Salix serissima (Bailey) Fern. (autumn willow): A Technical Conservation Assessment

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Cover Photo Credit

Salix serissima (autumn willow). Photograph by Tom Cottrell, used with permission.

Summary of Key Components for Conservation of *Salix serissima*

Status

Salix serissima (autumn willow) is a boreal willow and an obligate wetland species whose distribution is concentrated in the northeastern United States and in Canada from Newfoundland to British Columbia. It is found in disjunct populations within USDA Forest Service (USFS) Region 2. Known occurrences in Region 2 include four in the Black Hills of South Dakota (two on the Black Hills National Forest); one in the Sherman Mountains of Albany County, Wyoming (on the Medicine Bow National Forest); seven in north-central Colorado (one on the Arapaho-Roosevelt National Forest); and one in southwestern Colorado (potentially on the San Juan National Forest). *Salix serissima* is currently considered a sensitive species in Region 2, but it is not listed as threatened or endangered under the Federal Endangered Species Act. The NatureServe global conservation status rank for *S. serissima* is G4. Its state Natural Heritage Program rank in South Dakota, Wyoming, and Colorado is S1.

Primary Threats

The foremost threat to the persistence of *Salix serissima* in Region 2 is hydrologic alteration of the peatland habitats where it is found; any activity that disrupts saturated soils and peat formation is likely to have a negative impact on *S. serissima*. Hydrological alteration has occurred in the past at several *S. serissima* sites and is a current threat to some occurrences. This threat interacts to some degree with all other threats to this species. Other activities currently threatening *S. serissima* occurrences include grazing and road construction. The effects of global climate change and small population sizes have the potential to eliminate the species from Region 2; these effects are gradual, unpredictable, and difficult to control or evaluate. Potential threats to the species include peat mining, recreational use, alteration of fire regimes, and competition from invasive plant species.

Primary Conservation Elements, Management Implications and Considerations

Of the 13 or 14 reports of *Salix serissima* in Region 2, five are on National Forest System lands, one is in Rocky Mountain National Park, one is on land owned by The Nature Conservancy, and one is on private land under a conservation easement. Additional occurrences are on private land where the abundance, condition, and conservation status of the species are generally unknown. Although the species is managed for conservation by several other owners, the USFS has responsibility for maintaining the viability of a large proportion of the species within the administrative boundaries of Region 2.

The primary conservation element essential to maintaining viable populations of *Salix serissima* in Region 2 is a stable, appropriate substrate and hydrological regime. Occurrences in Region 2 are most vulnerable to changes in the environment that affect their peatland habitat.

Occurrences of *Salix serissima* in Region 2 are generally small and isolated from each other in habitat patches that are comparatively rare on the landscape. Population sizes and sex ratios are unknown for most occurrences; these characters may have important implications for the viability of each occurrence. Any management activities that maintain the hydrologic regime for these habitats will contribute to the persistence of *S. serissima*. Conservation strategies currently in place on National Forest System lands include sensitive species status in Region 2 and Botanical Area designation and site restoration for one site on the Black Hills National Forest. Further surveys are needed for additional occurrences, especially on public lands. It would also be useful to document site conditions, population numbers, and approximate sex ratios for known occurrences in order to clarify the relative importance of known occurrences to conservation of the species in Region 2.

TABLE OF CONTENTS

EDITORS: Beth Burkhart and Kathy Carsey, USDA Forest Service, Rocky Mountain Region

List of Tables and Figures

Tables:

Figures:

Introduction

This assessment is one of many being produced to support the Species Conservation Project for the Rocky Mountain Region (Region 2), USDA Forest Service (USFS). *Salix serissima* (autumn willow) is the focus of an assessment because it is a disjunct species whose population viability is identified as a concern based on its extremely limited distribution in Region 2. The USFS lists *S. serissima* as a sensitive species in Region 2 (USDA Forest Service 2005). Within the National Forest System, a sensitive species is a plant or animal whose population viability is identified as a concern by a Regional Forester because of significant current or predicted downward trends in abundance and/or in habitat capability that would reduce its distribution (USDA Forest Service 2003). A sensitive species may require special management, so knowledge of its biology and ecology is critical. This assessment addresses the biology, ecology, conservation status, and management of *S. serissima* throughout its range in Region 2. The introduction defines the goal of the assessment, outlines its scope, and describes the process used in its production.

Goal of Assessment

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

Scope of Assessment

This assessment examines the biology, ecology, conservation status, and management of *Salix serissima* with specific reference to the geographic and ecological characteristics of the USFS Rocky Mountain Region. Although much of the literature on this species and its congeners is derived from field investigations outside the region, this document places that literature in the ecological context of the central Rocky Mountains and adjacent Great Plains. Similarly, this assessment is concerned with the reproductive behavior, population dynamics, and other characteristics of *S. serissima* in the context of the current environment rather than under historical conditions. Previous work by Hornbeck et al. (2003) treated these topics in detail for *S. serissima* occurrences on National Forest System lands in the Black Hills of South Dakota.

In producing this assessment, I reviewed refereed literature, non-refereed publications, research reports, and data accumulated by resource management agencies and other investigators. While *Salix serissima* is mentioned in a variety of sources, there are no publications devoted to the species other than the original published description and the assessment of Hornbeck et al. (2003). Because basic research has not been conducted on many facets of the biology of *S. serissima*, literature on its congeners was used to make inferences in this assessment. The refereed and non-refereed literature on the genus *Salix* and its included species is more extensive and includes other disjunct or rare species. Specimens of *S. serissima* were viewed at University of Colorado Herbarium (COLO), Colorado State University (CSU), Rocky Mountain Herbarium (RM), and Kalmbach Herbarium, Denver Botanic Gardens (KHD). Element occurrence records were obtained from the Colorado Natural Heritage Program, the Wyoming Natural Diversity Database, and the South Dakota Natural Heritage Program. The assessment emphasizes refereed literature because this is the accepted standard in science, and refereed literature is used to address general ecological and management concepts. Non-refereed publications or reports were used in the assessment since they are often the only source of information about occurrences of *S. serissima* in Region 2, but they were regarded with greater skepticism than the refereed literature.

Treatment of Uncertainty in Assessment

Science represents a rigorous, systematic approach to obtaining knowledge. Competing ideas regarding how the world works are measured against observations. 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). It is, however, difficult to conduct experiments that produce clean results in the ecological sciences. Often observations, inference, critical thinking, and models must be relied on to guide our understanding of ecological relations. Information on the biology and ecology of other *Salix* species has been used to draw inferences regarding similar characteristics for *S. serissima*, but these inferences have not been tested. In this assessment, the strength of evidence for particular ideas is noted, and alternative explanations are described when appropriate.

Treatment of This Document as a Web Publication

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

Peer Review of This Document

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

MANAGEMENT STATUS AND NATURAL HISTORY

Management Status

Salix serissima is considered a sensitive species in USFS Region 2 (USDA Forest Service 2005). The species is also on the Colorado Bureau of Land Management State Director's Sensitive Species List for the Royal Gorge Field Office (USDI Bureau of Land Management 2000). Although *S. serissima* is widely distributed in the northern United States and Canada, occurrences in Region 2 are small and disjunct from the main distribution. In Region 2, the species is known from 13 to 14 locations (eight or nine locations in Colorado, one location in Wyoming, and four locations in South Dakota; **Figure 1**, **Table 1**). Of these, two South Dakota occurrences are on lands of the Black Hills National Forest; the Wyoming occurrence is on the Medicine Bow National Forest; and Colorado occurrences include one on the Arapaho-Roosevelt National Forest, one that may be in part on the San Juan National Forest, and one questionable record on or near the Pike-San Isabel National Forest. This last record is based on a specimen at the Oklahoma State University Herbarium that is probably misidentified (Tyrl personal communication 2005); *Salix serissima* has never been collected by USFS botanists on the Pike-San Isabel National Forest (Elliot personal communication 2005).

The McIntosh Fen occurrence (#13 in **Table 1**) on the Black Hills National Forest is part of a Special Interest Botanical Area designated in 1997. The botanical area is to be managed in such a way that the fen and associated botanical features for which it was established are not impaired (Hornbeck et al. 2003). Although there is a designated Research Natural Area named Sheep Creek in southern Larimer County, Colorado, the Sheep Creek occurrence (# 6 in **Table 1**) on the Arapaho-Roosevelt National Forests is not part of the Research Natural Area of the same name. None of the other occurrences on National Forest System lands is under any USFS special protective designation. In Colorado, one occurrence is on lands managed by the National Park Service in Rocky Mountain National Park, one is within a preserve owned and managed by The Nature Conservancy, and one is protected by a conservation easement. The remaining occurrences in Colorado and South Dakota are on privately owned lands, or do not have sufficient location information to determine ownership, and they have no protective or special management designation.

The current NatureServe global conservation status rank for *Salix serissima* is G4. The global (G) rank is based on the status of a taxon throughout its range. A G4 ranking is defined as "Apparently Secure—Uncommon but not rare; some cause for long-term concern due to declines or other factors" (NatureServe 2005). State Natural Heritage Program ranks are S1 in Colorado, Wyoming, and South Dakota (NatureServe 2005). The state (S) rank is based on the status of a taxon in an individual state. The S1 rank signifies that the species is "critically imperiled in the state because of extreme rarity (often five or fewer occurrences) or because of some factor(s) such as very steep declines making it especially vulnerable to extirpation from the state" (NatureServe 2005).

In Colorado, *Salix serissima* is represented in six Potential Conservation Areas (PCAs) designated by the Colorado Natural Heritage Program as having

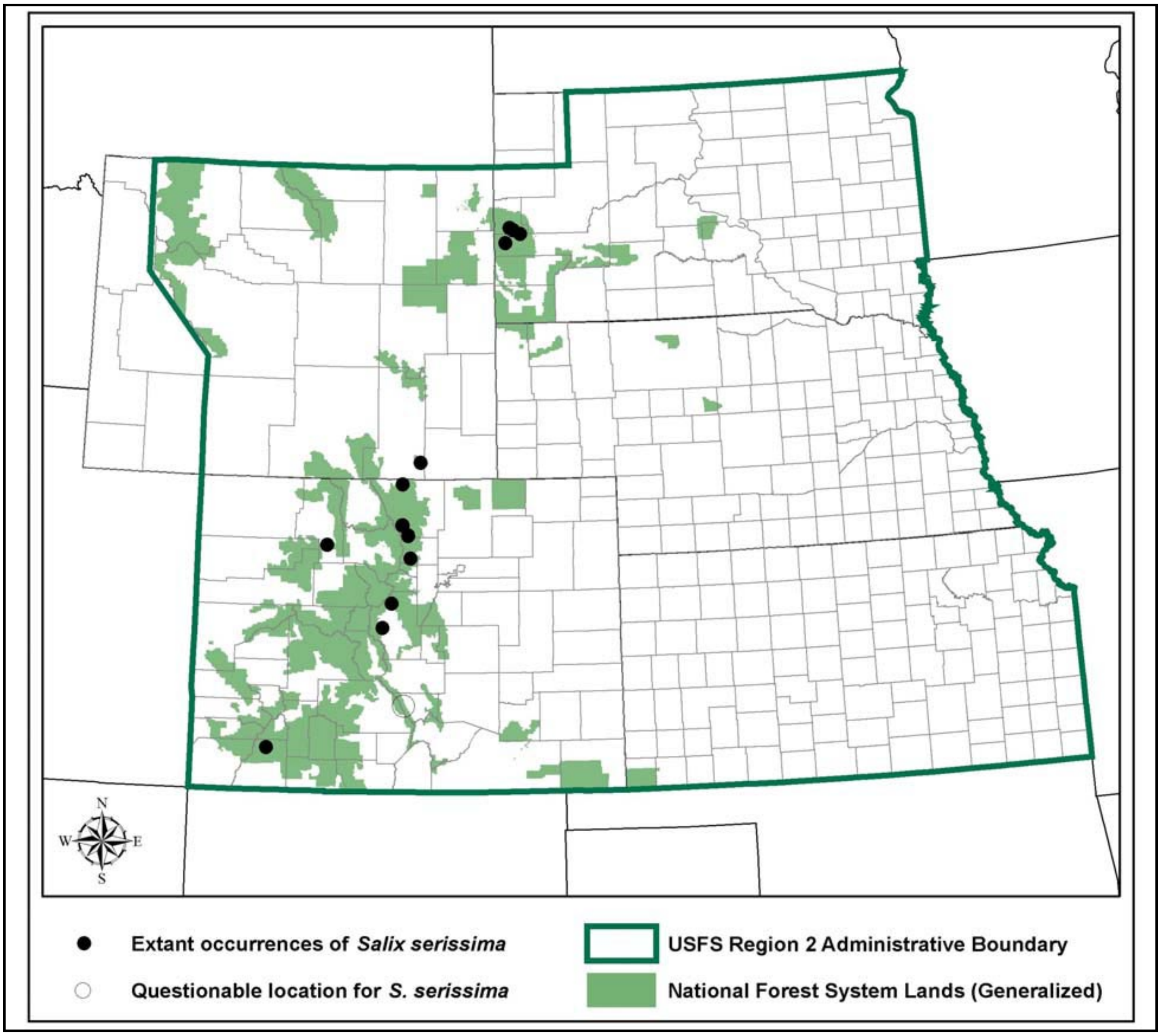


Figure 1. Distribution of *Salix serissima* within Region 2.

natural heritage significance. PCA designation does not confer any regulatory protection to a site, nor does it automatically exclude all activity. PCA boundaries are based primarily on factors relating to ecological systems, and they represent the best professional estimate of the primary area supporting the long-term survival of the targeted species or plant associations. Such boundaries delineate ecologically sensitive areas that may require careful planning and management of land-use practices to ensure that they are compatible with protection of natural heritage resources and sensitive species (Colorado Natural Heritage Program Site Committee 2002).

Existing Regulatory Mechanisms, Management Plans, and Conservation Strategies

Salix serissima has never been listed as, or been a candidate for, threatened or endangered status under the Endangered Species Act. At the southern edge of its range in eastern North America, it is given special status by several states: Connecticut (special concern), Illinois (endangered), Indiana and Pennsylvania (threatened). There are no special state management designations for *S. serissima* in Region 2. Because it is a sensitive species in Region 2, USFS personnel are required to “develop

Table 1. Documented occurrences of *Salix serissima* within USDA Forest Service Region 2. Historic or questionable occurrences are shown with shading. Occurrences are arbitrarily numbered and arranged by location (state and county). Habitat type names are given as in the original source. Population sizes are numbers of individual plants. Sources include element occurrence data from Colorado Natural Heritage Program (CNHP), South Dakota Natural Heritage Program (SDNHP), and Wyoming Natural Diversity Database (WYNDD), and herbarium labels. Element Occurrence ID's are of the format EO-00. Herbarium label ID's are collector name and collection number.

	State County	Land Ownership/ Management	Date Last Observed	Location	Elevation (ft.)	Habitat	Population Size	Source ID
1	CO Boulder	Private	20-Aug-1999	North of Nederland	8,400	Peaty fen in broad gently sloping valley	unknown	N. Lederer #99-80, #99-84, #99-85, #99-88
2	CO Custer	Unknown	12-Aug-1976	Hermit Pass Road	10,200	Moist loam near creek	unknown	CNHP EO-05; J. Smith #38
3	CO La Plata	Private/State/ San Juan National Forest?	15-Jul-1995	Haviland Lake	8,300	Calcareous fen	unknown	Dorn #6205
4	CO Larimer	Private	29-Aug-1962	Inn Brook	9,000	Swampy ground	unknown, possibly extirpated	CNHP EO-01; E.C. Smith #1429, #1482, #2120; G.N. Jones #35206; W.A. Weber #5735
5	CO Larimer	Rocky Mountain National Park	25-Jul-1990	Horseshoe Park / Endovalley	8,600	Willow carr, deep peat	30+	CNHP EO-04 and -07
6	CO Larimer	Arapaho-Roosevelt National Forest	2-Jul-2000	Sheep Creek	8,300	Stream bank	unknown	R. Dorn #8320
7	CO Park	The Nature Conservancy	29-Jun-1999	High Creek Fen	9,700	Infrequent in the isolated stands of spruce in the fen	unknown	CNHP EO-02 W.A. Weber #19471
8	CO Park	Private	13-Aug-2000	Northwest of Jefferson	9,720	On hummocks in an extreme rich fen; higher ground around fen	unknown	J. Sanderson #988; L. Senser #s.n.
9	CO Routt	Private	17-Sep-1991	Phillips Creek at Nelson's Ranch	7,800 to 7,880	Wet, boggy willow carr	20 to 100	CNHP EO-03; G. Kittel #2194
10	SD Lawrence	Private	10-Sep-1986	Bull Dog Ranch	5,950	Saturated organic substrate of fen	unknown	SDNHP EO-03
11	SD Lawrence	Private	199?	Jim Creek	5,220	Sedge-willow bog	unknown	SDNHP EO-04
12	SD Lawrence	Black Hills National Forest	10-Sep-2002	Middle Box Elder Creek (Crago Flats Exclosure near Nahant)	5,810	Sedge/grass wet meadow in valley bottom; plants found in saturated meadow	13	SDNHP EO-01; S.G. Froiland #1925
13	SD Pennington	Black Hills National Forest	31-Aug-2001	McIntosh Fen	6,410	Wet, springy, organic soil	453	SDNHP EO-02/R. Dorn #8573
14	WY Albany	Medicine Bow National Forest	11-Aug-2002	North Branch Crow Creek	7,900	Fen	80 to 100	WNDD EO-01

and implement management practices to ensure that species do not become threatened or endangered because of Forest Service activities" (USDA Forest Service Manual, Region 2 supplement, 2670.22). Although such practices may include developing an individual species conservation strategy, as of this writing, a conservation strategy has not been written for this species at a national or regional level by the USFS or any other federal agency.

There are two regional federal policy documents specific to peatlands, the habitat of *Salix serissima*. The U.S. Fish and Wildlife Service (USFWS) Regional Policy on the Protection of Fens (U.S. Fish and Wildlife Service 1998) made the protection of fens in the USFWS Mountain-Prairie Region a priority, and determined that all functioning fens fall into Resource Category 1. Habitat designated as Resource Category 1 is "unique and irreplaceable on a national basis or in the ecoregion section." The mitigation goal for lands in Resource Category 1 is "no loss of existing habitat value." Regional guidance on fens is also provided by USFS Rocky Mountain Region Memo 2070/2520-72620 entitled Wetland Protection – Fens, signed by the Director of Renewable Resources (USDA Forest Service 2002). The memo informs forest supervisors of the USFWS policy and urges USFS personnel to "give careful consideration to avoiding impacts or identifying opportunities for restoration of these rare and irreplaceable habitats where they occur on National Forest System lands." The memo is not a directive, and it does not limit the kinds of management activities that can be taken in wetlands supporting *S. serissima*.

Salix serissima is considered an obligate wetland indicator species across its entire distribution in the United States (USDA Natural Resources Conservation Service 2005). A variety of federal regulations and policies provide direction for the wetlands where *S. serissima* occurs. The primary federal law regulating wetland habitats is Section 404 of the Federal Water Pollution Control Act (Clean Water Act) of 1977 (33 U.S.C. ss/1251 et seq.). Activities in wetlands regulated under this Act are required to avoid wetland impacts where practicable, to minimize potential impacts to wetlands, and to compensate for any unavoidable impacts through restoration or mitigation. However, the 2001 Supreme Court decision in SWANCC vs. USACE effectively removed regulatory oversight for wetlands lacking connections to surface water bodies such as streams ("isolated wetlands"). Any sites that lack surface connection to navigable waters of the U.S. and are considered isolated wetlands would not be subject to Clean Water Act regulations. In general, Region 2 sites that support *S. serissima* are not considered isolated wetlands and continue to be subject to regulation under Section 404.

Federal codes and regulations related to all federal actions or to those on USFS lands include the National Environmental Policy Act (NEPA) of 1969 (42 U.S.C. 4321-4347), the Organic Administration Act of 1897 (16 U.S.C. 475), the Multiple Use – Sustained Yield Act of 1960 (16 U.S.C. 528), the National Forest Management Act of 1976 (16 U.S.C. 1600-1602, 1604, 1606, 1608-1614), the Federal Land Policy and Management Act of 1976 (43 U.S.C. 1701-1782, FSM 2729), the Forest Service Manual, and individual Forest Management Plans. The Forest Service Watershed Conservation Practices Handbook (FSH 2909.25) provides guidance on the protection of soil, aquatic, and riparian systems. These codes and regulations all provide some degree of focus on the preservation of water resources, including wetlands. Finally, a policy of "no-net-loss" of wetlands has been a national goal since first announced as an administration policy under President George H.W. Bush in 1989.

Adequacy of current laws and regulations

The above-mentioned laws and regulations provide tools for the conservation of *Salix serissima*, especially on USFS lands. However, current laws and regulations are not necessarily adequate to protect *S. serissima* habitat in Region 2. Regulations in the Department of Agriculture and the Department of the Interior consider peat a renewable resource (USDI Bureau of Mines 1994) and a saleable mineral (PL-167, the Multiple Use Act of 1955). As of this writing, there were three active peat mining permits in Colorado, one of which is in South Park (Colorado Division of Minerals and Geology 2006). Although permitting of new peat mining under Section 404 is unlikely due to the USFWS Regional Policy on the Protection of Fens (Carey personal communication 2006), the possibility of future permitting has not been eliminated. For occurrences on privately owned lands, current laws and regulations may be inadequate to prevent damage or destruction of an occurrence.

Adequacy of current enforcement of laws and regulations

There are no confirmed cases in which an occurrence of *Salix serissima* in Region 2 was extirpated due to the failure to enforce existing regulations. This does not necessarily indicate that current regulations or their enforcement are adequate for the protection of *S. serissima* or its habitat. In Region 2, where *S. serissima* is confined to a few islands of unique and relatively rare habitat, the destruction of hundreds of acres of peatland in Park County, Colorado, has probably impacted individuals and occurrences in the immediate vicinity. Furthermore, the National Research Council's Committee on Mitigating Wetland Losses (2001) concluded that mitigation criteria required for compliance with the provisions of Section 404 of the Clean Water Act often have not been attained, in part because permit expectations were unclear and compliance was never monitored. The Committee also found that although progress has been made since the 1980's, the goal of "no net loss of wetlands" is not being met (National Research Council 2001). The Committee report indicates that enforcement of at least some current laws and regulations is inadequate to protect the unique habitat of *S. serissima*.

Isolated incidents of extirpation have not yet threatened or endangered the persistence of *Salix serissima*. Even so, a steady but gradual loss of individual populations over time from a variety of causes could easily contribute to a contraction of its known range. Loss of peripheral and disjunct populations in Region 2 could reduce the genetic diversity of the species as a whole, as well as depress its resilience in the face of genetic, demographic, and environmental stochasticity (Huenneke 1991, Millar and Libby 1991).

Biology and Ecology

Classification and description

Salix serissima is a member of the willow family (Salicaceae). The Salicaceae is generally regarded as consisting of the genera *Populus* and *Salix*. Two additional genera have been recognized in treatments of Asian material but do not occur in North America (Argus 1997). The genus *Salix* includes some 450 species worldwide, and these are distributed primarily in the Northern Hemisphere (Argus 1997).

The classification of the genus *Salix* at a worldwide level has been fraught with confusion and discarded names. The primary difficulties have been (1) the tendency for authors to produce regional or continental classifications rather than to treat the genus as a whole, and (2) difficulty in assembling a suite of characters that is useful for classification across the entire group. Argus (1997) provides a comprehensive review of classification efforts from Linnaeus to the present. The most recent treatment of the entire genus (Andersson 1868) is now well over a century old although it still provides the foundation for more modern treatments. The North American *Salix* were treated more recently by Dorn (1976) and later by Argus (1997), who recognized four subgenera, 28 sections of native species, three sections represented only by naturalized species, and a total of 103 species present in the New World.

Salix serissima is placed by both Dorn (1976) and Argus (1997) in the subgenus *Salix*, section *Salicaster*. The other North American members of this section are *S. lucida* ssp. *caudata* and ssp. *lasiandra* (called *S. lasiandra* var. *caudata* and var. *lasiandra* by Dorn), and the naturalized *S. pentandra*, which is the type of this group. In Region 2, the subgenus *Salix* is characterized by deciduous fruiting bracts. Within subgenus *Salix*, the species of section *Salicaster* have bud scales with fused margins and mostly lanceolate to ovate leaves and three or more stamens (Dorn 1997).

History of knowledge

Salix serissima was originally briefly described under the name *S. lucida* Muhl. var. *serissima* Bailey by L.H. Bailey (1887) from a specimen collected at Mud River, in Minnesota. Although the species had been collected as early as 1867 in New Jersey, specimens were placed variously in *S. lucida*, *S. amygdaloides*, *S. lasiandra*, *S. arguta* var. *alpigena*, and *S. arguta* var. pallescens (Fernald 1904; USDA Natural Resources Conservation Service 2005). Fernald (1904) was the first to collate the different specimens and to recognize *S. serissima* as a distinct species. Subsequent to this clarification, the taxa has not been in dispute, and the synonyms given above are not currently accepted as valid. *Salix serissima* became known from Region 2 during the mid-1900's (1940: Larimer County, Colorado, and 1956: Black Hills, South Dakota). The species was documented from Canadian provinces from Quebec to the Northwest Territories from the 1930's to 1970's, and in Montana during the 1970's and 1980's. The single known Wyoming occurrence was first observed in 1986. Additional Colorado occurrences were documented in the 1990's.

Description

The following description is based on Fernald (1904), Froiland (1962), Dorn (1997), Fertig (2000), and Argus (2004). *Salix serissima* is a perennial, deciduous shrub that grows from 1 to 4 or 5 m tall. Individuals in Region 2, however, are more often reported to be less than 3 m in height. Bark color ranges from olive-brown or gray in older branches to yellowish-brown in younger branches, and the youngest twigs are glossy red-brown. The leaves of mature branches are dark green and shining on the top surface with a broad whitish midrib, and paler on the bottom surface. Leaves are elliptic or lanceolate, or on young shoots sometimes oblong-lanceolate, with minutely toothed margins and the distinguishing presence of glands on the petiole near the base of the leaf blade (**Figure 2**).

Salix flowers are produced in dense spikes called catkins or aments. Male (staminate) catkins of *S. serissima* are 1 to 2 cm long with three to nine stamens

Figure 2. Leaves and fruiting catkins of *Salix serissima* (top), and habit of *S. serissima* (bottom). Photographs by Tom Cottrell, used with permission

per flower. The female (pistillate) catkins are somewhat longer at 2 to 4 cm, with pale bracts or scales below the flowers that are deciduous in fruit. The fruits (capsules) are mostly 7 to 11 mm long when mature. One of the distinguishing features of *S. serissima* is that its catkins flower and mature noticeably later than those of other *Salix* species. While most willows are in flower before or during leaf emergence in early spring, *S. serissima* flowers from May to July, and fruits mature from June to September.

Salix serissima is distinguished from the closely related *S. lucida* ssp. *caudata* and *S. lucida* ssp. *lasiandra* (=*S. laisiandra* var. *caudata* and var. *lasiandra* of Dorn 1997) by its later period of flowering and fruiting, lack of well developed stipules (leaf-like appendages at the base of the leaf stalk or petiole), and longer capsules (7 to 11 mm vs. 4 to 7 mm).

Pending the completion of the treatment of the genus *Salix* by Dr. G.W. Argus in the forthcoming Volume 7 of the Flora of North America, the most complete technical description to date is found in Fernald (1904); others include Britton and Brown (1913), Smith (1942), Froiland (1962), Dorn (1997), Argus (2001, 2004), and Hornbeck et al. (2003). Dichotomous keys providing less detailed descriptions are found in the regional floras including Great Plains Flora Association (1986), Dorn (2001), and Weber and Wittmann (2001). A drawing and photograph of the plant and its habitat are available in the Colorado Rare Plant Field Guide (Spackman et al. 1997) and in the Wyoming Rare Plant Field Guide (Fertig 1994), in both online and print versions. Additional illustrations or photographs are available in Britton and Brown (1913) (**Figure 3**), Froiland (1962), Dorn (1997), Colorado Native Plant Society (1997), and others.

Figure 3. Illustration of *Salix serissima* from Britton and Brown (1913). This image is not copyrighted and may be freely used for any purpose.

Distribution and abundance

Salix serissima is a boreal species whose distribution is concentrated in the northeastern United States and in Canada from Newfoundland to British Columbia (Froiland 1962, NatureServe 2005). The species is confined to North America; it does not occur in the boreal regions of other continents.

In Region 2, occurrences are rare in South Dakota, Wyoming, and Colorado, where they are disjunct from the more northern center of distribution. The known regional distribution of *Salix serissima* is shown in **Figure 1** and described in detail in **Table 1**. Known occurrences in Region 2 are confined to the Black Hills of South Dakota and the Southern Rocky Mountains from southern Wyoming to southwestern Colorado. These two areas are separated by a distance of approximately 200 miles, and are 400 to 600 miles south of the main boreal distribution of the species in Canada and the northern tier of U.S. states. The four known occurrences in South Dakota are within 15 miles or so of each other. The single Wyoming occurrence and the seven occurrences in north-central Colorado are all within an area spanning about 150 miles from the Sherman Mountains of Albany County, Wyoming, to South Park between the Mosquito Range and Tarryall Mountains of Park County, Colorado. Occurrences in this area are generally separated by distances of 20 to 80 miles. A single occurrence in southwestern Colorado on the southern flank of the San Juan Mountains is separated from the nearest known occurrence in South Park by approximately 150 miles. This disjunct distribution of boreal and alpine species is typically attributed to the phytogeographical effects of glaciation (Weber 2003).

Although the several episodes of glaciation that occurred during the Quaternary (i.e., during the past two million years) certainly affected the distribution of plants, the last glacial maximum, the Wisconsinan, is the episode that contributed most to the definition of the distribution of modern North American biotas (Brouillet and Whetstone 1993). During the peak of the last continental glaciation about 18,000 years before the present, boreal forest communities dominated lands south of the continental ice cover to approximately 34º N latitude and extended across the Great Plains. Comparison of modern and fossil pollen assemblages indicates that these communities were similar in composition to modern boreal forest communities (Delcourt and Delcourt 1993). The southward retreat of boreal vegetation during the period of glacial increase resulted in the colonization of patches of suitable habitat, and some species, including *Salix serissima*, remained in these refugia when glaciers retreated and species ranges again moved north (Gates 1993).

Although abundance figures are not available, *Salix serissima* is considered secure or apparently secure in the central Canadian provinces, becoming vulnerable to imperiled at the edges of its distribution from British Columbia to Newfoundland in the north and from Montana to New Jersey further south. Where occurrence sizes have been reported in Region 2, numbers are generally small, with only one occurrence (#13 in **Table 1**) reported to be larger than 100 individuals (Hornbeck et al. 2003, Colorado Natural Heritage Program 2005, Wyoming Natural Diversity Database 2005).

Population trend

Only a few *Salix serissima* occurrences have been censused on more than one occasion, so data that would allow a detailed description of population trends are generally lacking. Moreover, the perennial life span of *S. serissima* means that detection of population trends may require many more observations over longer time periods.

Hornbeck et al. (2003) report population trends for two sites in the Black Hills. In 1984 about 50 plants were documented at McIntosh Fen; the population showed no expansion for a decade. Work to restore the natural water regime on the fen began in 1997 and included the planting of *Salix serissima* cuttings. The restored population contained 357 individuals in 2000. Burkhart (2005) reported that numbers of individuals had increased to 764 by 2003, but declined to 462 in 2004. Because high individual mortality was not reported, this apparent decline was interpreted as largely an artifact of inconsistent data collection procedures (Burkhart 2005). The occurrence at Middle Boxelder Creek was originally documented as several individuals in 1956. When this occurrence was relocated in 2002, 13 individuals were found. The size of the other South Dakota occurrences is unknown. The Wyoming occurrence at Crow Creek has been observed frequently since its discovery (Wyoming Natural Diversity Database 2005), but population numbers have been reported on only two occasions. Occurrence abundance appears to have been stable between these observations, with 80 to 100 plants reported in 1995 and 50 to 100 in 1998. Colorado occurrences are generally lacking in quantitative data. The first known Colorado occurrence at Inn Brook near Rocky Mountain National Park consisted of at least 15 individuals at the time of its discovery (Smith 1940). The occurrence was last observed in 1962, and it appears to have declined or been extirpated since that time; recent attempts to relocate the occurrence have been unsuccessful (Colorado Natural Heritage Program 2005). Two collections have been made from the occurrence at Horseshoe Park in Rocky Mountain National Park; the occurrence was reported as consisting of at least 30 plants on one occasion. The Phillips Creek occurrence in Routt County was reported as consisting of 20 to 100 individuals in 1996 (Colorado Natural Heritage Program 2005), but it has not been censused again. Population trends are unknown for the more northern main distribution, but they are presumed to be stable, as reflected in the conservation status ranks for the central Canadian provinces. Due to the comparative rarity of its habitat, *S. serissima* is likely to have always been rare in Region 2 in post-glacial times.

Habitat

Throughout its range, *Salix serissima* is typically associated with areas of permanently saturated soils where peat is present. In Region 2, these areas frequently have a high mineral content and an alkaline pH (Froiland 1962, Lesica 1986, Cooper 1996), and they are classified as calcareous or rich fens. Such habitats are scarce in Region 2, and so occurrences of *S. serissima* are also rare. Although peatlands appear to be the preferred habitat of *S. serissima*, it is not clear that the species is entirely restricted to them. A few specimens have been collected that do not include sufficient habitat characterization information to rule out the possibility that *S. serissima* can occur in other moist habitats such as stream banks (**Figure 4**).

Peatlands are generally defined as ecosystems having at least 30 to 40 cm of peat accumulation, and they are often imprecisely referred to by terms such as swamp, bog, fen, moor, muskeg, and mire (Charman 2002). Two basic types of peatland are generally recognized: 1) bogs, or peatlands that receive water and nutrients solely from rain and/or snow falling onto the surface, and that are generally nutrient poor and acidic and 2) fens, or peatlands that are influenced by water from outside their limits, (groundwater and surface runoff), and therefore tend to be more nutrient rich and alkaline (Charman 2002). All peatlands in Region 2 are properly classified as fens, but there is a great range in nutrient richness and hydrology (Cooper 1986, Cooper and Andrus 1994, Johnson 2000). The term *carr* is used to denote shrub-dominated peatlands (Benedict 1991), which may be either bogs or fens.

Figure 4. Habitat of *Salix serissima* on Phillips Creek. Photograph by Denise Culver, used with permission.

Fens form at low points in the landscape or near slopes where groundwater intercepts the soil surface. Groundwater inflows maintain a fairly constant water level year-round, with water at or near the surface most of the time. Constant high water levels lead to an accumulation of organic material. Fens are often sites with a relatively high proportion of disjuncts (i.e., species far from their primary area of geographic distribution), often species whose main distribution is the arctic and boreal regions of Canada and the Great Lakes (Bedford and Godwin 2003). The surrounding landscape may be ringed with other wetland systems (e.g., riparian shrublands) or a variety of upland systems from grasslands to forest.

Although some occurrences of *Salix serissima* in Region 2 are found in rich or extremely rich fen habitats, the species does not appear to be as closely linked to the unique water chemistry of these habitats as some other regional disjuncts. In a comparison of information from all reported habitats of *S. serissima* in Region 2, the common unifying factor appears to be the presence of peat. Physical and biotic processes that contribute to peatland formation are complex and variable across the continent. The habitat of *S. serissima* outside Region 2 is probably closely linked to the distribution of boreal fens where northern peatland successional processes of terrestrialization and paludification are important (Mitsch and Gosselink 1993), but this does not appear to be the case in Region 2. Successional processes in the disjunct peatland habitats of Region 2 are less well understood, beyond the importance of a positive water balance (i.e., permanently or nearly permanently saturated soils) and reduced decomposition leading to peat formation.

Salix serissima habitat of the Black Hills area is described by Hornbeck et al. (2003) as cold, permanently saturated wetland with an organic (peaty) substrate derived from the slow decay of grasses and sedges. In the Black Hills, these wetlands are limited to cold seep or spring-fed saturated substrates produced by unusual hydrologic conditions where sedimentary layers intersect impermeable schist or shale (Hornbeck et al. 2003). The habitat of the Wyoming occurrence is a willow carr on flooded, organic soil at the edge of a spring (Wyoming Natural Diversity Database 2005). Colorado habitats include extreme rich fens, calcareous fens, willow carrs with deep peat, and, in one or two instances, stream banks. Elevations of occurrences range from 5,220 to 6,410 ft. (1,590 to 1,950 m) in South Dakota, and from 7,800 to 9,720 ft. (2,375 to 2,960 m) or possibly higher in Colorado. The Wyoming occurrence is at 7,900 ft. (2,410 m). See **Table 1** for habitat descriptions of individual occurrences.

Salix serissima is associated with plant communities that are characteristic of fens and saturated soils. Data from specimen labels and element occurrence records show *S. serissima* occurring with the species shown in **Table 2**. Little information is available with which to characterize microhabitat preferences of *S. serissima* other than its association with saturated, peaty soils.

Reproductive biology and autecology

As a long-lived perennial species that devotes several years to vegetative growth before reproducing, *Salix serissima* can be regarded as a K-selected species in the classification scheme of MacArthur and Wilson (1967). Willows of riparian or floodplain areas are often colonizers of disturbed areas, but non-riparian willows are typically found in relatively stable habitats where successional changes are slow or non-existent (Kovalchik 2001). *Salix* species of non-riparian habitats, such as *S. serissima*, may be described as stress-tolerant competitors in the strategic schema of Grime (2001). *Salix serissima* occupies productive stable habitat, is a deciduous perennial, and is probably capable of rapid growth, suggesting that it has some competitive characteristics. *Salix serissima* and other willows also have characteristics that suggest elements of stress-tolerance (growing in waterlogged soils and low temperatures) or ruderal strategies (copious seed production and not highly clonal).

Salix serissima reproduces primarily sexually by seed. Although it can be easily propagated from cuttings, and broken or beaver-cut branches may root if forced into the ground, the species does not habitually form large clones by layering (Argus 2001, Hornbeck et al. 2003). Nearly all willows, including *S. serissima*, are dioecious; an individual plant has either male flowers or female flowers, but not both. Worldwide, this sexual system is found in perhaps 4 percent of species (Yampolsky and Yampolsky 1922). The conventional explanation for the advantage of separate sexes is based on the benefits of enforced outcrossing and the avoidance of inbreeding depression (e.g., Baker 1959, Thomson and Barrett 1981). Alternative explanations (Charnov et al. 1976, Charnov 1982) are founded on resource allocation models that focus on ecological and physiological conditions that could favor either hermaphroditism or dioecy (Thomson and Brunet 1990). Investigation of sexual reproduction in flowering plants is further complicated by the lack of stable sex determining mechanisms in many plants and the labile sex expression in many others. Although the Salicaceae appear to be almost exclusively dioecious, at least one regularly hermaphrodite species has been reported, and the production of mixed-sex catkins or fertile bisexual flowers has occasionally been observed in unseasonally flowering individuals (Smith 1942, Rohwer and Kubitzki 1984). This type of sex lability has not been reported in *S. serissima*, and dioecy appears to be stable for most North American Salicaceae species. One important implication of the dioecious condition is that many species exhibit sex differential response to environmental conditions (Bierzychudek and Eckhart 1988). This character could be important in evaluating the consequences of management actions.

Most willows are thought to be primarily insect-pollinated, but they do produce copious pollen that is dispersed by the wind (Karrenberg et al. 2002a). This mixed or generalist pollination syndrome is evidenced by the presence of adaptations for insect pollination such as nectar production and floral scent while anemophily (wind pollination) is suggested by large amounts of small pollen, and, for most species, precocious flowering (flowers emerging before leaves develop). Mixed pollination systems are thought to arise when the presence of insect vectors is unpredictable. In the few species for which pollen vectors have been determined, the results vary from almost exclusive insect pollination to primarily wind pollination (Peeters and Totland 1999, Karrenberg et al. 2002b).

Karrenberg et al. (2002a) investigated pollination in four floodplain willow species: *Salix alba*, *S. daphnoides*, *S. elaeagnos*, and *S. triandra*. Their results show that pollination is necessary for seed set (although seedless fruit developed in some instances), and that maximum seed set is associated with insect vectors. Reported insect visitors to *Salix* flowers include a variety of Dipteran, Hymenopteran, and Lepidopteran species (Sacchi and Price 1988, Totland and Sottocornola 2001, Karrenberg et al. 2002a). Pollen vectors for *S. serissima* have not been investigated but are likely to be primarily insects.

Salix serissima is unusual among the North American willows in that its flowering period may continue into September and is often serotinous (after leaf emergence); it is these two characters that give it the common name of autumn willow. Wind pollination is unlikely to be an important vector for gamete dispersal between populations of *S. serissima* in Region 2 due to the interference from developed leaves, and the limited period of pollen viability (Mosseler 1989).

Few specifics are known about the reproductive capacity of *Salix serissima*. Willows are generally characterized as producing large numbers of rapidly developing seeds although the total resources devoted to seed production may be much lower than that of prolific annual species. Even when the percentage of filled seeds per catkin is low, the numbers of catkins produced and the number of fruits per catkin often result in very large numbers of seeds per individual plant. In the Karrenberg et al. (2002a) study cited above, individual willows produced several hundred to several thousand catkins. Catkins had anywhere from 35 to 150 fruits each, and fruits contained between two and 22 seeds. The average number of seeds produced per individual plant over all four species was over 200,000. Under laboratory conditions, germination rates for many *Salix* species are high (close to 100 percent), but temperature requirements do vary (Densmore and Zasada 1983, Young and Clements 2003). Germination rates are typically lower under natural conditions. Sacchi and Price (1992) noted that *S. lasiolepis* reached seedling densities of up to 25,000 per square meter. Clearly, fertility and seed viability of *Salix* species can be extremely high. Seed set and seedling survival depend on a variety of factors, including pollination rates, resource availability, and weather conditions.

The seeds of *Salix* are surrounded by a spreading coma of fine, silky hairs that are longer than the seed itself, and that facilitate dispersal by wind (Argus 1986a). The 'drag chute' function of the plume of hairs allows the tiny seeds to gain height in even very gentle convective air currents, and spreading seed hairs allow many seeds to cluster together. When seeds are wetted, the hairs quickly collapse and release the seed (Karrenberg et al. 2002a). Although some species are also likely to be dispersed by water, this is not likely to be a primary dispersal mechanism in *S. serissima*.

Seedling mortality is high in *Salix* species. Available research is primarily on floodplain species. Sacchi and Price (1992) recorded mortality of first year seedlings at nearly 100 percent for *S. lasiolepis* in northern Arizona, and they found that a lack of soil surface moisture was the primary cause of seedling mortality. McBride and Strahan (1984) found similar results for *S. hindsiana* and *S. laevigata* in northern California. Although seedling survival rates for *Salix* species in fens are not available, Isselstein et al. (2002) found high seedling mortality and a strong effect of available moisture for perennial graminoid species in fen meadows.

In peatland habitats, open sites for establishment of seedlings may be rare and confined to localized areas produced by disturbance such as trampling by domestic or wild ungulates. Although a positive effect of such gaps on the germination of many herbaceous fen species has been demonstrated (e.g., Isselstein et al. 2002), Stammel and Kiehl (2004) found that tolerance of the adverse effects of trampling (e.g., soil compaction, changes in the availability of light and water) was not the same for all species. They concluded that gap creation by trampling may not be a suitable conservation tool for species that are rare in an area. Cottrell (1993, 1995) found that willow seedlings were completely absent in the continuous sedge/willow cover of Rocky Mountain National Park willow carrs and were only present in unvegetated peat.

Salix species are often described as producing short-lived seeds that lack dormancy (e.g., Brinkman 1974, Raven 1992). However, Densmore and Zasada (1983) found that some northern *Salix* species disperse dormant seeds. Species that disperse seeds in the summer produce short-lived, non-dormant seeds while fall-dispersing species produce seeds that develop dormancy while still on the plant and are unable to germinate at the low temperatures that prevail once they are dispersed. Densmore and Zasada hypothesize that fall dispersal of dormant seeds is an adaptation to a short growing season in cold climates that evolved from non-dormant summer-dispersing taxa. Both types of dispersal are represented in section *Salicaster*. *Salix lasiandra* is summer-dispersed and also flowers earlier than *S. serissima*. *Salix pentandra* has fall dispersal and produces dormant seeds. Seed dormancy for *S. serissima* is unknown, but its late flowering period suggests that it may produce dormant seeds that cannot germinate until the next growing season and may form a seed bank.

Although synthetic hybrids are easily formed between many *Salix* species, natural hybridization in willows is apparently rare in North America as a whole (Argus 1974, Dorn 1976). The difficulty of distinguishing between hybrid individuals and natural levels of phenotypic variation in this highly variable genus may have led to the under-reporting of hybridization events (Hardig et al. 2000). Isolating mechanisms in *Salix* include differences in flowering time, habitats, and ploidy levels (Dorn 1976). Hybridization has never been reported for *S. serissima*. Its late flowering period should tend to act as a strong mechanism against hybridization with sympatric species. Fifteen other *Salix* species have been reported as occurring with *S. serissima* (**Table 2**), so the possibility for occasional, rare hybridization exists. Argus (1986b) discusses the phenotypic variation in members of section *Salicaster* other than *S. serissima*. Variations in leaf shape and pubescence in these species are common, but appear to be random occurrences that do not deserve taxonomic distinction. Moreover, most willows also exhibit phenotypic variations in response to environmental variables such as moisture, nutrients, shade, and wind (Argus 2001). This variability makes it important to use mature, typical branches for identification.

Endomycorrhizal fungi belonging to the taxonomic order Glomales are a key component of one of the most common underground symbioses. These endomycorrhizae are characterized by inter-and intracellular fungal growth in the root cortex where they form fungal structures known as vesicles and arbuscles (Quilambo 2003). Vesicular-arbuscular mycorrhizal (VAM) relationships are geographically widespread and occur in about 80 percent of all vascular plants (Raven et al. 1986). Association with VAM has been reported for a variety of *Salix* species (Harley and Harley 1987, Newman and Reddell 1987, Dhillion 1994). Ectomycorrhizal associations have also been reported in many *Salix* (Dhillion 1994, Thormann et al. 1999). Some species support both conditions simultaneously (Dhillion 1994). The mycorrhizal status of *S. serissima* has not been investigated.

Demography

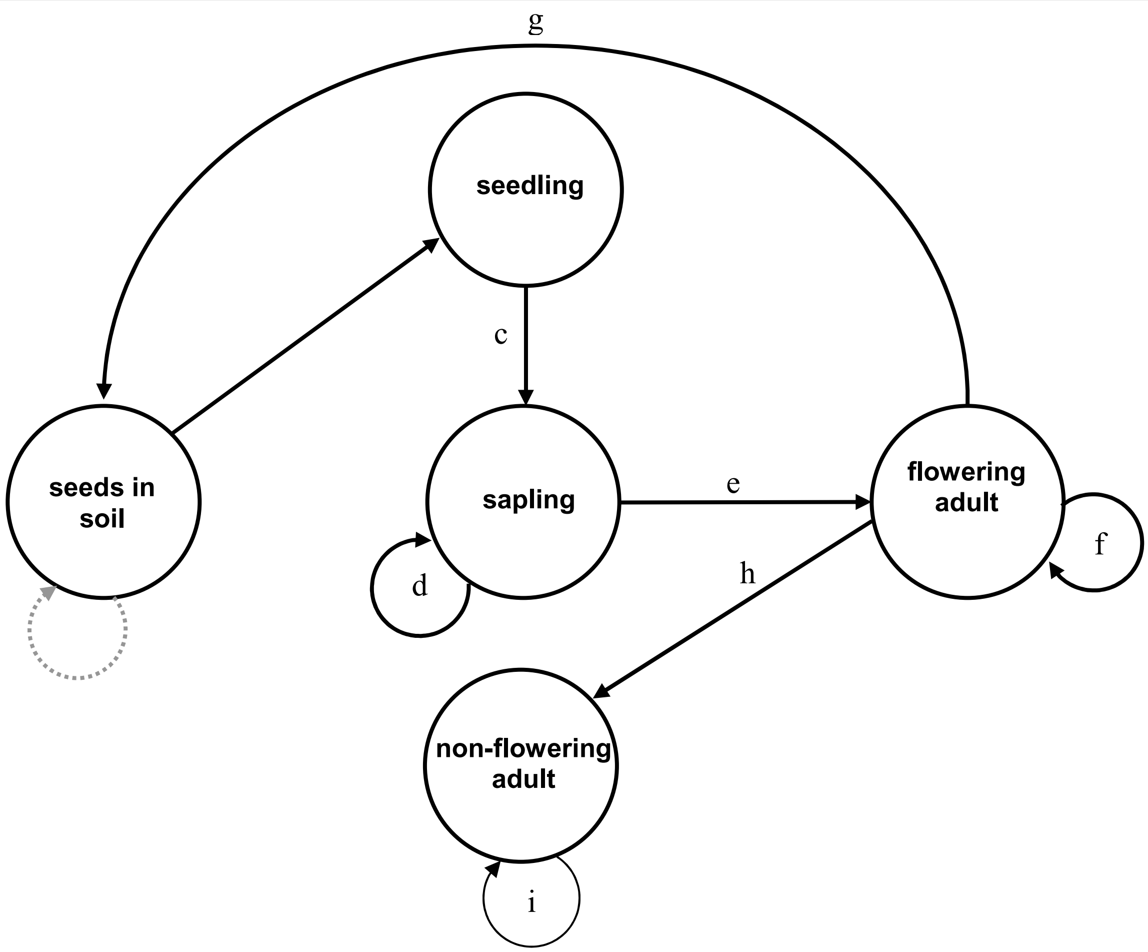
Recruitment, survival, reproductive age, and other vital rates for *Salix serissima* are unknown. Demographic studies in *Salix* are primarily of floodplain species. For willows of floodplain areas, population dynamics are heavily influenced by periodic flood events that allow recruitment of more or less distinct cohorts (e.g., Merigliano 1998). In such cases, large groups of individuals of the same age class are present, and few plants of intermediate age are evident. For plants of habitually saturated ground, such as *S. serissima*, disturbance events that allow recruitment are not necessarily tied to hydrologic events, and do not necessarily allow the establishment of large cohorts. Recruitment rates in all habitats are closely tied to the frequency and duration of disturbance events that create open sites. Mortality of established plants is presumably much lower, and plants are likely to survive for decades. Age at first flowering can be as low as two years for colonizing riparian species like *S. exigua* (Ottenbreit and Staniforth 1992); other

Table 2. Species associated with *Salix serissima* within USDA Forest Service Region 2. From element occurrence records and herbarium specimen labels.

Species	SD	WY	CO	Species	SD	WY	CO
Achillea millefolium	×			*Poa palustris*	×		
Agoseris glauca	×			*Populus tremuloides*	×		
Agrostis gigantea			×	*Ranunculus aquaticus* var. *fenestratus*	×		
Argentina anserina	×			*Salix bebbiana*	×	×	×
Aster spp.	×			*Salix boothii*		×	×
Betula glandulosa	×		×	*Salix brachycarpa*		×	×
Betula occidentalis	×			*Salix candida*	×	×	×
Bromus ciliatus	×			*Salix discolor*		×	
Calamagrostis canadensis	×			*Salix drummondiana*			×
Carex aquatilis		×	×	*Salix exigua*		×	
Carex nebrascensis	×			*Salix geyeriana*			×
Carex paupercula		×		*Salix interior*	×		
Carex retrorsa	×			*Salix lucida* ssp. *caudata*		×	
Carex simulata		×		*Salix ligulifolia*		×	×
Carex utriculata	×	×	×	*Salix monticola*		×	×
Cirsium arvense	×			*Salix myrtillifolia*			×
Dasiphora (*Pentaphylloides*) *floribunda*	×	×	×	*Salix petiolaris*	×	×	
Erigeron spp.	×			*Salix planifolia*	×		×
Eriophorum angustifolium ssp. *subarcticum*	×			*Salix pseudomonticola*	×		
Eriophorum polystachion	×			*Senecio pseudoaureus*	×		
Fragaria virginiana	×			*Spiranthes romanzoffiana*		×	
Gaillardia aristata	×			*Symphyotrichum boreale*	×	×	
Galium boreale	×			*Symphyotrichum falcatum* var. *falcatum*	×		
Gentiana affinis	×			*Thalictrum alpinum*			×
Geum aleppicum	×			*Thalictrum* spp.	×		
Juncus balticus	×			*Trifolium pratense*	×		
Lomatogonium rotatum		×		*Valeriana dioica*	×		
Mentha arvensis	×			*Valeriana edulis*	×		
Muhlenbergia glomerata	×			*Vicia americana*	×		
Parnassia palustris var. *montanensis*		×		*Viola* spp.	×		
Pedicularis groenlandica		×		*Zizia aptera*	×		
Phleum pratense	×						

species require up to ten years growth before becoming reproductive (Haeussler and Coates 1986). **Figure 5** shows a hypothetical life-cycle diagram for *S. serissima*. Because there are no studies of this species, transition probabilities are left unquantified.

It is not clear that metapopulation dynamics are operating in the extremely disjunct *Salix serissima* populations of Region 2. Due to the distance between populations, there is probably very little gene flow between most populations in Region 2. Flight distances of insect pollinators are poorly quantified, but distances of 10 to 50 miles have been reported for some species (Janzen 1971, Ghazoul 2005). Because *S. serissima* is primarily insect-pollinated, it is unlikely to have gene flow via biotic vectors between populations that are separated by distances of more than a few dozen miles. Although wind pollination can occur, most pollen is deposited close to its source (Levin and Kerster 1974). Under certain weather conditions, large amounts of pollen may be carried considerable distances from the source (Proctor et al. 1996), but if such long distance pollen dispersal events do occur in *S. serissima*, they are likely to be extremely rare.

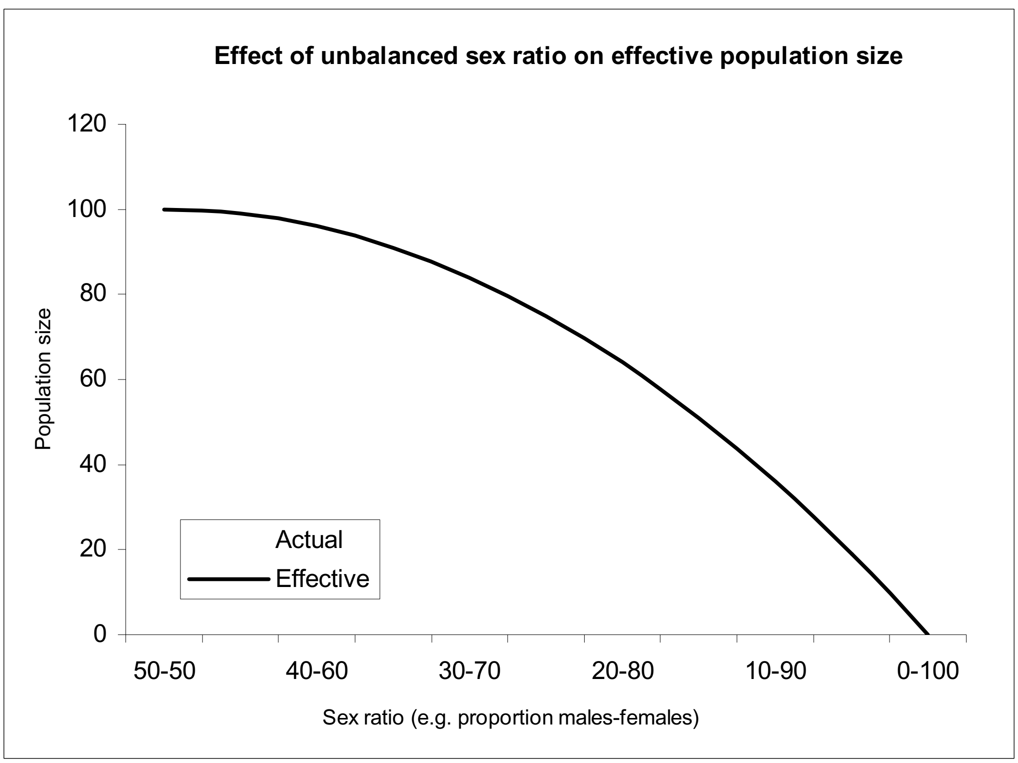


a. survival of dormant seeds in the seed bank (possibly none)
b. probability of seed becoming a seedling (extremely low)
c. survival of seedling to juvenile, pre-reproductive stage (low)
d. probability of juvenile remaining non-reproductive
e. probability of juvenile plant becoming reproductive
f. probability of flowering adult flowering again next year (very high)
g. seed production of flowering plants (high?)
h. probability of flowering adult not flowering next year
i. probability of non-flowering adult remaining non-flowering

Figure 5. Life-cycle diagram for *Salix serissima* (after Caswell 2001).

An important and perhaps often overlooked consequence of dioecy in plants is the effect of the sex ratio on effective population size (Hartl and Clark 1989). For dioecious species, any deviation of the sex ratio from equal numbers of male and female plants reduces the effective population size (**Figure 6**). A smaller effective population size increases the potential for inbreeding, genetic drift, and other consequences discussed above. Sex ratios have not been reported for any *Salix serissima* population.

Although potential problems for small, isolated populations are numerous, a variety of studies have concluded that small and peripheral populations can still be viable conservation targets (Lesica and Allendorf 1992, 1995, Lammi et al. 1999, Matthies et al. 2004). The theory of minimum viable population (MVP) was developed under the animal model of the sexually reproducing, obligate outcrossing individual, and it incorporated the effects of genetic stochasticity from elevated inbreeding coefficients in small population (Soulé 1980, Shaffer 1981). The MVP is the smallest population that is predicted to have a very high chance of survival for the foreseeable future (Primak 1995). Shaffer (1981) emphasized the probabilistic nature of the definition of an MVP, noting that survival probabilities and expected duration may be set at various levels (e.g., 95 percent, 99 percent or 100 percent, 100, 1000, or 10,000 years). Different "rule-of-thumb" estimates for MVP size have been suggested in response to the various types of uncertainty affecting populations (e.g., demographic stochasticity, environmental stochasticity, large scale natural catastrophe, and genetic stochasticity; see Shaffer 1981) Suggested MVP numbers have ranged from 50 to buffer demographic stochasticity, 500 to buffer genetic stochasticity (Franklin 1980), to a range of 1000 to 1,000,000 in the case of environmental stochasticity and natural catastrophes (Menges 1991). This variation in estimates highlights the necessity for Population Viability Analysis (PVA) models with robust parameters to be developed for each individual species. Such analyses, including numerical estimates of MVPs, require substantial empirical data and an understanding of the links among environmental



Effective population size (N_e) calculated as $N_e = \frac{4N_{males}N_{females}}{N_{males} + N_{females}}$ (Hartl and Clark 1989).

Figure 6. Effect of unbalanced sex ratio on effective population size.

variability, demography, and genetics in the species of interest (Menges 1991). There are currently no PVA models for *Salix serissima*.

Morris et al. (1999) discuss general classes of data sets and methods suitable for PVA including:

1) Count-based extinction analysis, which requires counts of individuals in a single population from censuses performed for a minimum of 10 years (preferably more).

2) Multi-site extinction analysis, which requires counts from multiple populations, including a multi-year census from at least one of those populations.

3) Projection matrix modeling, which requires detailed demographic information on individuals collected over three or more years (typically at only one or two sites).

Currently there are no data sets available that could be used for PVA of *Salix serissima*. Basic research on life-cycle stages of *S. serissima* would greatly facilitate viability analysis.

Community ecology

The community ecology of *Salix serissima* encompasses its interactions with populations of co-existing species, including competition for resources; the effects of herbivory, parasites, and disease; and any mutualistic or symbiotic interactions. Effects of competition and herbivory have not been investigated in *S. serissima*, but some inferences can be made from studies of its congeners and from its habitual association with peatland communities.

Peatland habitats are often densely vegetated, and species may have highly specialized niches along a micro-topographic or hydrologic gradient (Sanderson and March 1996). In spite of the tendency for niche specialization, mixed willow stands are common where *Salix serissima* is found, and any micro-topographic or hydrologic requirements that separate *S. serissima* from other willows and peatland vegetation are unknown. At the Rocky Mountain National Park site (#5 in **Table 1**), Cottrell (1995) found that *S. planifolia* was dominant in deep peat instead of the sympatric *S. monticola*, but attributed this to a greater ability of *S. planifolia* to colonize open sites rather than to competitive exclusion of established plants. The tendency for peatland species to rely on disturbance to create open sites for seedling establishment (Isselstein et al. 2002) means that *S. serissima* is likely to be in competition with other peatland plants for this resource as well.

Herbivory of *Salix serissima* has not been explicitly documented, but other species of *Salix* are known to be subject to herbivory. *Salix* species are often key structural components of wetland and riparian habitats, so the effects of grazing or browsing by domestic livestock, wild ungulates, beaver, and small mammals has been studied for numerous species. Some documented effects of vertebrate herbivory on willows include reduced aboveground biomass, height, survival, and sexual reproduction, as well as changes in plant morphology, population age, and size structure (Schulz and Leininger 1990, Maschinski 2001, Brookshire et al. 2002, Holland 2002). These effects can be seen in some instances even under relatively light levels of grazing (Brookshire et al. 2002) and may remain evident many years after the exclusion of grazers (Holland 2002). Effects of herbivory are generally related to the duration of exposure to herbivory, the amount of herbivore-free recovery time, and the numbers and kinds of herbivores present (Maschinski 2001). Trampling by large herbivores may contribute to the formation of open sites for seedling establishment, but it may also have a detrimental effect on the hydrology, microtopography, and canopy structure of a site (Stammel and Kiehl 2004).

Willows are subject to attack by a variety of insect herbivores (e.g., Stein et al. 1992, Kendall et al. 1996, Sipura 2002). The genus *Salix* apparently displays the spectrum of strategies between resistance to and tolerance of herbivory. Plants that develop chemical defenses (resistance) against herbivory are presumed to pay a price in reduced growth while plants that evolve tolerance to herbivory escape the metabolic costs of manufacturing secondary compounds and spend resources on regrowth instead. The rapid regrowth of some pioneering willow species is interpreted as tolerance to herbivory (e.g., Kudo 2003) while the characteristic phenolic glucoside salicylate produced by many *Salix* species acts as a defense against herbivory (e.g., Kendall et al. 1996). The strategy of *S. serissima* is not known, but the closely related *S. pentandra* is known to produce salicylates at the cost of additional growth (Ruuhola and Julkunen-Tiitto 2003).

Salix serissima is known to be susceptible to infection by a fungal rust of the genus *Melampsora*, thought to be *M. ribesii-pupureae*, a fungus that also infects gooseberry (*Ribes* spp.) (Hornbeck et al. 2003). *Salix serissima* populations may be more likely to be infected with the rust if *Ribes* species are present nearby. Plants infected with this fungus have been observed at the McIntosh Fen occurrence (#13 in **Table 1**) in the Black Hills. Hornbeck et al. (2003) speculated that since the fungus appears late in the growing season, it may not present a risk to the occurrence at this time. Monitoring efforts are planned to detect potential harmful effects of the fungus at McIntosh Fen (Hornbeck et al. 2003). Willows are also susceptible to a variety of insect borers and gall-forming species (e.g., Froiland 1962, Sipura 2002, Collet 2002), and Hornbeck et al. (2003) report that willow borers have damaged or killed *S. serissima* at the Middle Boxelder Creek site (#12 in **Table 1**). Several plants in the Wyoming occurrence have been reported as being infected with an orange rust fungus (species unknown) as well as showing signs of gall infestation (Wyoming Natural Diversity Database 2005).

Conservation

Threats

Based on the available information, there are a variety of threats to the persistence of *Salix serissima* in Region 2. In order of decreasing priority, these are hydrologic alterations, global climate change, consequences arising from small population size, grazing, peat mining, recreational use, alteration of natural fire regime, road construction/maintenance, and invasive species.

Altered hydrology

Due to the specialization of *Salix serissima* on peatland habitats, hydrologic alteration is the foremost threat to the species. Changes in hydrologic regime can influence nutrient cycles, sedimentation, soil oxygen levels, fragmentation, and habitat quality in wetland systems, resulting in altered vegetation composition. Most of the threats listed below, such as grazing, vehicle use in wetlands, road construction activities, peat mining, and global climate change, can influence the hydrology of *S. serissima* habitat in addition directly affecting populations and individual plants.

Any alteration that disrupts saturated soils and peat formation is likely to adversely affect *Salix serissima*. Hydrologic alteration can result from numerous natural and human impacts to watersheds supporting *S. serissima* occurrences, including diversions, ditching, groundwater withdrawals, long-term drought, elimination of beaver populations, and high tree density in adjacent uplands (Bursik and Moseley 1992, Chadde et al. 1998, Charman 2002). Diversions and groundwater withdrawal may be for local agricultural use or to meet the water needs of municipalities outside the immediate area. For example, in the mid 1990's, the South Park Conjunctive Use Project proposal would have drawn water from creeks and from the water table under the wetlands in South Park to supply the city of Aurora in the Denver Metro area with 20,000 acre-feet of water per year (Federal Register: February 4, 2005 - Volume 70, Number 23). Modeling of the potential effects of this project predicted groundwater drawdowns across much of the north end of the park ranging from 0.5 ft. to many tens or even hundreds of feet (Sanderson personal communication 2005). Sanderson's (2000) assessment of the potential effects of this drawdown on another fen species (*Ptilagrostis porteri*) concluded that because many wetland plants are sensitive to drawdowns of 0.5 feet or less, such withdrawals could seriously damage fens in South Park. The South Park Conjunctive Use Project proposal was ultimately rejected, but growing water requirements along the Colorado Front Range mean that similar proposals may appear in the future.

Several *Salix serissima* occurrences in Region 2 have already experienced hydrological alterations. At McIntosh Fen in the Black Hills, the current fen size is apparently smaller than it was when originally reported, due to the effects of drainage ditches that were dug when the area was under private ownership (Hornbeck et al. 2003). Recent restoration efforts appear to have mitigated this damage to some extent. At the Crow Creek occurrence in Wyoming, trampling by domestic livestock appears to have modified the surface structure to some extent (hummocking) and probably altered hydrology in some areas (Heidel and Laursen 2003). The presence of a road at one end of the fen may also have altered hydrology in the area. The Inn Brook site in Larimer County, Colorado, where *S. serissima* was first discovered in the state, has undergone severe hydrological modification, and the occurrence may have been extirpated (Colorado Natural Heritage Program 2005). The High Creek Fen site in Park County, Colorado, has been ditched in places, with possible adverse effects to site hydrology (Spackman et al. 2001). Irrigation diversions around the Jefferson site (also in Park County) do not appear to have had a significant impact on site hydrology to date (Spackman et al. 2001). At Phillips Creek in Routt County, the occurrence is adjacent to agricultural lands including irrigated hay meadows, but the hydrology appears to have been minimally affected by these activities to date (Culver and Sanderson 1996). Hydrology at the Haviland Lake occurrence in La Plata County is reported to be intact despite the nearby presence of roads, dams, and residential development (March et al. 2004). Hydrological conditions for other locations are unknown.

Global climate change

Although global climate change is potentially the most serious threat to the persistence of *Salix serissima* in Region 2, there is great uncertainty regarding its regional effects and severity. Although global climate change is likely to have wide-ranging effects in the near future for all habitats, changes will be most obvious in ecosystems where the structure and composition are strongly influenced by limiting conditions of temperature or rainfall (Walker 1991), such as peatlands. Peters and Lovejoy (1992) summarized characteristics of species or populations that are expected to be most susceptible to climate change:

- ❖ peripheral populations that are at the contracting edge of a species' range
- ❖ geographically localized species
- ❖ highly specialized species
- ❖ poor dispersers
- ❖ montane and alpine communities
- ❖ arctic communities
- ❖ coastal communities.

Populations of *S. serissima* in Region 2 are certainly peripheral, with specialized habitat requirements, and often occur in montane areas. The effects of global climate change in Region 2 will not necessarily have the same effect on *S. serissima* as in its primary distribution in northern boreal ecosystems (Gates 1993).

Predicted effects of climate change include loss of species diversity, change in phenology, increase in incidence of species invasions or disease, and change in correlations between ecological factors that are important for species survival (Gates 1993, McCarty 2001, Walther et al. 2002). Temperature changes due to climate change could also alter the duration and frequency of insect herbivory for many species (Bale et al. 2002). For *S. serissima*, climate change is most likely to have an impact through changes in hydrology and temperature that affect the local nutrient and moisture availability as well as the physical process of peat formation, rather than a direct limiting effect on individual plants (Charman 2002). Finally, the effects of climate change could also result in shifts in vegetation dominance that would eventually eliminate *S. serissima* from its habitat. Because of the disjunct nature of *S. serissima* populations in the southern extent of the range, and the fact that these populations will be unable to retreat to more suitable conditions nearby, this threat is pertinent to all occurrences within Region 2.

Small population size

Most *Salix serissima* occurrences in Region 2 are small enough for the consequences of demographic, genetic, and environmental stochasticity to be important considerations. In small populations, the effects of these processes are increased relative to larger populations. Demographic stochasticity, or the chance variation in vital rates such as reproduction and survival, is thought to be relevant only to populations of 50 or fewer (Menges 1991). Reported numbers of individuals at several *S. serissima* populations in Region 2 are sufficient to buffer against the probability that a fluctuation in vital rates will take the population to the extinction threshold. For most populations, numbers are either unknown or below the generally accepted minimum of 50. As a dioecious plant, *S. serissima* is also vulnerable to chance variation in the population sex ratio that could drastically reduce effective population sizes, or even eliminate one sex from the population altogether. Although sex ratios are not known for any *S. serissima* populations, at least one other sensitive *Salix* species in Region 2 (*S. myrtillifolia*) has a population consisting of only female plants (Neid et al. 2004), and the possibility of a similar occurrence for *S. serissima* cannot be ruled out at this time.

The potential genetic consequences of small population size include increased inbreeding, loss of genetic variation due to genetic drift, and the accumulation of deleterious mutations (Matthies et al. 2004). Inbreeding depression, or a loss of fitness due to decreased heterozygosity, results from an increased number of matings between closely related individuals. Although inbreeding through selfing is not a concern for *Salix serissima*, in isolated populations, matings are necessarily between individuals that are more closely related than are two randomly chosen members of the species. In isolated populations, loss of genetic variation by drift is not compensated for by immigration of seeds or pollen from other populations (Oostermeijer et al. 2003).

Finally, environmental stochasticity, or temporal variation in reproduction and survival as a consequence of changing environmental conditions such as weather, herbivory, pollinator availability, and other factors, can also lead to local extinction (Lande 1998, Oostermeijer et al. 2003). For a single population, this includes natural events happening at random intervals that cause mortality of a large proportion of individuals in the population. Such events may occur very rarely, but they can still have a large impact on the persistence of the population (Menges 1991). For *Salix serissima*, severe drought and outbreaks of fungal rust or insect borers could be significant environmental events. Multiple populations can have a mitigating effect against environmental stochasticity. For disjunct populations, however, catastrophic local events can eliminate the species from part of a region.

Grazing

Major impacts of grazing by both domestic livestock and large native herbivores such as elk or moose include removal and reduction of vegetation, compaction of soil, and increased erosion. These impacts have been shown to affect hydrology, water chemistry, and other variables (Menke 1977, Johnston and Brown 1979, Chadde et al. 1998). Pearson and Leoschke (1992) found that grazing modified the vegetation structure of the fen plant community through selective utilization of plant species and altered the physical structure of the wetland by trampling. Grazing animals can create paths in peaty soils, eventually channeling water that would otherwise move through the sloped peatlands in a sheet fashion, resulting in increased drainage (Windell et al. 1986, Bursik 1993, Chadde et al. 1998). If the grazing regime is intense enough to produce channelization, the extent of fen habitat will be reduced and animal traffic may increase (Bursik 1993).

Grazing by domestic livestock has been observed at several *Salix serissima* occurrences in Region 2, and all Region 2 occurrences are likely to be grazed by native herbivores. Heidel and Laursen (2003) report that in some areas of the peatland at the Crow Creek occurrence in Wyoming nearly half of the herbaceous vegetation was removed by grazing. Most vegetation in the fen showed signs of trampling, and some areas had hummock development. Trampling and other indirect effects of grazing have also shifted vegetation composition at the site. Grazing status of South Dakota occurrences on private lands is unknown. In the past the McIntosh Fen occurrence on the Black Hills National Forest has been subject to trespass grazing, but the installation of gates was planned to mitigate this problem (Hornbeck et al. 2003). The Middle Boxelder Creek occurrence is fenced to exclude livestock. In Colorado, the Phillips Creek site in Routt County is grazed by cattle, but there appear to be fewer impacts in the peatland than in adjacent drier areas (Culver and Sanderson 1996). The occurrence near Jefferson in Park County is exposed to grazing by cattle, and the nearby High Creek Fen occurrence has been subject to trespass grazing as well (Spackman et al. 2001). The Sheep Creek area in Larimer County was very heavily grazed prior to the 1940's (Schulz and Leininger 1990) and is currently grazed at a much lower stocking rate (Holland 2002). The *S. serissima* occurrence in Rocky Mountain National Park is protected from grazing by domestic livestock, but it is likely to be subject to extremely heavy browsing by elk (Peinetti et al. 2002). The response of *S. serissima* to grazing at these locations has not been reported. Grazing status of other occurrences is unknown.

Peat mining

Colorado is the only area in Region 2 where commercial peat mining is permitted and is ongoing (USDI Bureau of Mines 1994, Austin personal communication 2004). In Colorado, peat is primarily mined for horticultural use. Peat mining has the effect of reducing vegetation cover and species richness, altering species composition, eliminating microtopography, and altering edaphic properties. These effects generally change soil and groundwater chemistry, seriously impairing wetland functioning (Johnson 2000). Peat mining also severely alters hydrology, interrupting the sheet flow of water that maintains peat formation. Due to its slow accumulation rates (20 to 28 cm per 1,000 years; Cooper 1986), peat in Region 2 cannot be considered a renewable resource. There has been peat mining in the past immediately adjacent to the High Creek Fen occurrence (Spackman et al. 2001). Although none of the documented occurrences of *S. serissima* in Region 2 is known to be currently affected by peat mining, it is likely that occurrences were affected by previous mining activities. Where *S. serissima* occurs in substantial peat deposits on private lands, it is still potentially threatened by peat mining activities.

Recreation

Threats to *Salix serissima* from recreational use vary with the type and intensity of use. The most serious threat is from illegal off-road vehicular use of wetlands, a practice known as mud-bogging. It is very difficult, if not impossible, to control this type of activity, and on several occasions, mud-boggers have destroyed wetlands (Caspar Star-Tribune, April 17, 2003). Incidental trespass by off-road vehicle users may produce similar damage. Habitat that is in close proximity to roads is likely to be at increased risk of damage from off-road vehicles, but the prevalence of these vehicles on public lands throughout Region 2 means that most wetlands on public lands are potentially at risk. Trampling or trail-making by hikers, fishers, hunters, or pack stock may damage peatlands by breaking up peat, changing flow patterns, and lowering the water table in addition to damaging or destroying individual plants.

Road construction and maintenance

Roads and trails impact wetlands by affecting key physical processes such as water runoff and sediment yield. Even at some distance from a wetland, a road can concentrate water flows, increase flow rate, increase erosion, and reduce percolation and aquifer recharge rates (Forman and Alexander 1998). The Wyoming occurrence of *Salix serissima* on the North Branch of Crow Creek is the most directly threatened by road building activity (Heidel and Laursen 2003). All known Colorado occurrences are within half a mile of roads; most are probably much closer. Both occurrences on the Black Hills National Forest are near roads that may indirectly affect hydrological flows (Hornbeck et al. 2003). In most cases, the presence of roads can also facilitate the spread of invasive species (see below).

Fire

In general, the wetness of peatlands means that they are less susceptible to fire than the surrounding landscape although dry summer conditions can allow top layers of peat to become combustible (Charman 2002). While fire return intervals in boreal fen systems are generally long, fire is an important mechanism in maintaining non-forested open wetland conditions and preventing the terrestrialization of fen habitat (Charman 2002). Fire frequency and severity are likely to be different for disjunct populations of *Salix serissima* in Region 2 in comparison with occurrences in boreal communities in the heart of its range.

Fire suppression and the subsequent increase of woody vegetation in the surrounding uplands can affect the hydrology of peatland habitat. There is no information available on the response of *Salix serissima* to fire, but *Salix* species are generally assumed to resprout from the root crown when top-killed by fire (FEIS). A rare catastrophic fire could easily damage or destroy a small population of *S. serissima*. No documented occurrences in Region 2 are known to have been affected by fire.

Invasive species

Direct impacts to *Salix serissima* from invasive species have not been reported, and the magnitude of this threat is not known. Canada thistle (*Cirsium arvense*), butter and eggs (*Linaria vulgaris*), and houndstongue (*Cynoglossum officinale*) are known to occur in close proximity to both occurrences in the Black Hills National Forest (Hornbeck et al. 2003), and they are likely to affect nearby occurrences on private land as well. It is possible that restoration of the hydrology at these sites may make them vulnerable to invasion by purple loosestrife (*Lythrum salicaria*), which has been documented near Rapid City, South Dakota, approximately 20 to 25 miles east of the sites (Hornbeck et al. 2003). The Crow Creek occurrence in Wyoming is largely free of exotic species (Heidel and Laursen 2003), but its proximity to a road makes it vulnerable to the spread of invasive species from elsewhere. Colorado occurrences known to be threatened by the expansion of non-native species are Haviland in La Plata County, where Canada thistle, houndstongue, and musk thistle (*Cardus nutans*) may invade from the south (March et al. 2004), and High Creek Fen in Park County, where a small patch of Canada thistle has been documented (Spackman et al. 2001).

Conservation Status of Salix serissima in Region 2

There is insufficient information about population sizes to determine the stability of *Salix serissima* in Region 2. Although occurrences at McIntosh Fen and Crow Creek are believed to be stable, there is no evidence that occurrences other than the restored occurrence at McIntosh Fen are expanding. Likewise, there is little direct evidence to show that the species is in decline in the region. The current perception of its insecure status in Region 2 arises from the low number of occurrences, small or unknown population sizes, and the disjunct or peripheral nature of these populations.

There are 14 known occurrences of *Salix serissima* in Region 2, and most of these have fewer than 100 individuals. For a few occurrences with abundance estimates, numbers appear to be sufficient to mitigate against genetic and demographic stochasticity. The total number of individuals in Region 2 is unknown but may be fewer than 1000. Occurrences are isolated from each other to a great extent, making the recolonization of extirpated sites unlikely without human intervention. Stochastic processes and normal environmental variation could easily result in extirpation of any of the Region 2 populations, regardless of current levels of protection.

Salix serissima depends on a small-patch type of habitat that is found only in a narrow range of environmental conditions, where it is often isolated from similar habitat on the landscape. Moreover, populations in Region 2 at the edge of the normal range of the species are probably found in environmental conditions that would be atypical compared to those experienced by populations farther north. The current distribution and abundance of *S. serissima* in Region 2 are primarily the legacy of the retreat of glacial conditions of the Pleistocene. As glaciation ended, *S. serissima*, along with many other species of boreal habitats, generally migrated north, following the retreating ice. In a few isolated locations, local conditions (i.e., peatlands) allowed for the persistence of relictual populations. Although these isolated populations may have shifted somewhat as habitat shifted during short term climate changes, these glacial disjuncts are now isolated both from other disjunct populations and from the central range of the species. Ultimately, the survival of these species in Region 2 habitats depends on future climatic trends as well as on the conservation efforts of land managers and owners. It is important for land managers to consider the cumulative impacts of all threats discussed, as well as their potential interaction with natural disturbances.

Management of Salix serissima in Region 2

Implications and potential conservation elements

There is no documentation of the consequences of historic, ongoing, or proposed management activities on the abundance and distribution of *Salix serissima* on a regionwide basis. Conservation management has only recently been implemented for the two Black Hills National Forest occurrences. Although current knowledge of the distribution and abundance of *S. serissima* suggests that the species' presence is precarious in Region 2 due to its specialization on a relatively rare habitat and a small number of disjunct occurrences, additional information is needed to clarify its status. We also know very little about patterns of abundance throughout the main part of its distribution, which makes it difficult to determine the importance of Region 2 occurrences. The potential significance of Region 2 occurrences would be increased if *S. serissima* occurs primarily in small, widely scattered populations throughout its extensive range.

Disjunct and peripheral populations of *Salix serissima* are of interest to conservationists even when the survival of the species does not depend directly on these populations. *Salix serissima* is part of a unique relictual post-glacial community that provides key information about the Quaternary natural history of the North American continent. Peripheral populations may be important as genetic reserves since outlying populations sometimes contain atypical genetic variation in response to different environmental conditions at the edge of the species' ecological range (Lesica and Allendorf 1995). Peripheral and disjunct populations can also be important resources for research in biogeography, metapopulation dynamics, population genetics, and other topics.

Salix serissima populations in Region 2 are most vulnerable to changes in the environment that affect their peatland habitat. Any management activities that maintain the proper hydrologic regime for these habitats will contribute to the persistence of *S. serissima*. This includes the regulation and monitoring of hydrological modifications, domestic or wildlife grazing, fire suppression or reclamation, logging, mining, and road construction, and recreational use. Hydrological modifications are pervasive throughout the range of *S. serissima*. Natural environmental changes may also affect the peatland habitat favored by *S. serissima*. Changes in precipitation patterns and effects of natural disturbances elsewhere in the watershed may also lead to altered hydrology that is detrimental to the persistence of *S. serissima*. In these instances, management policy could focus on mitigating these effects when feasible.

The establishment of protected areas that are managed for the conservation of *Salix serissima* is a useful conservation strategy for this species. A Special Interest Area designation or Research Natural Area status for the Medicine Bow National Forest occurrence could help to ensure the protection of this species on USFS lands in Wyoming.

Desired environmental conditions for *Salix serissima* include an intact natural hydrological regime with little or no evidence of wetland alteration due to increased or decreased drainage, clearing, livestock grazing, anthropogenic nutrient inputs, or mining (especially peat mining). Conservation management for *S. serissima* may require restoring water tables and drainages, changing livestock management, controlling invasive species, and establishing seedlings or cuttings. Management activities may need to focus on adjacent land use as well.

Tools and practices

The relocation and census of reported occurrences that have not been recently counted or observed is a priority for *Salix serissima* because it will clarify the relative importance of known occurrences to conservation of the species in Region 2. The identification of potential habitat and the subsequent search for additional occurrences are also high priorities for *S. serissima*. Tools available to the USFS for conservation of *S. serissima* in Region 2 include continued listing as a sensitive species, regulating the use of USFS lands where the species occurs, and increasing the protective level of management area designations for *S. serissima* occurrences. Finally, conservation efforts for *S. serissima* and other sensitive species can be enhanced by information sharing among management agencies and among different units of the same agency. Wider dissemination of such information will facilitate the analysis of cumulative threats to the species across the region.

Species and habitat inventory

It is important to census known occurrences of *Salix serissima* and to determine approximate numbers of individuals of each sex in each occurrence. Inventory efforts will be most effective during the flowering and fruiting season (June to September), especially when the sex of individual *S. serissima* plants can be determined. For occurrences whose exact location is uncertain, the acquisition of precise location data would be helpful in tracking population trends in Region 2, and in determining management responsibility. Initial efforts could concentrate on similar habitat (i.e., peatland) near known occurrences. Search areas can be closely linked to digital, georeferenced data, especially aerial photographs (both visual spectrum and infrared images), detailed soil maps, and vegetation maps. Locations of known occurrences overlaid on aerial imagery would provide a quick method of identifying the extent of similar habitat in the areas where *S. serissima* has been documented. This information can be cross-checked and augmented with the expert knowledge of local USFS personnel who are familiar with the area.

Existing protocols for species inventory are primarily based on surveys for rare, threatened, or endangered species. The following recommendations are adapted from USFWS (2000), California Native Plant Society (2001), and Cypher (2002). Areas with the highest likelihood of new occurrences are those with appropriate hydric and edaphic qualities, especially peatlands that have not been previously inventoried. The use of aerial photography, topographic maps, soil maps, and geology maps to refine search areas when conducting inventories of large areas has been highly effective in Colorado and elsewhere. It is most effective for species about which we have basic knowledge of its substrate (i.e., peatlands) and habitat specificity from which distribution patterns and potential search areas can be deduced. Surveys should be conducted by trained professionals who are familiar with the taxa in question. In addition, USFS personnel who visit likely habitat in the course of other work can be alerted to check for the presence of *Salix serissima*, and to record possible occurrences carefully. Personnel for the initial survey should be familiar with detailed methods of soil and habitat characterization. The return from the effort invested in species inventory will be maximized by careful documentation of results, both positive and negative. A comprehensive survey report would document the location that was visited, the date of the visit, the number and condition of individuals in the occurrence, the presence of carpellate and staminate plants, habitat and associated species information, evidence of disease or predation, and any other pertinent observations. The use of Global Positioning System (GPS) devices allows for quick and accurate data collection of location and occurrence extent. If a new occurrence of *S. serissima* is located, then a completed element occurrence report form for the appropriate state, accompanied by a copy of the appropriate portion of a 7.5-minute topographic map with the occurrence mapped, should be submitted to the state Natural Heritage Program. Occurrence boundaries should be mapped as accurately as possible. It is appropriate to collect voucher specimens if the occurrence size permits, and to submit them to regional herbaria. Regardless of occurrence size, voucher photographs should be taken, and the location should be determined as exactly as possible. Occurrences located on National Forest System lands could be permanently marked in some way, to facilitate population monitoring. The use of multiple markers (e.g., corner stakes) and GPS coordinates can be great help in relocating occurrences. Records should also document areas that were searched unsuccessfully. However, negative results are not a guarantee that the plant is absent from an area.

Conclusions about the need for further inventory, the extent of the population, and critical habitat characteristics should be shared among state and federal agencies, natural heritage programs, local and regional experts, and interested members of the public. Surveys usually attempt to target all species of concern in an area. In the case of inventory for *Salix serissima*, this practice is particularly applicable since there are many other rare species in the peatland habitats that support *S. serissima*. Although peatlands are significant biodiversity resources, habitat inventory of peatlands has not been done on a regionwide basis (Heidel and Laursen 2003). A regionwide peatland inventory could provide habitat information for a variety of species of concern. Although a complete inventory of peatlands in Region 2 would be a major undertaking, an effort similar to that of Chadde et al. (1998) in the Northern Rocky Mountains would be extremely useful.

Population and habitat monitoring

Monitoring efforts are most effective when goals and objectives are clearly stated and collected data are sufficient to reveal trends. Elzinga et al. (1998) provide a thorough discussion of monitoring program design. Monitoring population trends and the effects of management or management changes would provide the most immediately useful information for land managers. Monitoring sites under a variety of land use scenarios will help to identify appropriate management practices for *Salix serissima* and help managers to understand its population dynamics and structure. To be effective, the implementation of such monitoring must be accompanied by a resolve to adjust management practices based on the results.

The Black Hills National Forest has been monitoring *Salix serissima* at McIntosh Fen since 2001. Baseline data were collected as an aid to developing monitoring questions, and monitoring protocols are intended to be adaptively modified as necessary to address these questions. Monitoring of *S. serissima* and other sensitive species is intended to determine whether the species is persisting on the Black Hills National Forest, and if so, whether occurrences are in good condition, relative to individuals, the population, and the habitat (Burkhart 2005). Following the 2004 monitoring season, the monitoring protocol was revised to include the following steps (Burkhart 2005):

1. Use GPS to determine the endpoints of two subpopulation boundaries that were delineated through previous monitoring efforts.

2. Establish a minimum of 10 permanent markers along the boundaries and assess the condition/vigor of the five closest individuals/clumps, including rust infection.

3. Take annual surface water measurements along established transects.

4. Document any noxious weeds or other invasive species and note whether weeds are co-located with *Salix serissima*, or at what distance the weeds are located from the occurrence (if occupying the same ecological community type).

This example of a basic monitoring protocol could easily be adapted to the site-specific conditions and management questions of other *S. serissima* occurrences.

Additional monitoring that collects demographic data on growth patterns, recruitment, seed production, plant longevity, and population variability can also provide useful information for both management and the scientific community, but may be of lower priority. The apparent small size of many known occurrences means that it may be possible to monitor all individuals, and even to collect demographic data with a slight additional effort. The first year of monitoring might concentrate on establishing the timing of critical seasonal elements such as flowering and fruit set, and on determining the most useful and practical data collection protocols. Subsequent years could concentrate on collecting data at these established times.

For peatlands that support *Salix serissima*, habitat monitoring can be conducted concurrently with population monitoring. Because the peatland habitat of *S. serissima* often supports other regionally rare species and communities, habitat monitoring would be the most efficient way to detect impacts and population trends for a suite of important resources. Monitoring soil moisture, water table, and water chemistry would be useful for this species since it relies on a narrow range of hydrologic conditions. Documenting the scope and severity of any disturbance in monitored occurrences would also be useful. Correlation of this information with population trends would greatly augment our present understanding of the habitat requirements and management needs of *S. serissima*.

Habitat monitoring of known *Salix serissima* occurrences will alert managers to new impacts such as damage from anthropogenic activities or grazing, and allow proactive management changes to be implemented in time to prevent serious damage to occurrences. Change in environmental variables might not cause observable demographic repercussions for several years, so resampling the chosen variables may help to identify underlying causes of population trends. Geographic Information System (GIS) technology can provide a powerful tool in the analysis of the scope and severity of habitat impacts. Alternatively, the use of photopoints for habitat monitoring is a technique that can be done quickly in the field. Techniques are described in Elzinga et al. (1998). Practical details of photographic monitoring are covered exhaustively in Hall (2001). Although it does not provide detailed cover or abundance data, it can help to elucidate patterns observed in quantitative data.

Seed banking and restoration methods

No seeds or genetic material are currently in storage for *Salix serissima* at the National Center for Genetic Resource Preservation (Miller personal communication 2004). Nor is it among the National Collection of Endangered Plants maintained by the Center for Plant Conservation (Center for Plant Conservation 2004). Determining the dormancy status of *S. serissima* seeds will have important implications for the potential preservation of its genetic diversity through seed storage.

Restoration methods have been developed as part of the restoration efforts at McIntosh Fen in the Black Hills. Initial efforts focused on restoring the hydrologic function of the fen by filling ditches with straw bales, and augmenting the population of *Salix serissima* by planting rooted cuttings (Hornbeck et al. 2003).

Information Needs

The foremost need for *Salix serissima* is surveys for additional occurrences, especially on public lands. It would also be useful to determine site conditions, population numbers, and sex ratios for known occurrences throughout the region. Basic life history information, including the possibility of seed dormancy, rates of recruitment and survival, the effects of disease and insect outbreaks, and genetic variation would contribute to conservation and restoration efforts. Finally, the restoration and monitoring methods developed for the McIntosh Fen occurrence in the Black Hills, together with results, analyses, and lessons learned, should be made available to other land managers and owners as soon as possible.

DEFINITIONS

Ament – same as catkin.

Bud scale – modified leaves covering a bud (Harris and Harris 1994).

Catkin – an inflorescence consisting of a dense spike or raceme of apetalous, unisexual flowers (Harris and Harris 1994).

Cohort – a group of individual plants that became established in the same year.

Coma – a tuft of hairs on the tip of a seed (Harris and Harris 1994).

Congener – a member of the same genus.

Dioecious, Dioecy – plant breeding system in which male and female reproductive structures are borne on different plants (Allaby 1998).

Disjunct – occurring in two or more widely separated geographic areas (Weber and Wittmann 2001).

Dormant – of seeds, a condition where germination is inhibited that must be broken by external stimuli such as moisture, light, temperature change, seed coat abrasion, etc.

Effective population size – the size of an ideal population (i.e., one that meets all the Hardy-Weinberg assumptions) that has the same properties with respect to genetic drift as that of the observed population; usually smaller than the observed population size.

Endomycorrhizal – involving a symbiotic relationship between a fungus and the root of the plant in which the fungal hyphae grow between and within the root cells.

Extremely rich fen – a type of fen whose pH and calcium concentration values are on the upper end of the continuous range of fen variation; generally fens with pH >7 and calcium concentration >20 to 30 mg/l.

Hermaphroditism – the condition of having both male and female reproductive structures present in the same individual.

Heterozygosity - a measure of genetic diversity within and between populations, expressed as the frequency of having two different alleles of the same gene across individuals.

Inbreeding depression – a decrease in vigor among offspring after inbreeding, due to an increase in the homozygous expression of deleterious genes.

K-selected species – relatively long-lived species that produces only a few, often fairly large progeny.

Lanceolate – long and narrow, broadest at the base (Weber and Wittmann 2001).

Metapopulation dynamics – the spatial and temporal variations of a set of interacting populations of the same species.

Oblanceolate – reversely lanceolate, long and narrow, but broadest at the tip instead of the base (Weber and Wittmann 2001).

Outcrossing – mating between unrelated individuals.

Paludification – the conversion of land into a peat-forming ecosystem.

Potential Conservation Area (PCA) – a best estimate of the primary area supporting the long-term survival of targeted species or natural communities; PCAs are circumscribed for planning purposes only (Colorado Natural Heritage Program Site Committee 2001).

Precocious – of flowers, emerging before leaves are developed.

Rank – used by Natural Heritage Programs, Natural Heritage Inventories, Natural Diversity Databases, and NatureServe. Global imperilment (G) ranks are based on the range-wide status of a species. State-province imperilment (S) ranks are based on the status of a species in an individual state or province. State-province and Global ranks are denoted, respectively, with an “S” or a “G” followed by a character (NatureServe 2005). *These ranks should not be interpreted as legal designations*.

Rich fen – a type of fen that has a middle range of pH (generally >5.7) and calcium concentration (>10 mg/l) in comparison with poor fens (more acidic) and extremely rich fens (more alkaline).

Rill – a small, intermittent watercourse with steep sides; usually only several centimeters deep (Horton 1999).

Riparian – pertaining to the banks of a river, stream, waterway, or other, typically, flowing body of water as well as to plant communities along such bodies of water (Horton 1999).

Serotinous – late developing; of flowers – emerging after leaves are developed.

Sheet flow – the overland flow or downslope movement of water in the form of a thin, continuous film over relatively smooth soil or rock surfaces and not concentrated into channels larger than rills (Horton 1999).

Stochasticity – random processes, governed by chance.

Sympatric – applied to species whose habitats (ranges) overlap (Allaby 1998).

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