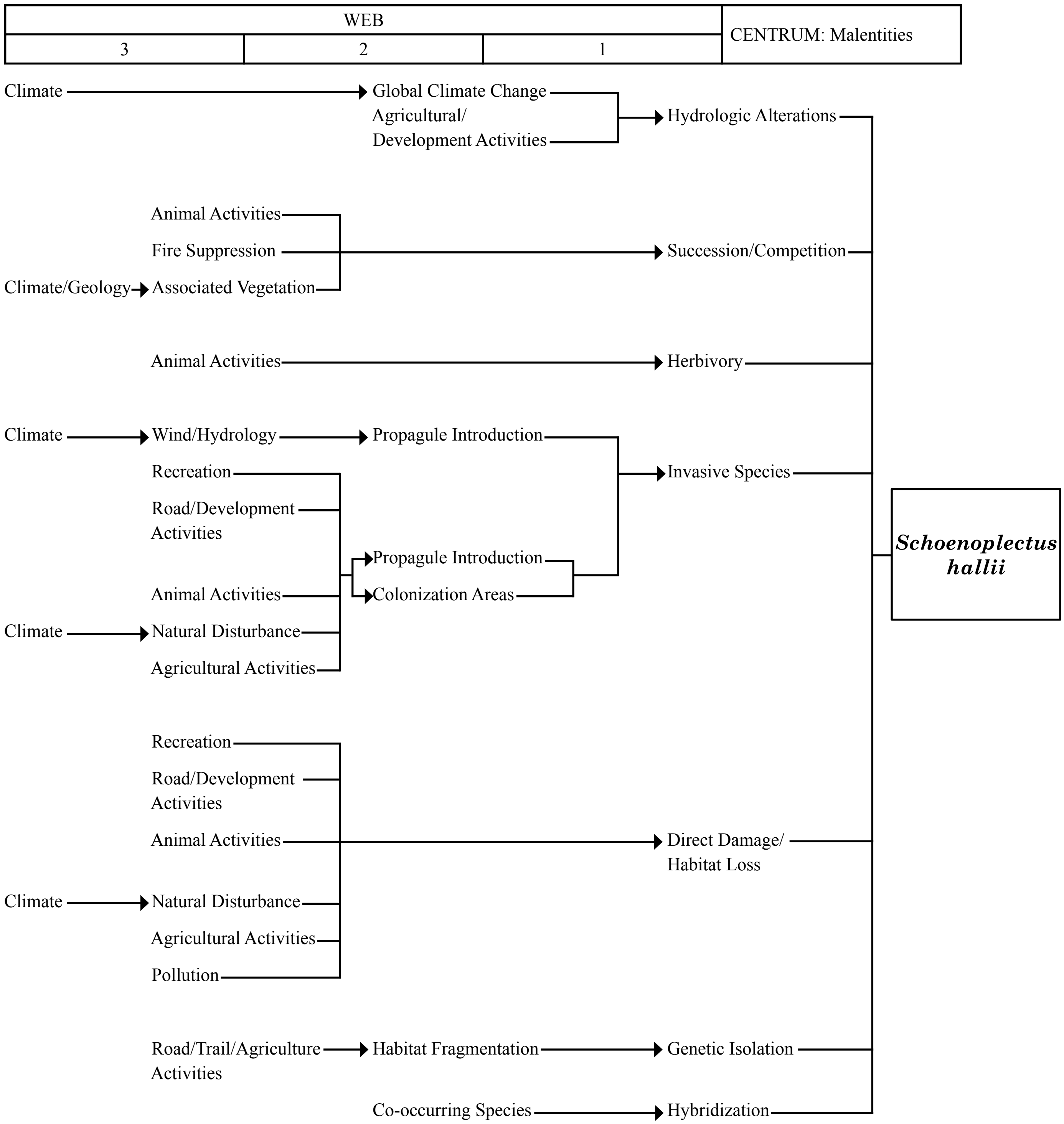


Figure 5. Envirogram outlining potential malentities to *Schoenoplectus hallii*.

of *Scirpus androchaetus* discovered that leaf longevity decreased when water levels increased slightly (Lentz and Dunson 1998). In contrast, greenhouse studies found that *Schoenoplectus hallii* individuals were more robust (i.e., greater number of culms, greater biomass, greater seed mass, and greater number of seeds) on soils with organic matter up to 9.9 percent, suggesting that this species is not restricted to sandy sites with low organic matter because of physiological constraints (M. Smith 2003).

There is no information on the capabilities of *Schoenoplectus hallii* to disperse, colonize, and establish new populations around the landscape. The establishment of new populations most likely depends on barriers to dispersal and the availability of suitable germination sites and conditions. It is also unclear what type, size, intensity, or frequency of disturbance regime is important for *S. hallii*. Disturbances in these environments can include hydrologic fluctuations (e.g., flooding), animal activity (e.g., waterfowl activity and livestock grazing/trampling), surface soil disturbances (e.g., excavation of borrow pits), fire, erosion (e.g., wind), and human influences (e.g., off-highway vehicle use). These disturbances could either create suitable habitat throughout a landscape or directly impact an existing population, depending on the intensity and location of the disturbance. *Schoenoplectus hallii* habitat was created in Missouri where topsoil in a shallow borrow pit was removed for construction of an interstate overpass (Missouri Department of Conservation 2002). *Schoenoplectus hallii* also flourishes at a disturbed sanitary landfill area in Illinois where sandy pond-like habitat exists in wet years (Illinois Department of Natural Resources 2002). Historically, wind erosion and fire have been important ecological components shaping the dynamic sandhills landscape (Pfeiffer and Steuter 1994). Fire can be an important component of wetlands by removing the accumulation of dead surface litter in the late summer or fall when water levels have dropped (Pfeiffer and Steuter 1994, Ostlie et al. 1997). Fire occurrence can be as often as every five years in some portions of the sandhills region (Pfeiffer and Steuter 1994). A lightning-started wildfire occurred recently in the McKelvie National Forest, affecting over 20,000 acres (M. Croxen personal communication 2004). The role of fire specifically in *S. hallii* wetland habitats is unknown.

Spatial characteristics

Characteristics that could influence the spatial distribution of *Schoenoplectus hallii* may include hydrology, disturbance patterns, seed dispersal patterns, competition with other vegetation, landscape features, and microsite heterogeneity. In a given year, only a portion of the seedbank in a region may germinate, depending on where suitable habitat exists.

Generally, *Schoenoplectus hallii* tends to inhabit the zone between low- and high-water marks at ephemeral wetlands (T. Smith personal communication 2002). The habitat belt can be extensive, and the bulrush can be seen from the edge of the water extending to the vegetated area (Missouri Department of Conservation 2002). *Schoenoplectus hallii* grows as large, dense, monospecific populations as well as scattered patches of 4 to 15 individuals (Nebraska Natural Heritage Program 2002). M. Smith (2001) hypothesized that the advancing and receding of water levels could affect the distribution of seeds. Because *S. hallii* seeds float, some seeds would be deposited at higher elevations during maximum water levels in the spring and some seeds would be deposited at lower elevations during minimum water levels in the summer and fall.

Botanists have found *Schoenoplectus hallii* populations near roads and trails while driving by private land (Steinauer 2001). The species is also commonly seen along cattle trails in wet areas (Nebraska Natural Heritage Program 2002). With exposed, barren substrate and moist conditions, roadside ditches and trails appear to provide suitable habitat for this species. However, Steinauer (2001) observed that roadside populations tend to be smaller than ones in adjoining or nearby wetlands.

Genetic characteristics and concerns

The genetic status of *Schoenoplectus hallii*, including issues related to hybridization, polyploidy, and genetic variability, has not been studied. The chromosome count for this species is 2n=22 (Schuyler 1969).

Schoenoplectus hallii has an extensive range with a small number of widely scattered populations. The amount of genetic variability and distinctiveness of each known population is not known. Issues related to gene flow, inbreeding, and genetic isolation could affect the demography, ecology, and management considerations for this species. Researchers found that *Scirpus ancistrochaetus* seeds were locally adapted to slightly different habitats through variation in germination requirements (Lentz and Johnson 1998). However, they did not study the potential genetic basis of those differences.

The extensive seedbank of *Schoenoplectus hallii* is an important source of genetic variability and may contain a range of genotypes collected over time. "Permanent seed pools contain a multitude of genotypes, produced in past environments and potentially capable of germinating at any time. It is important for annuals in unpredictable environments to have an accumulation of genotypes from the past to increase the chance that a well-adapted genotype will be present for a germination event." (Barbour et al. 1987).

Factors limiting population growth

Population growth or establishment of *Schoenoplectus hallii* could be limited by inappropriate hydrologic or temperature conditions, competition with other species (e.g., invasive species), excessive herbivory or trampling disturbance, inadequate pollination, or reduced habitat availability as a result of human-related changes or environmental fluctuations. The rate at which colonization and establishment of new populations occurs is unknown. Because *S. hallii* is an annual or weak perennial species dependent on new germination for replacement of populations, successful fruit production by adult individuals in a given year is critical for replenishing the seedbank. If the seedbank is depleted by germination in the spring followed by pre-flowering mortality due to drought or damage, then this could lead to population decline and loss of ability to recover (M. Smith 2003). For example, one population in Illinois was flooded (i.e., overtopped) due to excessive summer precipitation and failed to set seed. If a high percentage of the seeds germinated but the seedbank was not replenished that year, then the viability of that population in future years may be reduced (Robertson et al. 1993).

Community ecology

Herbivores and relationship to habitat

Because *Schoenoplectus hallii* populations are located in prairie and wetland habitats, this species is susceptible to herbivory by introduced livestock (e.g., cattle) and native herbivores (e.g., waterfowl, mammals, insects). *Schoenoplectus hallii* appears to be fairly tolerant to grazing, as large populations of the bulrush are located in areas that receive significant cattle, bison (*Bison bison*), or elk (*Cervus canadensis*) use (Steinauer 2001, Magrath 2002, NatureServe 2003). In contrast, grazing at heavy intensities has been implicated as a potential threat to *S. hallii* populations in Missouri and Wisconsin (McKenzie 1998, NatureServe 2003). Waterfowl (e.g., ducks and geese) use temporary ponds, feed on many wetland plants, use wetland plants for nesting material, and may be a dispersal vector for many wetland species (Belanger and Bedard 1994, Kantrud 1996, McClain et al. 1997, NatureServe 2003). Sedge species are also used for food and cover by mammals such as muskrats (*Ondatra zibethica*), nutria (*Myocastor coypus*), and deer (Kantrud 1996, Lentz and Cipollini 1998).

The palatability of *Schoenoplectus hallii* to livestock or other animals is unknown. Some sedges are avoided by cattle because of their high silica content, spiny leaf blade margins, and/or generally small size. Some grazed *S. hallii* plants were noted at sites in Oklahoma (Magrath 2002). Even though *S. hallii* plants in grazed areas in Nebraska appeared stunted compared to plants in ungrazed or lightly grazed areas, flower and fruit production did not appear to be affected (Steinauer 2001). Magrath (2002) hypothesized that amphicarpy may be a response to heavy historical grazing pressure by bison, elk, and deer. By producing basal achenes, a plant can ensure seed production even if it is heavily grazed. Thus, basal achenes could ensure reproductive success even if overall fruit production was reduced as a result of grazing pressure from herbivores (P. McKenzie personal communication 2003). A clipping experiment on *Scirpus androchaetus* found that low intensity grazing by deer was unlikely to affect growth and fitness, but intense grazing could reduce growth by damaging basal leaf meristems (Lentz and Cipollini 1998). Waterfowl may also feed on the achenes, shoots, rhizomes, and corms of bulrush species (Kantrud 1996). Predation on achenes and vegetation from increasing populations of mute swans (*Cygnus olor*) and Canada geese (*Branta canadensis*) potentially threaten *Schoenoplectus hallii* in some locations (McKenzie 1998). Researchers recorded up to five species of invertebrates occurring on *S. californicus* although only one species was considered a primary herbivore (Keiper et al. 2000).

Trampling action by cattle or bison may serve to create or to improve *Schoenoplectus hallii* habitat by removing competing vegetation (e.g., *Eleocharis acicularis* or *Drepanocladus aduncus* mats) and exposing suitable substrate (Steinauer 2001). In addition, Magrath (2002) recorded that plants at sites in Oklahoma were uprooted at mud flat sites used by bison and other animals, but the number of uprooted plants tended to be less than 0.5 percent of the plants at those locations. Thus, Magrath (2002) concluded that the damage to the populations was localized and negligible and that the animals may actually play an important role in dispersing seeds and inflorescences through their activities.

On non-USFS lands in Region 2, the impact or extent of grazing at ephemeral wetlands on *Schoenoplectus hallii* has not been determined. The palatability of this bulrush, the long-term effects of grazing, and the optimal grazing regime for its persistence are not known.

Competitors and relationship to habitat

Schoenoplectus hallii is considered an early successional species. This sedge inhabits bare areas that are generally kept free of competing vegetation by disturbances such as fluctuating water levels, hoof action of cattle, or agricultural tillage (Schuyler 1969, Steinauer 2001, NatureServe 2003). The role of fire in maintaining open *S. hallii* habitat in USFS Region 2 has not been researched. Schuyler (1969) also suggested that these habitats are "well-suited for the growth of *S. hallii* but few other species of flowering plants." Steinauer (2001) noted that the presence of dense *Eleocharis acicularis* or *Drepanocladus aduncus* mats appeared to preclude *S. hallii* from growing in suitable habitat. At one site, *S. hallii* grew in the holes in a *Drepanocladus aduacus* moss mat created by cattle trampling activity (Nebraska Natural Heritage Program 2002). Ormes (1998) also stated that once perennial vegetation is established through successional processes, *S. hallii* does not persist. Magrath (2002) did not find *S. hallii* at seemingly suitable drawdown mud flat sites that had too much perennial vegetation. A site in Indiana is threatened by woody encroachment, and a pond in Illinois had too much coverage from *Typha* spp. and *Salix* spp. to support *S. hallii* populations (McKenzie 1998, Illinois Department of Natural Resources 2002). Succession by woody encroachment is less likely in typical Nebraska sandhills habitat.

Many exotic perennial species can invade disturbed or undisturbed sites, reproduce vegetatively, form dense, monospecific stands, and outcompete native species. *Lythrum salicaria* (purple loosestrife), an aggressive wetland invader, has been implicated as the cause of *Schoenoplectus hallii* extirpation in Massachusetts and poses a threat to other populations of the bulrush (e.g., Lake County, IN) (McKenzie 1998). Although *L. salicaria* is fairly rare in the Nebraska sandhills region, Steinauer (2001) observed this invasive plant at roadside sites within 3 miles of *S. hallii* populations. Steinauer (2001) postulated that, "…over time [Purple loosestrife invasion] may be the greatest threat to this species in the Sandhills of Nebraska." Introducing palatable forage species in hayfields is also a source of non-native plants in *S. hallii* habitats (Ostlie et al. 1997). No *L. salicaria* populations have been documented on the Nebraska National Forest; however, *Euphorbia esula* (leafy spurge) has invaded parts of the forest and has been targeted for control though herbicide use (M. Croxen 2004).

Parasites and disease

There are no reports of parasites or diseases on *Schoenoplectus hallii*. Limited research on coastal, perennial bulrushes has shown that the fungus *Uromyces lineolatus* was reported to parasitize *Scirpus maritimus*, and two species of nematodes form root galls on *Scirpus robustus* (Kantrud 1996). A number of fungal species were found on *Schoenoplectus litoralis* in freshwater environments (Wong and Hyde 2001).

Symbiotic interactions

The positive interactions between associated species and *Schoenoplectus hallii* are unknown, as is the role of mycorrhizal associations. Studies of another colonizing sedge of ephemeral wetland habitats, *Scirpus cyperinus*, found that sedge seedlings were preferentially established near clumps of *Eleocharis olivacea*. In this case, researchers found that the bristled *S. cyperinus* seeds were wind-blown and tended to lodge and become established in the plant clumps.

Habitat influences

Schoenoplectus hallii is a "specialized, primary successional plant with a narrow niche" (Yatskievych personal communication 1995 in McKenzie 1998). As a wetland habitat obligate, this bulrush is restricted to habitats characterized by fluctuating water levels and minimal competing vegetation (Ormes 1998). The availability of current or historical suitable habitat (i.e., seedbank) likely controls the localized distribution of this species. The availability and quality of suitable habitat varies from area to area, depending on heterogeneity in topography, hydrology, substrate, environmental fluctuations, associated species, disturbance factors, and competition with other species. In addition, historical habitat availability affected where seedbanks were created and thus where potential populations may be established in the future.

CONSERVATION

Threats

Based on occurrence records, status reports, and studies from states outside USFS Region 2, *Schoenoplectus hallii* populations and habitat throughout its range are potentially threatened by human-related actions, environmental changes, and biological vulnerabilities. Land use and habitat characteristics differ from state to state, so not all threats may affect *S. hallii* at all locations. *Schoenoplectus hallii* has not been identified on any USFS lands in Region 2, and thus, no threats analysis exists specifically with respect to National Forest System lands. M. Croxen (personal communication 2004) provided insights about potential threats to *S. hallii*, if it was discovered on Nebraska National Forest lands. Records from Nebraska NHP (2002) and Kansas NHI (2002) outlined potential threats to *S. hallii* populations on non-USFS lands within Region 2. McKenzie (1998) also provided a summary of threats on a state-by-state basis. Populations in Kansas and Nebraska are most likely to be affected by groundwater depletion, wetland loss, non-native plant invasion, road maintenance, pollution, excessive livestock grazing, hybridization, and global climate changes (Ostlie et al. 1997, Kansas Natural Heritage Inventory 2002, Nebraska Natural Heritage Program 2002). Human-related activities and other disturbances can either create suitable habitat throughout a landscape or directly impact an existing population, depending on frequency, intensity, size, and location of disturbance. Direct impacts could either damage the existing individuals or reduce their reproductive success, the amount of available habitat, the establishment of new populations, or other factors important for the long-term persistence of the species.

Human-related threats to *Schoenoplectus hallii* include hydrologic changes (e.g., irrigation), habitat loss and alteration (e.g., residential development, agriculture), livestock grazing and other agricultural activities, off- highway vehicle use, pollution, road maintenance, and landscape fragmentation. Human influence could alter the hydrologic regime by decreasing or increasing available water, or altering the frequency, intensity, or timing of storm events. M. Smith (2003) noted that *S. hallii* establishment and growth in Missouri required groundwater levels to remain within 1 meter of the surface throughout the growing season. Favorable conditions for *S. hallii* may be a period of spring flooding followed by adequate temperature and moisture conditions throughout the growing season (M. Smith 2001, 2002, 2003). Not only does this species require flooding, but it is necessary for the flood waters to subside and soil moisture/groundwater levels to remain adequate for continued growth (M. Smith 2003). Changing stormwater runoff or septic effluent patterns could cause permanent flooding or otherwise alter hydrologic conditions at a site. Groundwater depletion (through residential, agricultural, and livestock demands) could reduce the frequency of wetland habitat creation. In Nebraska and Kansas, groundwater supplies are threatened by ditching and pumping for agriculture and livestock (McKenzie 1998). Center-pivot irrigation lowers the groundwater level and can dry out nearby wetlands (Ostlie et al. 1997). M. Croxen (personal communication 2004) noted that a reservoir south of the McKelvie National Forest in Nebraska drops considerably during the irrigation season. The specific local or regional effects of irrigation on *S. hallii* populations in Kansas or Nebraska have not been studied.

Habitat alteration also reduces the number of available suitable wetlands. Dredging or filling wetlands for agricultural or residential development reduces the occurrence of sandy ponds. Many *Schoenoplectus hallii* populations in Illinois occur in shallow, sandy ponds in soybean, broom corn, and squash fields, and draining those fields decreases available habitat (Illinois Department of Natural Resources 2002). Draining wet meadows to increase hay production for ranching operations in the sandhills can decrease wetland habitat (Ostlie et al. 1997). Highway construction and residential development can also decrease habitat or affect hydrologic patterns. A new truck stop recently destroyed a large portion of the only *S. hallii* population site in Kentucky (McKenzie 1998). Road maintenance could potentially increase habitat by exposing substrate and creating ditches, but the use of herbicides, salt, or magnesium chloride, and surface disturbances could damage existing populations. Many wetland plants are sensitive to the quality of the water, which can be polluted by use of herbicides, fertilizers, or other chemicals. High nitrate levels in the soil (e.g., from fertilizer runoff) may inhibit the production of ethylene by microbes, which could consequently prevent seed germination (M. Smith 2003). The extent and effects of atmospheric pollution (e.g., deposition of nitrogen oxides) in this region are unknown. In Michigan, off-highway vehicle use and trail bikes have severely damaged *S. hallii* habitat (McKenzie 1998). Those populations closest to roads, trails, popular off-highway vehicle use areas, development regions, or agricultural areas are likely to be at the most risk. The extent of landscape fragmentation in areas with this species has not been studied or quantified. Because *S. hallii* populations "consist of rather small, localized, or fragmented colonies, this species is highly vulnerable to further decline and range contraction." (Penskar and Higman 2002).

Current land management activities may play a beneficial role in maintaining suitable habitat for *Schoenoplectus hallii*, but these same activities could also be detrimental at high intensities or unsuitable timing. *Schoenoplectus hallii* appears to tolerate moderate to heavy grazing, but excessive overgrazing has been pinpointed as a problem for certain populations (McKenzie 1998). The timing and intensity of grazing are important factors to consider; high-intensity grazing during inflorescence development and seed production would likely have larger impacts on *S. hallii* than low-intensity winter grazing. Trampling by bison was noted to uproot plants at sites in Oklahoma, but the effects were localized and not thought to significantly impact population growth (Magrath 2000). In addition, grazer activities may serve to reduce interspecific competition and to disperse seeds. Livestock activity also has the potential to disturb soils, to alter moisture levels through soil compaction, to import weed seeds, and to facilitate exotic species invasion. The effects of grazing on native sandhills prairie remnants in Kansas and Nebraska are unknown (McKenzie 1998).

Environmental and biological threats to populations of *Schoenoplectus hallii* include succession/competition, extreme environmental fluctuations (e.g., drought or storm events), non-native plant invasion, hybridization, genetic isolation, global climate changes, excessive herbivory, or changes to the natural disturbance regime that would affect habitat creation. *Schoenoplectus hallii* is generally not threatened by timber harvest activities in its prairie habitat or by overutilization for educational, horticultural, or scientific purposes. Disturbances and fluctuations in precipitation could either create suitable habitat throughout a landscape or directly impact an existing population, depending on the timing, frequency, intensity, size, and location of the events. As discussed previously, *S. hallii* requires spring flooding at times with appropriate temperatures, followed by a period of drawdown to expose suitable habitat with adequate moisture. However, extreme storm events or drought during the growing season can damage existing plants (M. Smith 2003).

Changes to existing climatic and precipitation patterns, perhaps as a result of global environmental change, could also impact this species. For example, average temperatures are projected to increase, and precipitation is projected to decrease over some areas in the interior regions of North America (Watson et al. 2001). Climate change and other potential changes to a suite of environmental variables have the potential to affect plant community composition by altering establishment, growth, reproduction, and death of plants. The fact that *Schoenoplectus hallii* has demonstrated the ability to germinate after many years of dormancy in the seedbank and grows in areas that are subject to periodic droughts will likely help this species to exist during environmental fluctuations (P. McKenzie personal communication 2003, M. Smith 2003). However, severe droughts or flooding events during the growing season, especially after a portion of the seedbank has germinated but not yet matured, have the potential to significantly affect the survival of this species by depleting the seedbank and reducing future population growth rates (M. Smith 2002).

Schoenoplectus hallii prefers sparsely vegetated habitats and encroachment by woody vegetation or succession by persistent wetland or upland plants could reduce available substrate for germination. *Lythrum salicaria* has been found near *S. hallii* sites in Nebraska (Steinauer 2001), and this aggressive wetland invader has been implicated in the extirpation of other *S. hallii* populations (McKenzie 1998). Introducing palatable forage species in hayfields is also a source of non-native plants in *S. hallii* habitats (Ostlie et al. 1997). If natural fire, erosion, or successional patterns were altered, then appropriate habitat for *S. hallii* might not exist. The effects of burning and fire suppression, and the role of fire ecology in *S. hallii* habitat are unknown.

Schoenoplectus hallii occurrence records did not indicate excessive native herbivory, but a decrease in fruit production for a season could potentially reduce the number of seeds contributed to the seedbank and the source of seeds for future populations.

Schoenoplectus hallii is known from 36 occurrences throughout Kansas and Nebraska; the amount of gene flow between and among populations, genetic variability, and inbreeding are unknown for this species. Possible hybridization between *S. hallii* and *S. saximontanus* and between *S. hallii* and *S. erectus* has been identified at sites outside USFS Region 2, but the presence and effects of these species at sites with *S. hallii* in Kansas or Nebraska have not been fully ascertained. C. Freeman (personal communication 2003) noted that at least one site in Kansas has both *S. hallii* and *S. saximontanus*. Hybridization is a possible threat, based on conservation issues raised for other rare plant species (e.g., Glenne 2003). Further studies would help to identify the extent or effect of hybridization with *S. hallii*.

Threats to the long-term persistence of *Schoenoplectus hallii* populations or habitats likely differ for each of the 36 occurrences in USFS Region 2 states. If this species is discovered on National Forest System lands in Region 2, threats could possibly include non-native plant invasion, recreational activities, groundwater depletion, livestock overgrazing, global environmental changes, pollution, and hybridization. As discussed previously, there are no known populations of *S. hallii* on National Forest System lands; these potential threats are hypotheses based on existing land uses and information from *S. hallii* populations outside USFS Region 2, not on actual observations from USFS lands. Refer to the Potential Management of the Species in USFS Region 2 section for further discussion of management implications on National Forest System lands in Region 2.

Conservation Status of the Species in USFS Region 2

Schoenoplectus hallii is a species of special concern because it is a rare species of ephemeral wetlands with potential threats to existing populations and habitat. *Schoenoplectus hallii* has not been identified on any National Forest System lands in Region 2, and thus, no viable populations exist specifically with respect to USFS lands. The viability of this species on non-USFS lands in Kansas and Nebraska is difficult to ascertain because its full range and distribution within the region are unknown, its abundance fluctuates greatly depending on environmental fluctuations, and its seedbank potential has not been measured. Groundwater depletion, residential development, non-native plant invasion, pollution, global environmental changes, hybridization, and excessive livestock grazing potentially threaten this species. Although much has been learned about this species as a result of studies by M. Smith and colleagues (e.g., M. Smith 2001, 2002, 2003), the applicability of those results to populations of *S. hallii* in USFS Region 2 is unknown. Additional information on the abundance, distribution, biology, and demography of *S. hallii* populations in the region is needed. It is difficult to predict the fluctuations of *S. hallii* populations as a result of environmental stochasticity and the effects of any future environmental or management changes.

Population declines

Based on existing estimates of abundance, we are unable to conclude that the distribution or abundance of *Schoenoplectus hallii* is declining or expanding throughout its range. Abundance estimates for the Nebraska populations ranged from under 10 individuals to hundreds and thousands of individuals per site; there were no abundance estimates for Kansas populations (Steinauer 2001, Kansas Natural Heritage Inventory 2002, Nebraska Natural Heritage Program 2002). Population trends for *S. hallii* are difficult to estimate. As an annual species that is highly dependent on annual precipitation patterns, *S. hallii* is likely to fluctuate greatly from year to year. Although population sizes have been estimated in some cases, multi-year population or demographic monitoring has not been initiated for any site in USFS Region 2.

Ostlie (1998) stated that, "In spite of much suitable habitat, this species is remarkably rare. Seems unlikely that many new populations will be found." However, in USFS Region 2, *Schoenoplectus hallii* may be more abundant than previously thought because it is fairly cryptic and may have been overlooked in the past (R. Schneider personal communication 2003). In addition, areas may have been surveyed during years when environmental conditions were not favorable for germination and growth (P. McKenzie personal communication 2003). Several new populations were discovered in Nebraska in 1999, 2000, and 2001 through surveying efforts for other rare sandhill plant species (Steinauer 2001, Nebraska Natural Heritage Program 2002). Because of *S. hallii*'s ability to adapt to ephemeral wetlands, there may be more occurrences yet to be discovered, especially in infrequently surveyed areas away from trails and roads (Steinauer 2001). In contrast, *S. hallii* has not been observed in Kansas since 1997, despite revisiting sites and surveying sandhill prairie communities (McKenzie 1998).

The rate at which *Schoenoplectus hallii* disperses and colonizes new locations is unknown because we know little of its dispersal and establishment capabilities. The abundance could be overestimated or underestimated, depending on the full spatial extent of the species, undiscovered populations, and effects of environmental fluctuations.

Habitat variation and risk

Ephemeral wetlands are inherently unpredictable in time and space. The available habitat area for *Schoenoplectus hallii* can fluctuate greatly at a site from year to year, from less than 10 acres to approximately 50 acres (Missouri Department of Conservation 2002). Wetlands disappear and reappear over a period of many years in response to precipitation and groundwater fluctuations. Ephemeral ponds are small, very sensitive to environmental perturbation, and therefore prone to local extinctions (Lentz and Cipollini 1998). Wetland loss, primarily to draining and filling for agricultural or other human uses, is significant throughout the Great Plains region (Ostlie et al. 1997). The local and regional effects of groundwater depletion on wetland habitat in USFS Region 2 have not been studied. The sandhills region has an estimated 15 to 45 percent loss of wetlands, which may increase with greater irrigation and groundwater depletion for agricultural and residential demands (Ostlie et al. 1997, McKenzie 1998).

Many populations of *Schoenoplectus hallii* are not protected. Populations of *S. hallii* in USFS Region 2 occur largely on private land (e.g., ranches). The largest populations of *S. hallii* are found in sandy ponds within agricultural contexts in Illinois and are unprotected (McKenzie 1998). All of the areas in Illinois that had large populations of *S. hallii* in 1995 were returned to agricultural production by the next year when groundwater levels decreased (McClain et al. 1997). The interaction of water level fluctuations, agricultural practices, and seedbank longevity likely plays an important role in the persistence of *S. hallii*.

Researchers believe that future surveys in Nebraska will find significant numbers of additional *Schoenoplectus hallii* populations because the sandhills region has an estimated 19,300 square miles of sandy habitat with numerous wetlands (Ostlie et al. 1997, McKenzie 1998, Steinauer 2001). Potential habitat for this species may exist in the Samuel McKelvie or Halsey national forests, associated units of the Nebraska National Forest (Morse 2001). The Samuel McKelvie National Forest has several areas of sandhill habitat with perched water tables, and perennial and ephemeral wetlands of natural and man-made origin are plentiful there (M. Croxen personal communication 2004). The Halsey National Forest may be less likely to have potential habitat because the main wet areas in that national forest are perennial rivers, not ephemeral ponds or lakes (M. Croxen personal communication 2004). These conclusions are based on hypothesis and not systematic survey of potential habitat regions. Although habitat on USFS and non-USFS lands in Kansas and Nebraska appears plentiful, the microhabitat requirements for *S. hallii* in this region are undefined, lands are generally not protected, and ephemeral wetlands are threatened by environmental fluctuations and habitat alteration (McKenzie 1998). It is also possible that additional wetlands may be created by human activities, such as irrigation overflow ponds, stock watering ponds, or wildlife habitat enhancement (e.g., creating or enhancing wetlands for waterfowl and fish habitat). It is generally difficult to predict the effects of hydrologic stochasticity (e.g., storm events during the growing season) and other environmental fluctuations, such as the spread of non-native invasive plants and potential risk of alteration to plant communities. As a result of increased habitat alterations and unpredictable environmental fluctuations, significant habitat variation and risk exists for *S. hallii*.

Potential Management of the Species in USFS Region 2

Currently, *Schoenoplectus hallii* has not been discovered on USFS lands in Region 2, thus there are no regulations or management actions specifically protecting populations of this species on National Forest System lands. If this species is discovered on USFS lands in Region 2, management issues related to livestock management, other local and regional agricultural activities (e.g., irrigation, herbicide use), non-native plant control efforts, recreational activities, wildlife habitat enhancement, and fire suppression/prescribed fires/thinning may need to be analyzed. Studies of possible impacts from human land uses on *S. hallii* populations and its habitat in Kansas and Nebraska have not occurred. Based on the available information, we can only hypothesize how current and future management activities and other environmental influences may affect the abundance, distribution, and long-term persistence of this species.

Management implications

Schoenoplectus hallii populations and habitat may be at risk as a result of management activities or the lack of protection throughout its range. The response of *S. hallii* to current or future management actions such as grazing, prescribed fires/fire suppression, or fluctuating water levels is unknown (NatureServe 2003). *Schoenoplectus hallii* appears tolerant to current grazing at sites on non-USFS lands in Region 2 (Steinauer 2001). Seasonal, rotational cattle grazing occurs from spring to fall/early winter in Nebraska National Forest (M. Croxen personal communication 2004) and direct effects (e.g., trampling, overgrazing) or indirect effects (e.g., soil compaction, importation of invasive plant species) could potentially impact *S. hallii* populations or habitat, if any populations are discovered. As discussed previously, grazing activities may also facilitate the dispersal of *S. hallii* seeds and maintain early successional wetlands. Windmill irrigation for livestock water could potentially lower local groundwater levels, or it could provide ephemeral wetland habitat in the form of overflow ponds. Irrigation, introduction of non-native forage species, and prescribed burning/fire suppression for hay fields could also potentially affect wetland hydrology and composition of vegetation in *S. hallii* habitat. Motorized (i.e., off-highway vehicles, dirtbikes) and non-motorized (i.e., camping, hiking, fishing) recreational activities are a significant land use in the Nebraska National Forest (M. Croxen personal communication 2004, Nebraska Off Highway Vehicle Association 2004), and they could possibly cause direct damage to *S. hallii* plants. A new travel management plan for the Nebraska National Forest is being established to address concerns of resource damage associated with unrestricted, cross-country motorized vehicle travel (M. Croxen personal communication 2004, Nebraska Off Highway Vehicle Association 2004). *Euphorbia esula* is a non-native plant invader that has been identified on the Nebraska National Forest lands and is controlled with herbicide use; the effects of this species or the associated control efforts on possible *S. hallii* populations or habitat are unknown. Other impacts to lands in Nebraska National Forest include wildfires and timber thinning (M. Croxen personal communication 2004), but these are not thought to heavily impact *S. hallii* habitats. Wildlife habitat enhancement efforts in the Nebraska National Forest, such as the creation of waterfowl/fishing ponds with dams and fences excluding livestock from wetland areas, may also serve to create or protect *S. hallii* habitat. The actual beneficial or detrimental effects of these current or future management activities on *S. hallii* and its habitats have not been studied or monitored.

The long-term persistence of *Schoenoplectus hallii* will rely on monitoring the effects of current management practices, reducing human-related threats to existing populations, and protecting the hydrologic environment within watersheds where this species occurs. Priority conservation tools for *S. hallii* may include monitoring existing populations and population trends, documenting the effects of current land-use practices and management activities within the region, reducing any human-related threats to existing high-risk populations (e.g., use of monocot-specific herbicides), maintaining suitable habitat (e.g., early successional wetlands) and minimizing changes to hydrologic regimes, and assessing the density and extent of the seedbank. Additional key conservation tools may include surveying high probability habitat (e.g., lands in the Samuel R. McKelvie and Halsey national forests in USFS Region 2) for new populations, preventing non-native plant invasions and livestock overgrazing, studying demographic parameters for populations in the region, establishing a private land owner contact program to provide technical assistance, acquiring lands with extant populations or creating easements for protection of populations on private lands, supporting development of long-term monitoring and research, and assessing the effects of future management activities or changes in management direction. Habitat management could also consider issues related to the surrounding landscape, such as watershed hydrology, barriers to dispersal, waterfowl movement patterns, and herbicide drift. McKenzie (1998) suggested that land acquisition, easements, and other partnerships can be established with landowners through programs such as The Nature Conservancy Registry Program and USFWS Partners for Wildlife Program.

Potential conservation elements

Schoenoplectus hallii is a rare, scattered wetland species with a small number of recorded populations and potentially high vulnerability to human-related activities and environmental changes. Features of *S. hallii* biology that may be important to consider when addressing the conservation of this species (i.e., key conservation elements) include its reliance on specific hydrologic conditions for germination and growth (e.g., spring flooding followed by drawdown and adequate soil moisture throughout the growing season), dependence on early successional wetlands, possible requirements for certain soil qualities, apparent preference for barren substrates and areas with low interspecific competition, mostly annual habits with a reliance on seedbank additions for population replenishment, a long-lived seedbank, ability to adapt to environmental stochasticity, potential hybridization with *S. saximontanus* and *S. erectus*, production of both basal and terminal achenes, seed dispersal by water movements or animal activities, and potential for reintroduction in restoration efforts. This species can persist in the seedbank for decades and then flourish when environmental conditions are optimal, a trait that will help this species to persist despite long-term environmental fluctuations (e.g., drought) (P. McKenzie personal communication 2003). The full ecological amplitude of this species (e.g., preferred soil types) and the intensity, frequency, size, and type of hydrologic events optimal for persistence of this species in USFS Region 2 have not been studied. Changes in the timing, intensity, or frequency of hydrologic events and other disturbances have the potential to damage existing populations and/or to reduce habitat or habitat conditions for future recruitment. For example, livestock grazing may maintain suitable habitat and facilitate dispersal at low intensities, but at heavy intensities it could negatively impact existing plant populations. Other limiting factors may include competition from native or non-native species, changes to hydrological patterns altering flooding patterns and moisture availability, global climate changes, and genetic isolation of disjunct populations. The lack of information regarding the extent of the seedbank, the capability for long distance dispersal, the susceptibility to herbivory, or the genetic variability of this species makes it difficult to predict its long-term vulnerability. In addition, factors related to metapopulation dynamics, such as the amounts of gene flow, genetic variability within and between populations, inbreeding depression, and minimum viable population size, are unknown for *S. hallii*. It is possible that geographically isolated occurrences may harbor rare alleles important to conserve for the long-term persistence of this species. Hybridization with other co-occurring *Schoenoplectus* species has not been fully assessed, but it is a possible threat, based on conservation issues raised for other rare species (e.g., Glenne 2003). Management decisions could consider the effect of management activities on hydrology, landscape fragmentation, and introduction of invasive species.

Tools and practices

Little is known about the biology, ecology, and spatial distribution of *Schoenoplectus hallii* in Kansas and Nebraska. Studies by M. Smith and colleagues (e.g., M. Smith 2001, 2002, 2003) in Missouri, Illinois, and Kentucky are an important first step in obtaining an understanding of the biological and ecological needs for this species; additional long-term monitoring and research studies in USFS Region 2 will build on this information base. Additional habitat surveys, quantitative population inventories and monitoring, and ecological studies are priorities for constructing a conservation plan specific to USFS Region 2. Inventories are useful for re-locating historical populations, estimating current abundance, and identifying high-quality populations. Surveys will help to locate any undiscovered populations. Quantitative monitoring will help to obtain data for population trend and demographic modeling and to assess the effects of management activities. Short-term research studies (e.g., genetic analyses, seedbank studies) and long-term research studies (e.g., effects of environmental fluctuations) can supplement the current biological knowledge of this species and help to estimate long-term persistence.

Species inventory and habitat surveys

The distribution of *Schoenoplectus hallii* is widely scattered, with populations or groups of populations spread over a wide geographic range in a variety of land use types. Current reports of existing *S. hallii* populations on non-USFS lands in Region 2 provide a useful base of information, but the full distribution and total abundance of this species in the region are not sufficiently known to formulate regional conservation strategies (NatureServe 2003). Steinauer (2001) found several *S. hallii* populations while surveying for another rare species, mostly by surveying potential habitats while driving, but he did not perform a systematic survey. Steinauer (2001) suggested that additional populations of *S. hallii* may exist, especially in areas away from roads. Systematic surveys of high probability habitat are needed to discover any additional populations and to document the full spatial extent of this species in Nebraska and Kansas. McKenzie (1998) also suggested that, "Despite past intensive surveys of sand prairie communities…additional searches for the species in Kansas is warranted." Surveys could focus on high probability habitat on USFS lands in Region 2, such as the Samuel R. McKelvie and Halsey national forests.

Steinauer (2001) found sites with extensive areas of sparsely vegetated wet sand that were adjacent to *Schoenoplectus hallii* sites, but where the species was absent or where there were only small populations (e.g., Forgey Ranch, Nebraska). These and adjacent sites should be regularly monitored, especially during years when conditions are optimal for germination and growth. Characterizing the habitat at existing sites would also be useful in planning surveys for additional populations (NatureServe 2003). Researchers could also identify wetland areas using topographic maps, geologic maps, and aerial or satellite images. For example, Kansas geological maps depict physiographic provinces with potentially suitable sandy habitat in Harper, Harvey, Kingman, McPherson, Reno, Rice, Sedgwick, and Sumner counties. Surveys for *S. hallii* could occur concurrently with surveys for other rare sandhills plant species, such as *Platanthera praeclara* (Great Plains white fringed orchid) and *Penstemon haydenii* (blowout beardtongue). Ascertaining the current abundance of *S. hallii* would help to estimate the vulnerability of this species to environmental fluctuations.

Once located, the size and extent of *Schoenoplectus hallii* populations could be mapped, labeled, and recorded using global positioning system and geographic information systems (GIS) technology. Mapping the extent of each known population of this species will maintain consistency for future observations, facilitate information sharing between different management organizations, and help in making estimates of density and abundance. Mapping exercises will also elucidate the spatial distribution of populations at the local and regional levels and provide a framework for creating a metapopulation study. High-quality populations in pristine habitat could be identified. Populations in areas slated for various management, maintenance, or disturbance activities could be readily identified.

Population monitoring and demographic studies

McKenzie (1998) considered life history research to be of high priority for *Schoenoplectus hallii* conservation efforts. Additional information is needed to gain an understanding of the life cycle, demography, and population trends of *S. hallii* in USFS Region 2. Research efforts by M. Smith and colleagues (e.g., M. Smith 2001, 2002, 2003) in Missouri, Illinois, and Kentucky provide the basis for future demographic monitoring and population viability assessments. Information is lacking on germination requirements, seedbank longevity, and gene flow between populations. For example, seedbank studies and germination trials could assess the status of the seedbank and elucidate potential limiting factors for the establishment of populations. Periodically checking sites would track *S. hallii* populations for both short-term and long-term information. Long-term monitoring studies could yield helpful information, such as temporal and spatial patterns of abundance and dormancy; environmental factors that influence abundance (e.g., drought), and whether populations are increasing, decreasing, or remaining stable. Monitoring populations, measuring physical parameters (e.g., soil moisture), and recording climatic conditions should be performed simultaneously to begin correlating the status of extant populations and the effects of environmental fluctuations (NatureServe 2003). These studies will be difficult or impossible at some locations as a result of rapid changes in available habitat (P. McKenzie personal communication 2003). Studies on the genetic differences between and among populations will clarify metapopulation dynamics.

Understanding certain aspects of demography and genetics is a priority in order to provide basic population information and is indicated by these questions:

- ❖ What are the rates of survival and recruitment?
- ❖ What is the effect of amphicarpy on reproductive success?
- ❖ What are the population fluctuations from year to year?
- ❖ What are the effects of environmental fluctuations on demographics?
- ❖ What is the status and longevity of the seedbank?
- ❖ What is the gene flow between populations?

Several groups have developed protocols for monitoring population and demographic trends of rare plant species. These protocols can be easily accessed and used to develop specific monitoring plans for use in USFS Region 2. For example, Hutchings (1994) and Elzinga et al. (1998) are general references that provide concrete guidance on designing and implementing quantitative monitoring plans for rare plant species. In addition, population matrix models that measure individual fitness and population growth provide flexible and powerful metrics for evaluating habitat quality and identifying the most critical features of the life history of a species (Hayward and McDonald 1997). Deterministic demographic models of single populations are the simplest analyses and are powerful tools in making decisions for managing threatened and endangered species (Beissinger and Westphal 1998). Studies of other endangered sedges provide models for monitoring programs in wetland habitats, although not all of the techniques would apply to an annual species (e.g., Rawinski 2001).

Habitat monitoring and management

The general habitat characteristics of *Schoenoplectus hallii* have been identified, but there are too many unknowns regarding microhabitat requirements (e.g., competition, soil moisture content, soil structure) and basic population dynamics to determine which factors are critical in maintaining or restoring habitat for this species. Studies by M. Smith and colleagues (e.g., M. Smith 2001, 2002, 2003) provided descriptions of optimal flooding and soil moisture requirements for *S. hallii* germination and growth at sites in Missouri. Similar studies in USFS Region 2 would help to elucidate the optimal hydrologic regime for populations of *S. hallii* in the region. In an ecological characterization study for *Scirpus androchaetus*, researchers sampled 16 ponds (four ponds with the target species) for 26 habitat variables (Lentz and Dunson 1999). Through linear discriminant analysis, they found that wetland area, percent forest canopy cover, percent soil organic matter, soil exchangeable sodium, and pH were significant indicators of species. These types of studies elucidate factors that may control distribution as well as evaluate possible habitat for reintroduction of this species. Supplementing characterization studies with a seedbank analysis would also help to predict where future germination events may occur.

Land management techniques, such as livestock grazing and other agricultural practices, are used throughout *Schoenoplectus hallii* habitats and may influence the persistence of this species. Documenting land management and monitoring habitat could occur in conjunction with population monitoring efforts in order to associate population trends with environmental conditions. Ascertaining the awareness and perception of *S. hallii* by private landowners is also important for understanding the effects of land management and fostering stewardship for this species.

Biological and ecological studies

Much of the information regarding habitat requirements, establishment, reproduction, dispersal, potential predation and dispersal by herbivores, competition with other species, and overall persistence has not been studied for *Schoenoplectus hallii*. In particular, the response of *S. hallii* to hydrologic changes is not known in sufficient detail to evaluate human-related or ecological changes. Research studies to evaluate the effects of drought and succession at several scales (local and regional) would provide valuable input to the development of conservation strategies and management programs. It will be difficult to determine to what extent disturbances are necessary to create habitat and/or maintain a population, what disturbance intensity and frequency may be most appropriate, and what factors would result in local extinction of a population. Population genetic studies of widely scattered *S. hallii* populations will help determine the distinctiveness of each known population. Studies on the role of waterfowl or other animals in *S. hallii* dispersal would be helpful to understand patterns in long-range dispersal. There is a body of research on the biology and conservation of other sedge species that would provide useful information and tools for designing future studies of *S. hallii* (e.g., Dietert and Shontz 1978, Wilcox et al. 1985, Hill and Johansson 1992, Lentz and Cipollini 1998, Lentz and Dunson 1998, Lentz and Johnson 1998, Lentz and Dunson 1999, Baskin et al. 2000). For example, Lentz and Dunson (1999) identified important microhabitat variables to help explain the distribution of *Scirpus androchaetus*. In addition, recovery plans for the conservation of other endangered sedge species discuss important issues to consider (e.g., Rawinski 2001).

Availability of reliable restoration methods

The production and germination of *Schoenoplectus hallii* seedlings in greenhouse environments introduces the possibility for restoration efforts. The Chicago Botanic Garden has collected achenes for long-term storage from several Illinois and Missouri populations as part of its program with the Center for Plant Conservation. Achenes have been dried over silica gel and stored in airtight envelopes at –20 ºC. Achenes stored for five years under these conditions have been germinated and grown to reproductive maturity. The persistence of achenes in the soil seedbank for several years suggests that long-term seed storage is likely to be successful in this species (K. Havens personal communication 2003). Germination and transplantation studies in natural environments would be helpful to assess reintroduction potential at extirpated sites. In addition, collection of seeds from sites in USFS Region 2 would augment existing collections.

Preliminary research indicates that restoration strategies for wetland habitats may have a high probability for success because *Schoenoplectus hallii* achenes in the seedbank have high density and viability (Shaffer et al. 2001). One private landowner provided additional habitat by excavating additional shoreline adjacent to an area with abundant *S. hallii* (T. Smith personal communication 2002). In addition, a favorable hydrologic regime was returned to sites in Missouri that previously had populations before cultivation, and *S. hallii* flourished from the existing seedbank (M. Smith 2003). There are a few studies on the restoration of wetlands using clonal/perennial sedge species that might provide helpful considerations for *S. hallii* restoration efforts (Clevering and van Gulik 1996, Lentz and Cipollini 1998).

M. Smith (2003) listed recommendations for restoration or reintroduction projects based on the results of studies conducted in Missouri from 2001 to 2003. The researchers concluded that *Schoenoplectus hallii* seeds should be deposited on the surface of bare soil during the fall or winter to satisfy light requirements. Only sites with the potential for natural or managed flooding at least every three to five years should be considered. For optimal germination and seedling survival, flooding should occur between April and June, flood waters must recede for seedlings to establish, and groundwater levels should remain within 1 meter of the surface during the growing season. Additionally, the researchers noted that invasive species can establish during dry years, so site management could consider invasive species removal.

Information Needs and Research Priorities

Based on our current understanding of *Schoenoplectus hallii*, we can identify research priorities where additional information will help to develop management objectives, to initiate monitoring and research programs, and to inform a conservation plan. To address these data gaps, information can be obtained through surveys, long-term monitoring plans, and extended research programs. There is so little known about the biology and ecology of this species that there are a large number of research projects that could be implemented.

Studying the distribution and abundance of *Schoenoplectus hallii*, its microhabitat requirements, the effect of hydrologic events and water availability on its germination and growth, its seedbank dynamics and other demographic factors, imminent threats (e.g., non-native plant invasion), and the effects of land management activities are of primary importance to further the understanding of this species in USFS Region 2. The following types of studies are priorities to supplement basic knowledge regarding this species:

- ❖ Re-visit and inventory known populations
- ❖ Monitor population trends
- ❖ Identify high-quality populations and habitat
- ❖ Survey for new populations, especially on USFS lands in Region 2
- ❖ Identify any imminent threats to known populations (e.g., non-native plant invasion)
- ❖ Document and monitor current land management practices
- ❖ Characterize and define microhabitat requirements
- ❖ Studies related to reproductive biology, including seedbank analyses and implication of amphicarpy on reproductive success
- ❖ Assess gene flow, variability, and possible hybridization through genetic analyses.

Additional research and data that may be useful but are not incorporated into this assessment include aspects related to managing data for efficient use. Data acquired during surveys, inventories, monitoring programs, and research projects are most easily accessible if they are entered into an automated relational database. Databases also facilitate the sharing of information to all interested parties. The Colorado NHP and NatureServe have developed databases and GIS components to assist in information storage and habitat modeling (D. Anderson personal communication 2003). Such a database should be integrated with GIS and allow the following activities:

- ❖ Efficient incorporation of data in the field
- ❖ Documentation and cataloging of herbarium specimens
- ❖ Generation of location and habitat maps
- ❖ Characterization of associated habitat types
- ❖ Identification of population trends over time
- ❖ Identification of data gaps that require further information gathering
- ❖ Easy modification as additional information becomes available.

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DEFINITIONS

Achene – Small, dry fruit with a close-fitting, hard wall surrounding a single seed.

Achlorophyllous – Lacking chlorophyll; appearing without a green color.

Acuminate – Gradually tapering to a sharp tip.

Amphicarpy – Production of both aerial and basal fruits.

Annual – A plant that completes its entire life cycle in one growing season.

Anther – Part of the flower reproductive structure (stamen) that bears pollen.

Caespitose – Growing in tufts; in low-branching pattern from near base.

Calyx – The collective name for sepals.

Candidate species – Taxa for which the U.S. Fish and Wildlife Service has sufficient information on their biological status and threats to propose them as endangered or threatened under the Endangered Species Act, but for which development of a listing regulation is precluded by other higher priority listing activities.

Category 2 ranking (C2) – Taxa for which current information indicates that proposing to list as endangered or threatened is possible but there is insufficient information to support immediate rulemaking.

Chasmogamy – The production of flowers that open before pollination and are cross-pollinated.

Cleistogamy – The production of small, closed, self-fertilized flowers.

Congener – A member of the same genus.

Corm – Swollen base of a stem.

Corolla – Portion of flower comprised of petals.

Culm – Specialized stem of grasses, rushes, and sedges.

Demographics – The study of fecundity and mortality parameters that are used to predict population changes.

Disjunct – A geographically isolated population or species outside of the range of other similar populations or species.

Dormancy – A period of growth inactivity in seeds, buds, bulbs, and other plant organs even when environmental conditions normally required for growth are met.

Ecotone – A transitional zone between two plant communities or regions.

Endangered – Defined in the Endangered Species Act as any species which is in danger of extinction throughout all or a significant portion of its range.

Ephemeral – Short-lived, temporary.

Fertility – Reproductive capacity of an organism.

Fitness – Success in producing viable and fertile offspring.

Fruit – The ripened, seed-containing reproductive structure of a plant.

G2 ranking – Imperiled globally because of rarity (6 to 20 occurrences) or because of factors demonstrably making a species vulnerable to extinction.

Genotype – Genetic constitution of an organism.

Hybridization – The result of a cross between two interspecific taxa.

Indehiscent – Remaining persistently closed.

Inflorescence – The flowering part of a plant, usually referring to a cluster of flowers.

Internode – Portion of a stem between two nodes.

Interspecific competition – Competition for resources between individuals of different species.

Intraspecific competition – Competition for resources among individuals of one species.

Involucral bract – Modified leaf subtending inflorescence.

Mesic – Characteristic of an environment that is neither extremely wet, nor extremely dry.

Metapopulation – Group of populations that are linked through migration of individuals.

Midrib – Main or central rib of a structure.

Mycorrhiza – Symbiotic association between a fungus and the root of a higher plant.

Mucronulate – Tipped with a short, sharp, slender point.

Node – Place on stem where leaves or branch originate; any swollen or knob-like structure.

Obovate – Inversely ovate, attached at narrow end.

Obovoid – Three-dimensional form of obovate.

Ovary – The enlarged portion of the female reproductive structure (pistil) that contains the ovules and develops into the fruit.

Ovate – Egg-shaped (two-dimensional), attached at broad end.

Ovoid – Egg-shaped (three-dimensional).

Ovule – Part of "female" plant reproductive system that becomes a seed after fertilization.

Palustrine – Marshy or marsh-dwelling.

Perennial – A plant that lives for three or more years and can grow, flower, and set seed for many years; underground parts may regrow new stems in the case of herbaceous plants.

Perianth – Part of flower consisting of calyx and corolla, usually used when these structures are incomplete or modified.

Phenotype – The external visible appearance of an organism.

Phenotypic plasticity – When members of a species vary in height, leaf size or shape, flowering (or spore-producing time), or other attributes, with changes in light intensity, latitude, elevation, or other site characteristics.

Pioneer species – Generally the first species to colonize an area during primary succession.

Pistil – The seed-producing organ of a flower, consisting of a stigma, style, and ovary.

Pistillate flower – A flower with "female" reproductive organs (pistils) and lacking "male" reproductive organs (stamens).

Plano-convex – With one flat and one outward curving face.

Pollen – The male spores in an anther.

Polyploidy – Having more than two complete sets of chromosomes per cell.

Population Viability Analysis – An evaluation to determine the minimum number of plants needed to perpetuate a species into the future, the factors that affect that number, and current population trends for the species being evaluated.

Propagule – A reproductive body, usually produced through asexual or vegetative reproduction.

Recruitment – The addition of new individuals to a population by reproduction.

Rhizomatous – Bearing rhizomes.

Rhizomes – Prostrate stem growing beneath the ground surface, usually rooting at the nodes.

Ruderal habitat – Temporary or frequently disturbed habitats.

Ruderal species – Species that can exploit low stress, high disturbance environments.

Rugose – With wrinkles or creased surface.

S1 ranking – Critically imperiled in the state because of extreme rarity (five or fewer occurrences or very few remaining individuals) or because of some factor making it especially vulnerable to extinction.

Scale – Thin bract subtending sedge flower.

Senescence – Changes that occur in an organism (or part of an organism) between maturity and death; aging.

Sensitive species – A species whose population viability is a concern due to downward trends in population numbers, density, or habitat capability, as identified by a regional forester of the USDA Forest Service.

Sepal – A segment of the calyx.

Sessile – Lacking a stalk.

Sheath – Part of a sedge or grass leaf that envelopes the stem.

Sinkhole – Natural depression in the land surface, often formed in limestone regions by collapse of a cavern roof.

Spikelet – A small or secondary spike (inflorescence with flowers sessile on an elongated axis).

Spinulose – Minutely spiny.

Stamen – The pollen-producing structures of a flower; the “male” part of a flower.

Staminate flower – A flower with “male” reproductive organs (stamens) and lacking “female” reproductive organs (pistils).

Stigma – The surface of the plant reproductive structures (pistil) on which pollen grains land.

Style – Stalk-like part of the pistil that connects the ovary and stigma.

Subterete – Almost terete (Cylindrical, round in cross-section).

Succession – The orderly process of one plant community replacing another.

Swale – A low tract of land, especially moist or marshy ground.

Sympatric – Occupying the same geographic region.

Terete – Cylindrical, round in cross-section.

Terminal – Occurring at the tip or end.

Threatened – Defined in the Endangered Species Act as any species which is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range.

Vegetative reproduction – A form of asexual propagation whereby new individuals develop from specialized multicellular structures that often detach from the mother plant.

Ventral – Belonging to inner or axis side of a structure.

Viability – The capability of a species to persist over time. A viable species consists of self-sustaining and interacting populations that have sufficient abundance and diversity to persist and adapt over time.

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