Salix myrtillifolia Anderss. (blueberry willow): A Technical Conservation Assessment

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Cover Photo Credit

Salix myrtillifolia (blueberry willow). Photograph by Janet Coles; use of the photo provided by the Colorado Natural Areas Program.

Summary of Key Components for Conservation of *Salix myrtillifolia*

Status

Salix myrtillifolia (blueberry willow) is a boreal species that occurs as a relictual disjunct in the Rocky Mountain Region (Region 2) of the USDA Forest Service (USFS). Populations are known only from highly specialized, extremely rich fens in two disjunct areas in Region 2, the mountains of central Colorado and of northwestern Wyoming. Of eight known locations of *S. myrtillifolia* in Region 2, two are within the management jurisdiction of the USFS. These include one location in the Swamp Lake Special Botanical Area on the Shoshone National Forest in Wyoming and one on the Pike-San Isabel National Forest in Colorado. *Salix myrtillifolia* is considered a sensitive species in Region 2. It is ranked G5 (secure - common; widespread and abundant) in its global range by NatureServe, but considered rare (S1; critically imperiled) by the Colorado Natural Heritage Program and Wyoming Natural Diversity Database because of its very limited distribution in these states. It is not listed as threatened or endangered on the federal endangered species list.

Primary Threats

Primary threats to *Salix myrtillifolia* in Region 2 are hydrologic alteration, peat mining, and global climate change. In addition to these general threats, site-specific threats to *S. myrtillifolia* include livestock grazing and catastrophic fire. The habitat of *S. myrtillifolia* in Region 2 is extremely rich fens, which are complex wetlands maintained by unique hydrology. They are particularly restricted in distribution and abundance and sensitive to environmental perturbation. Certain types of habitat degradation may produce impacts from which these fens cannot be restored. Therefore, every effort should be made to prevent degradation of water quality and alteration of the natural hydrologic regime of these wetlands, including the quantity of water reaching the wetland and the inter- and intra-annual variation in the water table.

The single occurrence of *Salix myrtillifolia* at Swamp Lake on the Shoshone National Forest in Wyoming may be at risk due to a unique threat, an absence of male plants. This population is only able to reproduce vegetatively and unable to produce viable seeds.

Primary Conservation Elements, Management Implications and Considerations

Our current understanding of *Salix myrtillifolia* distribution and abundance in Region 2 suggests that the species is vulnerable in the Rocky Mountain Region due to its small number of disjunct occurrences in a very rare and specialized habitat. Any management activities that maintain a natural hydrologic regime for these habitats, such as the regulation and monitoring of hydrological modifications, will promote the persistence of *S. myrtillifolia* in Region 2. Our current understanding of the distribution and abundance of *S. myrtillifolia* also suggests that it should remain a species of concern, and that land management personnel should focus on expanding our knowledge of its biology and habitat.

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INTRODUCTION

This species assessment for *Salix myrtillifolia* is one of many being produced for the Species Conservation Project of the Rocky Mountain Region (Region 2) of the USDA Forest Service (USFS). *Salix myrtillifolia* is the focus of an assessment because it is listed as a sensitive species in Region 2. Within the National Forest System, a sensitive species is a plant or animal whose population viability is identified as a concern by a Regional Forester because of significant current or predicted downward trends in abundance or significant current or predicted downward trends in habitat capability that would reduce its distribution (U.S. Forest Service Manual (FSM) 2003; 2670.5(19)). A sensitive species requires special management, so knowledge of its biology and ecology is critical.

This assessment addresses the biology, ecology, conservation status, and management of *Salix myrtillifolia* throughout its range in Region 2 (**Figure 1**). The broad nature of the assessment leads to some constraints on the specificity of information for particular locales. This introduction defines the goal of the species conservation assessments, outlines the scope of this assessment, and describes the process used in their production.

Goal of Assessment

Species conservation assessments produced as part of the Species Conservation Project are designed to provide forest managers, research biologists, and the public with a thorough discussion of the biology, ecology, conservation status, and management of certain species based on accumulated 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 may be based and focuses on the consequences of changes in the environment that result

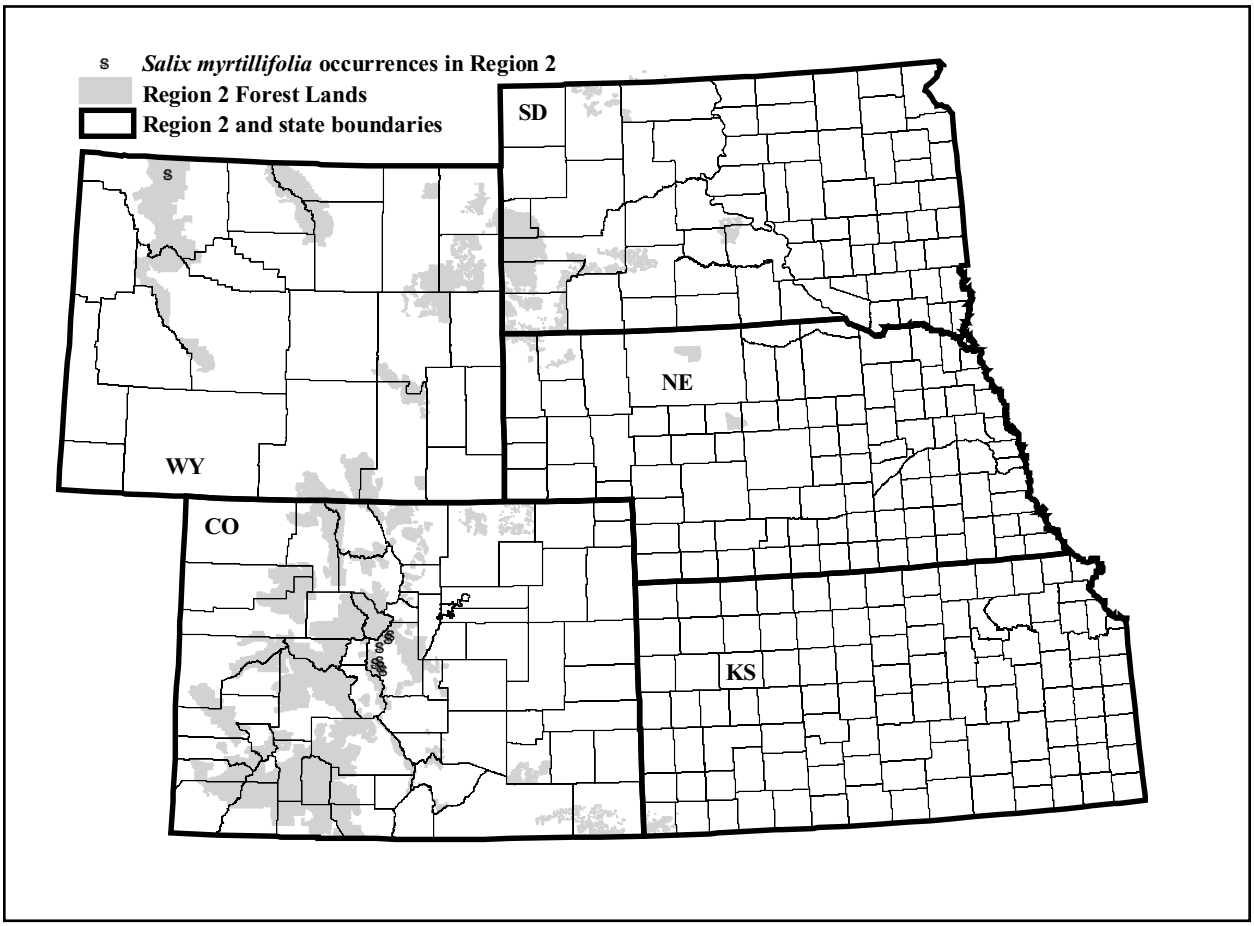

Figure 1. Documented occurrences of *Salix myrtillifolia* in states of USDA Forest Service Region 2.

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 species assessment examines the biology, ecology, conservation status, and management of *Salix myrtillifolia* with specific reference to the geographic and ecological characteristics of USFS Region 2. Although some of the literature on the species originates from field investigations outside the region, this document places that literature in the ecological and social context of the central Rocky Mountains. Similarly, this assessment is concerned with reproductive behavior, population dynamics, and other characteristics of *S. myrtillifolia* in the context of the current environment rather than under historic or prehistoric conditions. The evolutionary environment of the species is considered in conducting the synthesis, but placed in a current context.

In producing the assessment, refereed literature, non-refereed publications, research reports, and data accumulated by resource management agencies were reviewed. No refereed publications are devoted entirely to *Salix myrtillifolia*, but it is mentioned in a variety of sources. The refereed and non-refereed literature on the genus *Salix* and its species is quite extensive and includes many endemic or rare species. Not all publications on *S. myrtillifolia* or other *Salix* species are referenced in the assessment, nor are all published materials considered equally reliable. Material treating non-native species of *Salix* was generally omitted unless it provided the only information on a particular facet of *Salix* biology or management. Likewise, material that included only brief mention of *S. myrtillifolia* and did not provide new information was excluded. The assessment emphasizes refereed literature because this is the accepted standard in science. Some non-refereed literature, including reports prepared by and for state and federal agencies, online articles, and student research, was used in the assessment but regarded with greater skepticism. Unpublished data (e.g., Natural Heritage Program records) were important in estimating the geographic distribution of this species. These data required special attention because of the diversity of persons and methods used in collection.

The identification of *Salix* species can be difficult. The taxonomy of the genus *Salix* is based on a combination of characters that are not always concurrently present. Field identification often requires multiple, repeated visits before all pertinent characters are seen, and this is often not possible due to time and funding constraints. Herbarium specimens often lack crucial information or plant parts significant for identification, or characters can be lost in specimen preparation. Further, historical nomenclatural difficulties with *S. myrtillifolia* also make many reports and studies of this species less reliable. Absolute identification of *S. myrtillifolia* is often confounded by a lack of pertinent information on herbarium specimens regarding plant height and habitat, without which it is readily misidentified. Until a wider understanding of identifying characteristics of *S. myrtillifolia* is achieved by professionals and amateurs alike, the full extent of *S. myrtillifolia* distribution, threats to its occurrence and persistence, as well as its management status and any management implications cannot be fully determined.

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). In the ecological sciences, however, it is difficult to conduct experiments that produce clean results. 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. myrtillifolia*, 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 myrtillifolia is listed as a sensitive species in USFS Region 2 (USDA Forest Service Region 2 2003), where only eight occurrences are documented in Colorado and Wyoming. The Colorado Bureau of Land Management (BLM) also considers *S. myrtillifolia* a sensitive species (Bureau of Land Management 2004). It is more common in USFS Region 10 (Alaska Region; Viereck and Little 1972) and possibly in the western portion of USFS Region 6 (Pacific Northwest Region) in Washington and Oregon (Christy 2004, Crowe et al. 2004). It is not listed with special status in either USFS Region 6 or USFS Region 10. It is not listed as threatened or endangered on the federal Endangered Species List and has never been a candidate for listing.

NatureServe considers *Salix myrtillifolia* to be globally secure (G5). A G5 rank suggests the taxon is "demonstrably secure globally, though it may be quite rare in parts of its range, especially at the periphery" (NatureServe 2006). Although the taxonomic treatment currently displayed by NatureServe Explorer is now considered out of date (awaiting treatment by Flora of North America), the G5 rank is appropriate as the species is common in Alaska and Canada and rare at its southern periphery.

Salix myrtillifolia is listed as critically imperiled (S1) in Colorado (Spackman et al. 1997) and in Wyoming, where it is tracked at the varietal level as *S. myrtillifolia* var. *myrtillifolia* (Keinath et al. 2003). This species has only been tracked in Colorado and Wyoming since 1990 and 1992, respectively, reflecting its relatively recent discovery in these states. Outside of Region 2, *S. myrtillifolia* is ranked as secure (S5) from British Columbia to Ontario and as critically imperiled (S1) in New Brunswick and Newfoundland. It is state reported but not ranked (SNR) in Alaska, Yukon Territories, Northwest Territories, Nunavut, Quebec, and Labrador (**Table 1**; NatureServe Explorer 2004).

Existing Regulatory Mechanisms, Management Plans, and Conservation Strategies

Adequacy of current laws and regulations

Several federal regulations provide direction that may be relevant for the management of *Salix myrtillifolia*, including sensitive species status and the subsequent mandated environmental review of projects, and wetland regulation and mitigation policies. The USFS requires biological evaluations to assess the

Table 1. Conservation ranks of *Salix myrtillifolia* across its global range. State and province distribution from Argus (2004d) and State Rank information from NatureServe Explorer (2006).

States	State Rank	Province	Province Rank
Alaska	SNR	Alberta	S5
Colorado	S1	British Columbia	S5
California*	SNR	Northwest Territory	SNR
Idaho*	SNR	Nunavut	SNR
Minnesota*	SNR	Labrador	SNR
New Mexico*	SNR	Manitoba	S5
Montana*	SNR	Newfoundland	S1
Oregon*	SNR	New Brunswick	S1
Utah*	SNR	Ontario	S5
Washington*	SNR	Quebec	SNR
Wyoming	S1	Saskatchewan	S5
		Yukon Territory	SNR

Explanation of state ranks

S1= Critically imperiled
S2 = Imperiled
S3 = Vulnerable
S4 = Apparently secure
S5 = Secure
SNR = Not ranked/under review

*Reports of *Salix myrtillifolia* in these states are unconfirmed identifications (Argus 2004d).

impacts of projects on National Forest System lands to sensitive species (USDA Forest Service 1995). As a result of the evaluation, mitigation measures may be adopted to reduce the impacts of project activities. Sensitive species may not be collected on National Forest System lands without a permit (USDA Forest Service 1995). The Region 2 Threatened, Endangered, and Sensitive (TES) Plant Management Strategy (Austin et al. 1999) provides guidance for biological evaluations of TES plant species and also outlines long-term strategies to complement other USFS programs in achieving stewardship of "healthy, diverse ecosystems on National Forests and Grasslands." Although biological evaluations are not protection measures, they do offer a means to review projects for any impacts to sensitive species.

Federal regulation under the National Environmental Policy Act (NEPA) (U.S. Congress 1982) requires an assessment of environmental impacts associated with federal projects. *Salix myrtillifolia* has sensitive species status under USFS Region 2 and Colorado BLM agencies and therefore receives consideration in any NEPA analysis on these lands. However, no other federal agency lists *S. myrtillifolia* as a sensitive species, so any NEPA analysis on U.S. Fish and Wildlife Service, Bureau of Indian Affairs, or National Park Service lands or on Bureau of Land Management lands outside of Colorado might not identify *S. myrtillifolia*.

The single known occurrence of *Salix myrtillifolia* in Wyoming occurs in the Swamp Lake Special Botanical Area in the Clarks Fork Ranger District on the Shoshone National Forest. A Special Botanical Area is one type of Special Interest Area, which are areas designated to protect and manage National Forest System lands that contain unique botanical, zoological, geological, scenic, and archaeological interests (FSM 2372.02).. A Special Botanical Interest Area is defined as "a unit of land that contains plant specimens, plant groups, or plant communities that are significant because of their form, color, occurrence, habitat, location, life history, arrangement, ecology, rarity, or other features" (FSM 2372.05). While not as restrictive as Wilderness Area designation, this designation does confer additional management considerations. In Special Botanical Areas, developments, such as roads, trails, and other facilities, and the levels of usage of those developments are kept to the minimum necessary for public enjoyment of the area, provided they do not interfere with the primary values for which the area was established. Management plans that promote or maintain the environmental conditions needed for the survival of targeted species are critical to long-term success.

According to the National Wetlands Inventory of the U.S. Fish and Wildlife Service (USFWS), the national status of *Salix myrtillifolia* ranges from an obligate wetland plant (OBL) to facultative wet (FACW) (Reed 1988, U.S. Fish and Wildlife Service 1996). The 1996 list defines *S. myrtillifolia* as OBL to FACW while the 1988 list defines it as FACW to FACW+. Obligate wetland species almost always occur in wetlands under natural conditions (over 99 percent estimated probability of being in a wetland). Facultative wetland species almost always occur within wetlands but may be found outside of wetlands under natural conditions (67 to 99 percent estimated probability of being in a wetland). FACW+ indicates that the species occurs in wetlands at the higher end of the probability range given for FACW. This indicator status reflects the best scientific judgment of a panel of experts estimating the percent of the total number of individuals that occurs in wetlands (U.S. Fish and Wildlife 1996). The 1996 list defines *S. myrtillifolia* as OBL in USFWS Region 8 (Intermountain Region), which includes the area in USFS Region 2 where *S. myrtillifolia* occurs.

The wetland habitat where *Salix myrtillifolia* occurs is subject to provisions of Section 404 of the Clean Water Act, which regulates the filling of wetlands (33 §CFR328.3(b)). In 2001, the Supreme Court rendered an opinion that certain isolated wetlands may no longer fall under the jurisdiction of Section 404 (Solid Waste Agency of Northern Cook County v. U.S. Army Corps of Engineers). The wetland habitat of *S. myrtillifolia* in Region 2 does not fall into the category of isolated wetlands and therefore when *S. myrtillifolia* is found in a jurisdictional wetland (Environmental Laboratory 1987), its habitat is regulated by Section 404 of the 1977 Clean Water Act. Any impact to wetland water quality from the discharge of dredged or fill materials into waters of the United States requires a Section 404 permit from the U.S. Army Corps of Engineers. Although these wetland regulatory mechanisms are in place, it is uncertain how effective they are at protecting and/or minimizing impacts to known occurrences of *S. myrtillifolia*. The National Research Council (2001) found that the Section 404 permitting process was still resulting in a net loss of wetland functions and was producing a disparity in the hydrogeological equivalence of wetland types (i.e., wetland types are not being mitigated in-kind) even under the goal "no net loss policy" of wetlands initiated in 1989 by the federal government. It is unclear whether such actions have

affected known occurrences of *S. myrtillifolia*, but a net loss of wetlands does decrease potential *S. myrtillifolia* habitat in USFS Region 2.Federal agencies also receive direction on wetlands from Executive Order 11990, which, as amended, requires federal agencies exercising statutory authority and leadership over federal lands to "provide leadership and take action to preserve and enhance the natural and beneficial values of wetlands" in conducting federal activities and programs affecting land use and "to avoid to the extent possible, the long- and short-term adverse impacts associated with the destruction or modification of wetlands."

In Region 2, Watershed Conservation Practices guide management practices in and adjacent to wetlands (FSH 2509.25). These practices are designed to maintain long-term ground cover, soil structure, water budgets, and flow patterns of wetlands. Among the design criteria are standards for keeping vehicles, roads, trails, and buried utilities and pipelines out of wetlands. Additionally, there is direction to "avoid long-term reduction in organic ground cover and organic soil layers in any wetland (including peat in fens)" and "avoid the loss of any rare wetlands such as fens and springs."

The extremely rich fen habitat of *Salix myrtillifolia* is a type of peatland. Echoing the FSH, peatlands are designated as Resource Category 1 (Federal Register, Vol. 46, No. 15, February 4, 1981) by USFWS Region 6 (Mountain-Prairie Region) (U.S. Fish and Wildlife Service 1998). Resource Category 1 has the mitigation goal of "no loss of existing habitat value." Further, the USFWS Region 6 policy maintains that "every reasonable effort should be made to avoid impacting fens." Extremely rich fens are a product of an intricate relationship between hydrology, substrate, and geomorphology. They are irreplaceable once lost; restoration will not result in in-kind replacement.

A potentially confounding and conflicting message is presented by the U.S. Department of the Interior designation of peat, an integral facet of *Salix myrtillifolia* habitat in Region 2, as a commodity, renewable resource, and alternative fuel (USDI Bureau of Mines 1994, Secretary of the Interior 1994). The U.S. Department of Energy promotes peat mining for energy by guaranteeing a market and by conducting research. Further, by its designation as an alternative fuel, special tax incentives encourage major research, development, and construction investment. The USFS considers peat to be a saleable mineral (FSM 2822.1). As will be discussed later in this document, peat mining is a primary threat to *S. myrtillifolia* and its habitat in Region 2. The inherent loss of wetland habitat value associated with peat mining is in direct conflict with the Resource Category 1 designation of the U.S. Fish and Wildlife Service as well as USFS Region 2 Watershed Conservation Practices.

Adequacy of current enforcement of laws and regulations

While it is known that crucial potential habitat for *Salix myrtillifolia* has been lost through flooding and mining, there is no direct evidence to suggest that failure to enforce any existing regulations in Region 2 has resulted in the extirpation of an occurrence of *S. myrtillifolia* (Sanderson and March 1996). This does not necessarily indicate that current regulations or their enforcement are adequate for its protection. Referring again to Section 404 of the Clean Water Act, the National Research Council (2001) study on compensatory mitigation found that required mitigation projects (i.e., wetland creation, enhancement, and restoration activities) are often not undertaken or fail to meet permit conditions. Enforcement of such violations is the responsibility of the U.S. Army Corps of Engineers, but enforcement actions are not a high priority for the Corps due to restricted budget and staff (National Research Council 2001). While this has not yet resulted in the loss of known *S. myrtillifolia* occurrences, such lack of enforcement could affect potential habitat for *S. myrtillifolia*, especially in light of other federal incentives allowing use of its habitat. Also, the conflicting nature of wetland protection regulations in light of allowable resource usage needs to be rectified. On National Forest System lands, the U.S. Army Corps of Engineers generally relies on USFS to enforce wetland policies except for major construction actions such as ski areas (Roche personal communication 2004).

Biology and Ecology

Classification and description

Salix myrtillifolia is a member of the willow family (Salicaceae), a small plant family with four genera, the two most common of which are *Salix* (willow) and *Populus* (cottonwood) with the remaining genera described only from northeast Asia (Heywood 1993, Argus 1997). *Salix* is a large genus of 400 to 500 species throughout the world, with the majority of them distributed in northern areas of North America and Europe (Argus 1986). Members of the genus *Salix* are primarily shrubs or, less commonly, small trees. The Salicaceae is in the Dicot group of flowering

vascular plants, subclass Dilleniidae, and order Salicales (Heywood 1993, USDA Natural Resources Conservation Service 2004). Within the genus *Salix*, *S. myrtillifolia* is in the Subgenus *Vetrix* (Dumort.) Dumort. within the Section *Hastatae* (Fries.) A. Kerner (Argus 1997, Argus 2001). See **Table 2** for the full classification of *S. myrtillifolia*.

Section and subgenus analysis

The genus *Salix* is large, and its taxonomy is complex (Dorn 1976, Argus 1997) due to its ability to evolve relatively rapidly; evolution is likely still occurring within some species. *Salix* has broad ecological amplitude, occupying a myriad of ecological niches. Thus, it is subject to selective pressures that can result in evolutionary divergence. Also, species within *Salix* are highly variable morphologically; identification to species requires building a composite of many characters, some being more important for certain taxonomic sections than others.

The size and scope of the genus has made comprehensive treatment difficult (Dorn 1976, Argus 1997); a natural classification has long been sought but remains elusive. Linnaeus and his contemporaries first recognized the taxonomic difficulties of this group, and Linnaeus is said to have produced an artificial classification with much trepidation (Argus 1997). Various artificial classifications of *Salix* have been produced, beginning with *Species Plantarum* in 1753, which organized the known species into four major subdivisions based on leaf character. Most subsequent classifications modified and built upon this foundation, but some abandoned it entirely. Modifications inserted additional suites of characters to the classification, like phenology relative to leaf emergence, nectary position, stamen number, filament coalescence, and ovary characters.

The most recent, comprehensive *Salix* classification was set forth by Andersson in 1868 where three major groups were devised based on stamen number, floral bract color, and floral bract persistence. Although many nomenclatural problems have been elucidated from Andersson's treatment, it is the basis of modern *Salix* classification (Argus 1997). North American *Salix* have been given much needed attention more recently by Dorn with full generic synopsis (Dorn 1975) and systematic work within troublesome sections (Dorn 1976) completed. Dorn recognized two subgenera based on geographic origin and primitive vs. derived characters. Dorn placed *S. myrtillifolia* in *Salix* section *Cordatae* within the subsection *Hastatae*. The latest treatment of New World *Salix* was completed by Argus (1997), which forms the basis of the upcoming Flora of North America treatment (Volume 7). Argus' treatment is a phenetic classification using 235 morphological characters selected for their diagnostic usefulness and the accuracy with which they could be recorded. His analysis led to the recognition of four subgenera and several new sections, including *Hastatae*, which was separated from *Salix* section *Cordatae*. The classification of *S. myrtillifolia* is within subgenus *Vetrix*, section *Hastatae*.

Synonyms

Even according to the experts, the taxonomy of *Salix myrtillifolia* is confusing (Dorn 1975, Argus

Table 2. Classification of *Salix myrtillifolia* after USDA Natural Resources Conservation Service 2004, with sources of certain portions cited below.

Kingdom	Plantae (Plants)
Subkingdom	Tracheobionta (Vascular Plants)
Superdivision	Spermatophyta (Seed Plants)
Division	Magnoliophyta (Flowering Plants)
Class	Magnoliopsida (Dicotyledons)
Subclass	Dilleniidae
Order	Salicales
Family	Salicaceae (Willow Family)
Genus	*Salix*
Subgenus	*Vetrix*[1]
Section	*Hastatae*[1]
Species	*Salix myrtillifolia* Anders.

[1]Argus 2001

2001). Several varieties of *S. myrtillifolia* were first recognized by Andersson in 1868. Changes in the International Code of Botanical Nomenclature rendered many of these names illegitimate (Dorn 1976). This began a shuffle of its varieties into other taxa. Dorn (1975) provided the first clean-up reducing the number of varieties of *S. myrtillifolia* to two, *S. myrtillifolia* var. *myrtillifolia* and *S. myrtillifolia* var. *cordata*. *Salix myrtillifolia* var. *cordata* differed from the typical variety in being taller (1 to 3 m versus less than 1 m in the typical variety), having longer leaves (over 5 cm long), and growing in more well-drained situations. All other varieties of *S. myrtillifolia* were either elevated to species status or subsumed within other taxa. Also, *S. myrtillifolia* auct. non Anderss. (of authors, not Andersson) was recognized as misapplied and described as a new species, *S. boothii* (USDA Natural Resources Conservation Service 2004). Certain treatments are also known to have misapplied *S. myrtillifolia* Anderss., and the taxon referred to is *S. boothii* (Lesica 2002).

Treatment of *Salix* in the Flora of North America (Volume 7) will be completed by Dr. George Argus. Precursors to this treatment and early drafts no longer recognize varieties of *S. myrtillifolia*. *Salix myrtillifolia* var. *cordata* is considered a synonym of *S. pseudomyrsinites*, and the typical variety (var. *myrtillifolia*) encompasses the full species concept (Argus 2004d). Current synonyms attributed to *S. myrtillifolia* are listed in **Table 3**.

History of knowledge

Salix myrtillifolia has long been thought to be a boreal species of Canada and Alaska (Viereck and Little 1972, Argus 1973, Porsild and Cody 1980). However, in 1984, *S. myrtillifolia* was discovered on the Shoshone National Forest at Swamp Lake in an extremely rich patterned fen (Fertig and Jones 1992, Wyoming Natural Diversity Database 1997, Chadde et al. 1998, Heidel and Laursen 2003). In 1989, the species was discovered in South Park, in Park County, Colorado where it occurs in extremely rich fens (Cooper 1991). Species reports from additional states have occurred, but they are as yet unsubstantiated. For example, *S. myrtillifolia* was documented in Pine Butte Fen in Montana in 1986, but it is likely that the name was misapplied with the true identification of the occurrence as S .boothii (Lesica 2002). *Salix myrtillifolia* was reported from New Brunswick (Roberts 1965), but the specimens may be *S. ballii* or else a narrow endemic (Argus 2004d). *Salix ballii* differs from *S. myrtillifolia* in having glaucous abaxial leaf surfaces. Drying plant specimens under any sort of heat can destroy the waxy surface rendering it green in appearance, thus making herbarium specimens difficult to identify (Argus 2004d).

Non-technical description

As described by Dorn (1997), Collett (2002), and Argus (2004a, 2004d), *Salix myrtillifolia* is a short-statured shrub that very rarely reaches more than 0.6 m in height. The base of the stem tends to be trailing or prostrate, and it can root along its length; in this way it can vegetatively reproduce by layering. It is dioecious with female and male flowers occurring on different plants. Its leaves are elliptic, narrowly elliptic, obovate, or broadly obovate and smooth (without hairs) on both surfaces. Leaf edges vary from fine to relatively coarse toothed and they can be wavy or notched. Leaf tips are acute and sometimes rounded. Bottom leaf surfaces are green (not at all whitish) and upper surfaces are green and shiny. Newly emerging leaves are reddish or yellowish green and also smooth. Petioles are grooved on the top but otherwise smooth. Stipules, when present, are leaf-like and often persistent on later-developing leaves. Branches within the shrub are gray-, red-, or yellow-brown and hairy with small branchlets sparsely so and having only short, curved hairs. *Salix myrtillifolia* flowers as its leaves emerge in early May to late July depending on elevation. Flowers of both sexes are subtended by a persistent bract that ranges from pale in color to dark. Female flowers are moderately to densely clustered in catkins and have oblong, oval, or squarish nectaries beneath them. Ovaries are pear-shaped and smooth with the stigmatic surface having

Table 3. Synonyms of *Salix myrtillifolia* after Argus 2003.

Salix lingulata Andersson
Salix myrsinites var. *curtiflora* Andersson
Salix myrtillifolia var. *curtiflora* (Andersson) Bebb ex Rose
Salix myrtillifolia var. *lingulata* (Andersson) C. R. Ball
Salix novae-angliae var. *myrtillifolia* (Andersson) Andersson
Salix novae-angliae var. *pseudocordata* Andersson
Salix pseudocordata (Andersson) Rydb.

two plump lobes. Male flowers have oblong or square nectaries beneath them. Their anthers emerge purple in color but turn yellow with distinct, smooth filaments. Fruit of *S. myrtillifolia* is a capsule that is 4 to 6 mm long. Seeds have a dense plume of hairs.

In Region 2, *Salix myrtillifolia* is most often confused with *S. boothii*, *S. wolfii*, and *S. eastwoodiae* (Dorn 1997), all of which are in *Salix* section *Hastatae* (Argus 1997). *Salix myrtillifolia* is distinguished by a low, decumbent growth form (generally <1 m tall) in peat substrate. Mature leaves are green and glabrous on both surfaces. *Salix boothii* is a taller shrub (1 to 7 m) with more prominently pointed leaf tips and somewhat hairy leaf blades. *Salix wolfii* and *S. eastwoodiae* are both short-statured, like *S. myrtillifolia*, but both have hairy leaves (Dorn 1997).

Published descriptions and other sources

Complete technical descriptions of *Salix myrtillifolia* are available in Fernald (1950), Dorn (1975, 1997), and Argus (1973, 2001, 2004d). Of these, Argus (2001) and Argus (2003) are the most recent and the precursors to the upcoming Flora of North America treatment. Less technical and more abbreviated descriptions can be found in Hulten (1968), Viereck and Little (1972), Porsild and Cody (1980), Colorado Native Plant Society (1997), Fertig (2000), and Collett (2002). Viereck and Little (1972) provide a description with ecological comments specific to boreal regions of occurrence as well as line drawings. Additional drawings can be found in Hulten (1968), Spackman et al. (1997), and Fertig (2000). Photographs of the plant can also be found in Colorado Native Plant Society (1997) and Spackman et al. (1997); the latter is shown on the cover of this document.

Distribution and abundance

Salix myrtillifolia is a New World *Salix* species; it is not known from other continents. The global range for this taxon occurs primarily in boreal regions of northern North America. The current verified and unquestionable range of *S. myrtillifolia* extends from Alaska and British Columbia to Ontario, where it is relatively common, with disjunct occurrences in Wyoming and Colorado. An accurate distribution map of annotated *S. myrtillifolia* occurrences awaits the publication of Flora of North America, Volume 7. The range of the species may extend along the Pacific Coast south to Oregon (Christy 2004, Crowe et al. 2004), and additional disjunct occurrences may exist in Newfoundland and Quebec (Fernald 1950) and in New Brunswick (Roberts 1965). However, the identification of the New Brunswick material may be incorrect, and the Newfoundland, Quebec, Washington, and Oregon reports and specimens require final taxonomic verification (Argus personal communication 2004). The Washington and Oregon material may be *S. boothii*. Hitchcock and Cronquist (1973) lists *S. myrtillifolia* Anderss., but the name is misapplied. New Brunswick, Newfoundland, and Quebec material may be *S. ballii* (Argus personal communication 2004b).

USFS Region 2 has eight occurrences of *Salix myrtillifolia* in two disjunct areas, northwestern Wyoming and central Colorado. Two of these eight occurrences are on National Forest System lands (**Table 4**, **Figure 1**). The disjunct area in northwestern Wyoming has one occurrence of *S. myrtillifolia*; it is within the Swamp Lake Special Botanical Area on the Clarks Fork Ranger District of the Shoshone National Forest. This population occurs at 2,010 to 2,070 m (6,600 to 6,800 ft.) in elevation. The second disjunct area in central Colorado is within South Park in Park County with seven known occurrences that range from 2,725 to 3,050 m (8,940 to 10,000 ft.) in elevation. One of the Colorado occurrences is on National Forest System lands on the South Park Ranger District of the Pike-San Isabel National Forest. These two disjunct areas are geographically separated themselves, with the Colorado populations occurring 300 to 400 miles south of the Wyoming population, which is 300 to 400 miles south of the primary boreal range of the species in Canada. Populations are geographically and genetically isolated from their nearest neighbors (Sanderson and March 1996).

These southern disjunct populations of *Salix myrtillifolia* are very likely relicts of the most recent glacial period (maximum glaciation 18,000 years B.P.) when more boreal plants dominated the region (Andrews et al. 1975, Carrara et al. 1984). The Mosquito Range adjacent to South Park experienced its last period of glaciation during the Pinedale (Wisconsin) Glaciation that occurred from 12,000 to 6,500 years B.P. (Richmond 1965). South Park would have experienced periglacial processes, evident in the glacial alluvium deposits that blanket much of the intermountain basin (Scott 1965, De Voto 1971). Glacial refugia have been documented in nearby Fremont County (Wells and Stewart 1987, Mitton et al. 2000). The constant supply of groundwater and the relatively high elevations of *S. myrtillifolia* occurrences in Region 2 have maintained conditions similar to those in boreal regions. Thus Region 2 occurrences of *S. myrtillifolia* are presumably glacial relicts.

Table 4. Summary of occurrences of *Salix myrtillifolia* in USDA Forest Service Region 2.

	State County	Location	Land Ownership	Elevation (ft.)	Year last observed	Population size	Habitat and notes	Source ID
1	WY Park	Swamp Lake, Clark's Fork Valley	USDA Forest Service Shoshone National Forest Clarks Fork Ranger District Swamp Lake Special Botanical Area	6,700	1991	Unknown	Shrub 102dm high, semiprostrate; no staminate plants seen in White spruce bog with *Salix candida* and, *S. psuedomonticola*.	✹ WNND EO-001 ✹ Herbarium labels: (1) Dorn, R. #4118; (2) Evert, E.F. #7489; (3) Fertig, W. and G. Jones #13380; (4) Lichvar, R. #7039
2	CO Park	High Creek Fen, South Park	Private; The Nature Conservancy	9,290	1989	2000+	In extremely rich fen fed by calcareous seeps with *Salix planifolia* and *S. candida*.	✹ CNHP EO-001 ✹ Herbarium labels: (1) Cooper, D.J. #sn; (2) Sanderson, J. #943; (3) Jennings, W.F. #9438; (4) Weber, W.A and D. Cooper [annotated, orig. identification was S. wolfii]
3	CO Park	Northwest corner of Antero Reservoir	State of Colorado Antero State Wildlife Area Denver Water Board	8,940	1990	"abundant"	On peat hummocks in calcareous fen.	✹ CNHP EO-002 ✹ Herbarium label: Cooper, D.J. #1757
4	CO Park	Jefferson and Guernsey Creeks; Wahl Ranch	Private	9,700	1995	Unknown	Extremely rich fen.	✹ CNHP EO-003
5	CO Park	South Fork South Platte Fen; Sweetwater Ranch	Private	9,150	2000	"hundreds"	On hummocks. Extremely rich fen.	✹ CNHP EO-004 ✹ Herbarium labels: (1) Sanderson, J. #952; (2) Spackman, S. #SS-00-45
6	CO Park	South Fork of South Platte River, SW of Black Mountain	Private	9,360	2000	<75	Extremely rich fen.	✹ CNHP EO-005
7	CO Park	Crooked Creek	USDA Forest Service Pike-San Isabel National Forest South Park Ranger District	10,000	1995	Unknown	Low growing with *Salix candida, Ptilagrostis porteri, Kobresia simpliciuscula* and others in an extremely rich fen.	✹ Sanderson 1995 ✹ Herbarium label: Sanderson, J. #1036
8	CO Park	Michigan Creek	State of Colorado Teter-Michigan State Wildlife Area	9,660	1988	~15 plants	In saturated portions of fen with *Salix brachycarpa, S. candida, S. planifolia, Carex aquatilis* and others.	✹ Kettler 1999

Salix myrtillifolia occurs in extremely rich fens in Region 2, a habitat that is presumably very restricted in distribution and abundance in the region. Although there are additional extremely rich fens in South Park that do not currently have *S. myrtillifolia* (Sanderson and March 1996), there is relatively little suitable habitat in the surrounding vicinity of either disjunct area of *S. myrtillifolia*. Further, each disjunct area is surrounded by mountain ranges that act as relatively impervious barriers to dispersal. Therefore, these populations are in a sense stranded where they occur.

Population sizes of Region 2 *Salix myrtillifolia* occurrences are known for only half of the sites (**Table 4**). The largest population of *S. myrtillifolia* in Region 2 occurs on private land at High Creek Fen in Park County, Colorado, where there are estimated to be 2000+ individuals. Three other Colorado populations have numerical approximation information. Two of these occur on private land, and one has an estimated population size of hundreds of plants while the other has fewer than 75 individuals. The third occurrence for which there is a numerical estimate of abundance is on land managed by the State of Colorado; the conservative estimate for this site is 15 individuals. At another site managed by the State of Colorado, the population was described as "abundant."

Population trend

Salix myrtillifolia is a long-lived, woody perennial species, so populations of this species are not highly variable from year to year. Since the populations of these plants have been discovered only within the last two decades, long-term trends cannot be absolutely verified. However, *S. myrtillifolia* occurs in relatively stable successional stages within well-developed extremely rich fens in Region 2, and extremely rich fens with peat depths such as those found in Wyoming and Colorado take thousands of years to accumulate (Sanderson and March 1996). Thus, *S. myrtillifolia* will likely persist in Colorado unless land or water use patterns alter the local conditions where it occurs. The Swamp Lake population in Wyoming, although persistent for some time, may decline eventually. To date only female plants have been found at this site, and given that asexual seed production (apomixis) has not been reported for any *Salix* species (Fox 1992), the *S. myrtillifolia* plants at Swamp Lake can only spread vegetatively into areas immediately adjacent to where plants currently exist. Therefore, it is unlikely to expand into additional suitable habitat that is separated by different microhabitat (Fertig 2000). It is unknown how long *S. myrtillifolia* individuals may persist.

Six of the eight known occurrences of *Salix myrtillifolia* have been professionally observed only once, on the day they were discovered. Two occurrences in Colorado have been visited repeatedly. The Sweetwater Ranch occurrence, on private property along the South Fork of the South Platte River, appears to be recovering after grazing pressure was reduced. Although a census has not been attempted at this population, it has apparently increased from tens of individuals to hundreds. The High Creek Fen population, owned in part by The Nature Conservancy, has been seen repeatedly, but not specifically monitored. It has greater than 2000 plants, and it is likely that only dramatic changes in population numbers will receive attention due to its current size and protected status. A vegetation monitoring plan has been devised for the High Creek Fen system (Brand and Carpenter 1999). While *S. myrtillifolia* is not a target species of the monitoring, it will be addressed within the parameters of overall habitat monitoring associated with the targeted species assessments in the plan. Until the remaining occurrences of *S. myrtillifolia* are assessed again, no trend information can be discerned.

Loss of habitat occupied by *Salix myrtillifolia* has been documented in South Park. Sanderson and March (1996) estimated that 20 percent of extremely rich fen habitat in South Park has been lost to peat mining. With the creation of the Antero Reservoir, an unknown, but sizable, amount of well-developed extremely rich fen was lost. The remnant fen habitat still supports a population of *S. myrtillifolia*, but these fens were likely much more extensive before the reservoir was built and flooded.

Habitat

The most important physical and biological feature of *Salix myrtillifolia* habitat throughout the full extent of its geographic range is moisture availability. *Salix myrtillifolia* occurs in open wetlands, requiring full sun to become established and thrive, and its biology and reproduction rely on moist habitat. As with all willows, *S. myrtillifolia* also requires a minimum amount of disturbance that creates sites for establishment.

In the primary boreal range of *Salix myrtillifolia*, its typical habitat includes fens and muskegs, small stream- and riverbanks, and boreal and subalpine black spruce lowlands (Porsild and Cody 1980, Argus 2001, Collett 2002). Additional habitats in Canada also include sand dunes of large lakes and coal spoils (Argus 2004d). *Salix myrtillifolia* is often locally abundant following fires in lowland spruce stands, but

thins with succession following the burn (Viereck and Little 1972). In contrast to the more common habitat types occupied by *S. myrtillifolia* in boreal regions, the habitat of the southern disjunct occurrences of *S. myrtillifolia* in Wyoming and Colorado is restricted to extremely rich fens in high elevation montane valleys, a habitat maintained by unusual water chemistry (**Figure 2**). In Region 2, *S. myrtillifolia* is associated with the Montane Fen ecological system (Rondeau 2001), which corresponds to the Rocky Mountain Subalpine-Montane Fen ecological system of NatureServe (2003). Montane fens occur as a "small patch" type of system. Small patch systems usually have distinct boundaries, require specific environmental conditions, and are strongly linked to and dependent upon the landscape around them (Anderson et al. 1999). The intricate relationship of environmental conditions that maintain extremely rich fens in Region 2 stems from landscape position, groundwater, and climate. Fens usually form where groundwater intercepts the soil surface, often at low points within the landscape or on slopes (Crum 1988, Mitsch and Gosselink 1993, Rondeau 2001, Sjors and Gunnarsson 2002). Groundwater flow maintains the water level at near constant temperatures and levels, at or near the soil surface. In Region 2, groundwater of extremely rich fens percolates through enriched bedrock, dolomites and limestones high in calcium and magnesium bicarbonates and sulfates (Cooper 1996, Heidel and Laursen 2003). The constant soil saturation provided by upwelling groundwater creates anaerobic conditions. Lack of oxygen combined with cold temperatures dramatically slows or inhibits decomposition, leading to the accumulation of organic material in soils or the formation of peat (Mitsch and Gosselink 1993). The high pH produced by the enriched groundwater limits plant growth (McBride 1994) and attracts a highly specialized suite of calcium-tolerant plant species known as calciphiles that can tolerate the harsh conditions. Although occurrences of *S. myrtillifolia* are at elevations that keep temperatures relatively cool, the arid climate of Region 2 concentrates minerals in surficial layers through evaporation, further enriching these layers.

The microtopography of a fen consists of hummocks, hollows, strings, and other patterns on the soil surface. The microtopographic pattern of a peatland is derived from patterns of water flow through a fen and subsequent vegetation development. Patterned fens form where slow groundwater movement flows through broad gently sloped peatlands forming a series of peat ridges, called strings, separated by hollows (or flarks). Strings and flarks are arranged perpendicularly to the flow of water through the peatland and can form a regular pattern of parallel ridges and hollows or an intricate, anastamosing pattern (see Glaser 1987). Hummocks are remnants of past plant growth; perennial species add layers of vegetation that build up peat above the permanently saturated zone and allow a wider variety of species to colonize. Studies have also shown ants (Lesica and Kannowski 1998) and suggested frost heave as formative agents of hummocks. Dorr et al. (2003) report that peat depths of 10 to 15 cm allow establishment of herbaceous species like *Carex* spp. and other graminoids in Oregon peatlands. Further, peat depths greater than 15 cm were required before woody shrubs could establish.

In Wyoming, *Salix myrtillifolia* occurs in the Swamp Lake Special Botanical Interest Area on the Shoshone National Forest. This wetland is an extremely rich, patterned fen occurring in the montane zone along the Clarks Fork of the Yellowstone River. Swamp Lake is at 2,012 m (6,600 ft.), and the net relief occupied by

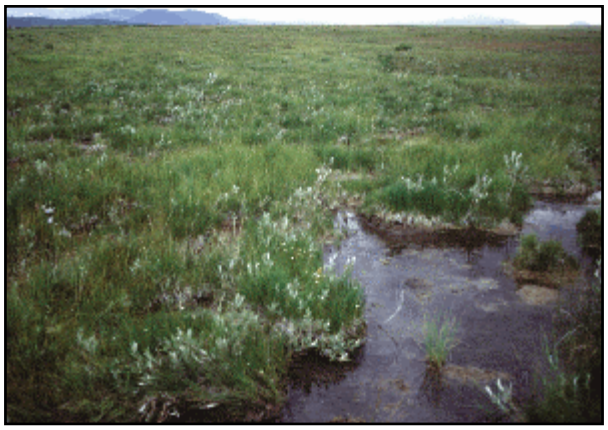

Figure 2. Habitat of *Salix myrtillifolia* in Colorado. Photograph by John Sanderson, Colorado Natural Heritage Program ©1999.

fen vegetation within the 138 ha (340 ac) site as a whole is approximately 2 m. The wetland is fed by many seeps and springs within a landscape that overlies bedrock high in calcium bicarbonates (Heidel and Laursen 2003). *Salix myrtillifolia* is known from three places within the Swamp Lake wetland, all of which are on the wetland's periphery. It occurs in relatively wet areas within the *Picea glauca* (white spruce) forest vegetation that occurs at the ecotone between the wetland complex (white spruce (*P. glauca*) muskeg and arrowgrass – spikerush (*Triglochin – Eleocharis*) vegetation types) and the surrounding *Picea engelmanii-Abies lasiocarpa* (spruce-fir) upland forest. *Salix myrtillifolia* appears occasionally on hummocks with *S. planifolia* (diamondleaf willow), *S. geyeriana* (Geyer willow), and *S. bebbiana* (Bebb willow). The hummocks also have abundant forbs including *Amerorchis rotundifolia* (small round-leaved orchid), *Pyrola asarifolia* (American wintergreen), *Orthilia secunda* (sidebells wintergreen), *Galium boreale* (northern bedstraw), *Antennaria pulcherrima* (showy pussytoes), and *Parnassia fimbriata* (fringed grass of Parnassus) (Fertig and Jones 1992).

In Colorado, *Salix myrtillifolia* also occurs only in extremely rich fens in South Park, a large intermountain basin in central Colorado that is bounded on all sides by mountain ranges. Depending on how conservative the estimate, South Park occupies 1,000 to 1,800 km^2 (385 to 695 mi^2). Known occurrences of *S. myrtillifolia* occupy fens with strong, constant springs and highly calcareous groundwater sources. *Salix myrtillifolia* is common only at two of seven occurrences; the remaining five sites have low abundance of *S. myrtillifolia* (**Table 4**). Plant associations in which *S. myrtillifolia* occurs include hoary willow / seaside arrowgrass (*Salix candida* / *Triglochin maritimum*) extreme rich fen, Bellardi bog sedge – alpine meadowrue (*Kobresia myosuroides – Thalictrum alpinum*) extreme rich fen, and simple bog sedge – (Rolland's bulrush) (*Kobresia simpliciuscula* – (*Trichophorum pumilum*)) extreme rich fen (Carsey et al. 2003). All of these plant associations are globally rare (G2) natural community types tracked by the Colorado Natural Heritage Program. These associations define the extremely rich fens of South Park, and all occur on hummocks that rise out of the rills and water tracks common in these unique wetlands. The hoary willow / seaside arrowgrass association tends to occur as widely scattered clumps on relatively drier hummocks than the Bellardi bog sedge – alpine meadowrue and simple bog sedge – (Rolland's bulrush) extreme rich fen associations. Extremely rich fens in South Park occur between 2,590 and 3,050 m (8,500 and 10,000 ft.) in elevation (Carsey et al. 2003). *Salix myrtillifolia* grows on tall sedge hummocks (20 to 50 cm) that arise from the wettest portions of the fens. The hummocks occupied by willows tend to be relatively drier microhabitats within the fens (Argus personal communication 2004c). Species associated with *S. myrtillifolia* in Colorado include *S. candida* (sageleaf willow), *S. brachycarpa* (shortfruit willow), *Kobresia simpliciuscula* (simple bog sedge), *K. myosuroides* (Bellardi bog sedge), and many other calciphiles (Cooper 1996, Sanderson and March 1996, Carsey et al. 2003, Johnson and Steingraeber 2003).

Not all extremely rich fens in Colorado have *Salix myrtillifolia*; of known fens in South Park approximately 30 percent have *S. myrtillifolia* populations. Further, *S. myrtillifolia* is not known from other types of fens in Colorado, poor or rich, despite much field work in these wetland types (Sanderson personal communication 2004). An estimated 20 percent of the extremely rich fen habitat in South Park has been lost or irreversibly degraded (Sanderson and March 1996). It is not known whether *S. myrtillifolia* occupied these areas before their demise. It is not known how much additional extremely rich fen habitat may occur in Wyoming; currently *S. myrtillifolia* is only known to occur at Swamp Lake where it occupies a small fraction of the potential habitat.

Reproductive biology and autecology

Salix myrtillifolia is able to reproduce both vegetatively and sexually (Uchytil 1992). Clonal reproduction is common in many *Salix* species, which are prolific root producers. Several species of willow initiate pre-formed dormant root primordia in stems within the first year of growth (Densmore and Zasada 1978). This allows these species to root quite rapidly when stems are excised from the plant. Some willows do not form specialized root primordia in the stem, but these species generally can produce roots relatively slowly from the base of the broken stem. Although no anatomical studies have been performed, *S. myrtillifolia* likely is one of the species that has pre-formed root primordia as it is known to vegetatively spread via layering (Argus 2001, Collett 2002). Also, its decumbent growth form is designed to root along its stems, anchoring them to additional substrate.

Salix myrtillifolia is dioecious, having separate male and female plants. Flowers develop early in the growing season as leaves emerge; *S. myrtillifolia* is coetaneous. Flowers are highly reduced, with only ovaries or stamens subtended by nectaries and a single floral bract. The species is pollinated primarily by

insects although some wind pollination likely occurs among plants that are in the same vicinity (Argus 1974, Tollsten and Knudsen 1992). Evidence for insect pollination is attributed to pollen and flower adaptations. Pollen adaptations that suggest insect pollination include pollen grains that are tricolpate and heavily reticulate (Argus 1974). Floral adaptations include the presence of nectaries with abundant and scented nectar and stiff and erect inflorescences with highly visible reproductive parts (Tollsten and Knudsen 1992).

Average flowering periods of *Salix* species range from one to two weeks in length. The short duration of flowering makes host specificity unlikely in willows (Mosseler and Papadopol 1989). There are no data specific to *S. myrtillifolia* regarding pollinators. Several insects have been noted on *Salix* species including honeybees (*Apis*), bumblebees (*Bombus*), flies (Diptera), wasps (Hymenoptera), and beetles (Coleoptera) (van der Werf 1983, Mosseler and Papadopol 1989). In a study of insect pollinators in an Ontario peat bog, dipteran and hymenopteran species accounted for more than 90 percent of the pollinating vectors (Small 1976). However, early flowering *S. fragilis* was visited more frequently by species of Leipidoptera and Coleoptera. Further, visitation does not ensure pollination; van der Werf (1983) demonstrated that certain insect species discriminate between *Salix* species and are apparently less effective at successful pollination.

Mosseler (1989) demonstrated limited pollen viability for several *Salix* species. In this study, 70 percent of pollen remained viable 48 hours after anthesis. Pollen viability can be maintained when desiccated male catkins are stored at 3 °C. Once pollinated, stigmas lose receptivity within a short time period (Mosseler 1989).

Artificial hybridization is easy to accomplish among most *Salix* species (Argus 1974). However, several barriers to natural hybridization exist. As many *Salix* species are sympatric, mechanisms are in place to limit interspecific hybridization and to promote fertilization by conspecific pollen. Both premating and postmating barriers exist between willow species (Mosseler 1989). Several early-flowering *Salix* share the same habitat and thus have similar suites of pollinators. In these situations, the predominant premating barrier is seasonal isolation via slightly different or minimally overlapping flowering times. Flowering phenology in *Salix* is thermally controlled; *Salix* species phenology can be tracked as a response to cumulative growing degree days (where the daily mean temperature exceeds 5 °C). However, there is variation, and species do respond to heat waves and cold snaps with more rapid flowering or delayed flowering, respectively, and species response to these temperature aberrations differ. Thus, annual weather patterns exert some influence over flowering, and variability can create opportunities for natural cross-pollination (Mosseler and Papadopol 1989).

Postmating barriers occur after pollination. Mosseler (1989) described incongruity or non-functioning pollen-pistil relationships as an interspecific, postmating reproductive barrier among willows. This mechanism emphasizes the entire complex of metabolic and physiologic interactions that allow pollen tube growth to be controlled at the stigmatic surface. Pollen germination, penetration, and growth of pollen tubes are delayed if pollen from a different species lands on a stigma. In certain crosses, pollen tube growth rates are dramatically lower than that of conspecific pollen once foreign pollen germinates and this varies with species and with direction of hybridization (Mosseler 1989). These mechanisms provide competitive advantage to conspecific pollen, but they do not preclude fertilization in all crosses.

Despite the reproductive barriers described above, many *Salix* species naturally and readily hybridize. *Salix myrtillifolia* has been noted to hybridize with *S. barclayi* (Hulten 1968). This specific hybridization was disputed by Dorn (1975) who recognized potential hybridization between *S. myrtillifolia* and *S. boothii*. Argus (2001) recognized possible hybridization between *S. myrtillifolia* and *S. candida*. Detection of hybrids has historically relied on intermediate morphological characters, but given the wide interspecific variability among willows, this is not as helpful as with other genera. Hybrids may also be detected via flavonoid chemistry, which is species-specific (Dorn 1975). However, certain species have similar and overlapping patterns of flavonoid production that may limit the use of this method of detection. Finally, hybrids may be detected via ploidy level. *Salix myrtillifolia* is a diploid (2n = 38; Argus 2004d).

In Region 2, *Salix myrtillifolia* co-occurs with *S. geyeriana*, *S. bebbiana*, and *S. planifolia* in Wyoming and with *S. brachycarpa*, *S. candida*, *S. serissima*, and *S. monticola* in Colorado. Although there are no explicit observations of flowering times for any of these willows in either state, *S. bebbiana* and *S. planifolia* flower before leaves emerge, so they may flower slightly earlier than *S. myrtillifolia*, which flowers as leaves emerge. This difference in flowering time would create a premating reproductive barrier. *Salix*

geyeriana, *S. brachycarpa*, and *S. candida* all flower as leaves emerge, like *S. myrtillifolia*. Although Argus (2001) suggests *S. myrtillifolia* may hybridize with *S. candida*, as yet no hybridization has been noted in Colorado where these two species co-occur. Likewise, no hybridization has been noted and no seed set has been documented in the past decade in Wyoming (Fertig and Markow 2001). *Salix myrtillifolia* likely has postmating reproductive barriers that preclude hybridization with many sympatric *Salix* species that likely have overlapping flowering times.

The genus *Salix* has a high degree of inherent morphological variation (Argus 1986). Expression of phenotypic plasticity and vegetative variability depends on site conditions, especially the amount of light and elevation (Argus 2001). Although several mechanisms are in place to reduce natural hybridization as mentioned above, it is important to consider the potential for hybridization to account for observed morphological variation (Hardig et al. 2000).

Specific information about much of the basic biology of *Salix myrtillifolia* is lacking, but many general principles of *Salix* biology apply. The following overview of willow seed germination, dispersal, and establishment is from Densmore and Zasada (1983), except where noted otherwise. Upon successful pollination, seeds typically develop rapidly in *Salix* species, maturing within weeks of anthesis. Seeds are wind-dispersed immediately upon ripening, wind dispersal being aided by the downy plume attached to the seed. Seeds are also water-dispersed (U.S. Department of Agriculture 1974). Once dispersed, seeds are short-lived and lack dormancy, germinating immediately upon reaching moist substrate. Seeds contain visible amounts of chlorophyll when mature, but very little or no endosperm. Seed coats are transparent and seeds begin to photosynthesize immediately upon moistening. Seed germination is rapid with hypocotyl elongation beginning after 24 hours. Along with hypocotyl elongation, many tiny hairs are produced on the hypocotyl ring within the next 48 hours to attach and hold the seed to the substrate (see Densmore and Zasada [1983] for illustration). There is less root elongation and fewer hypocotyl hairs produced under drier substrate conditions. Percent germination is high in *Salix*, ranging from 97 to 100 percent in most species. Germination also occurs over a wide temperature range (5 to 25 °C). Although the lowest temperatures in this range cause some delay in germination rate, they had no significant effect on total germination. *Salix* seeds do not produce viable seedlings beyond seven days after dispersal in both field and laboratory studies. Seed viability can be maintained for several years under cold (-10 to -20 °C), dry conditions (Zasada and Densmore 1979) or by freezing and desiccation (Maroder et al. 2000, Wood et al. 2003). Seeds should be collected soon after ripening (U.S. Department of Agriculture 1974).

Optimal substrate for seed germination of *Salix* species is open, moist soil that is immediately available upon seed dispersal (Argus 1986). Soils can be mineral or organic (Kovalchik 2001). *Salix myrtillifolia* is among the non-riparian willows, and as such is "less exacting with respect to soil aeration" (Argus 1986). Non-riparian *Salix* have greater tolerance for less aerobic settings of stagnant moisture conditions. In addition to their moisture requirement, *Salix* seeds readily colonize disturbed areas. In the fen habitat of *S. myrtillifolia* in Region 2, soil disturbance results from domestic or wild ungulates utilizing the wetlands. This provides the necessary seedbed conditions and reduces micro-scale plant competition long enough to establish willow seedlings (Kovalchik 2001).

As with most willows, *Salix myrtillifolia* is a long-lived perennial species requiring several years to reach reproductive maturity. Thus, it can be classified as a *K*-selected species occurring in stable habitats (sensu MacArthur and Wilson 1967). Although outwardly demonstrating characteristics of all three of Grime's categories of stress response (stress tolerant, ruderal, and competitive), *S. myrtillifolia* has more qualities pertaining to stress tolerant strategies (Grime 2001). *Salix myrtillifolia* exhibits persistent and sustained (yearly) reproductive effort in the unproductive, nutrient-restricted habitat in which it is found. This stress tolerant strategy, constancy of occupation and seed set, is required in order to take advantage of rare opportunities for colonization. Competitive characteristics found in *S. myrtillifolia* include its clonal growth, which is a common competitive strategy in unproductive habitats, and its intolerance of shade. Ruderal characteristics found in *S. myrtillifolia* are its copious seed production and prerequisite of disturbance for establishment. However, unlike typical ruderal species, *S. myrtillifolia* is not a fast-growing plant, but a long-lived perennial that does not devote a large portion of its resources to sexual reproduction nor senesce once seeds are dispersed.

Demography

Little is known about the population genetics of *Salix myrtillifolia*, and there are no specific demographic data for this species in Region 2. The two disjunct areas of occurrence in Region 2 are not

only geographically isolated from the main range of the species but also from each other. The cluster of occurrences in Colorado may be able to exhibit metapopulation dynamics, but the Wyoming occurrence is isolated from any other populations.

A generalized life cycle diagram for *Salix myrtillifolia* is shown in **Figure 3**. The basic structure starts from seed germination and establishment (A) to form juvenile vegetative plants, the persistence and survival of juveniles to maturity and flowering (B), to the probability of successful pollination and seed set (C). Vegetative reproduction can occur in both vegetative and flowering plants. To complete a population viability analysis, rates of mortality at various life cycle stages (M_1-M_3) would need to be determined. Without specific demographic studies on *S. myrtillifolia*, probabilities of reaching and persisting at various stages are not known and can only be roughly estimated. *Salix myrtillifolia*, like all willows, produces large amounts of seed. The probability of those seeds finding suitable substrate, disturbed microenvironment

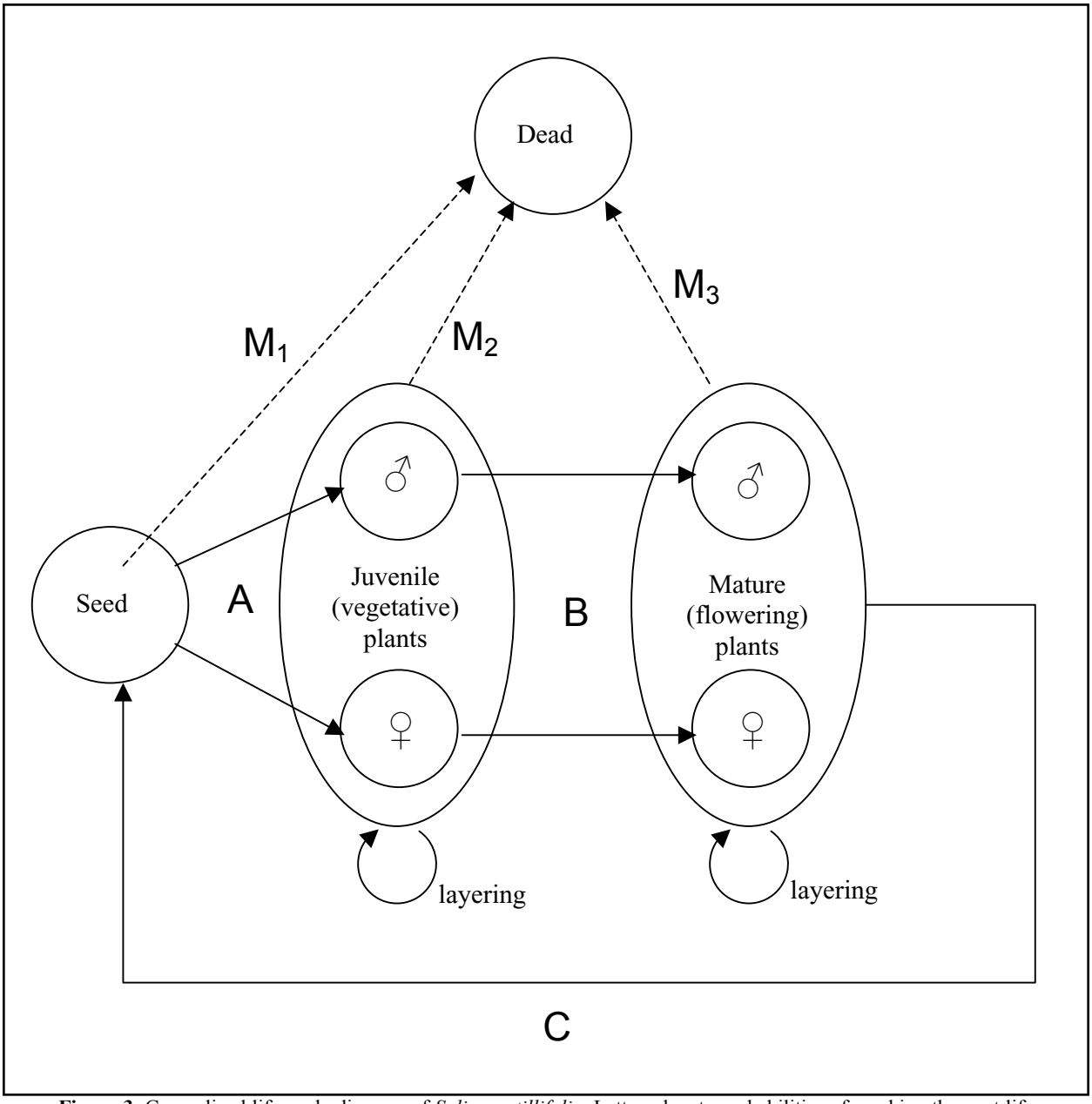

Figure 3. Generalized life cycle diagram of *Salix myrtillifolia*. Letters denote probabilities of reaching the next life cycle phase (A-C) or of mortality (M_1-M_3).

required by *Salix*, is likely to be quite low for *S. myrtillifolia*, which occupies a relatively stable, albeit later successional stage of peatland development (M_1 is likely to be high). Disturbance is generally very small in scale (i.e., footprints of large ungulates) and unpredictable in peatland systems. Once juvenile plants are established, the probability of reaching maturity (B) is likely high relative to A (M_2 is likely to be relatively low). As long-lived perennial plants, *S. myrtillifolia* individuals likely spend the greatest proportion of their life cycle in the mature plant stage. The probability of successful pollination (C) is unknown, but it requires two separate plants, female and male, establishing in close enough proximity for it to occur. Although some wind pollination does occur, *Salix* are primarily insect-pollinated, so the male and female plants must establish within the foraging range of their pollinators for successful and efficient pollination and seed set to occur. All mature plants of *S. myrtillifolia* are capable of vegetative reproduction via layering, but the rate at which individuals grow and spread is uncertain. The population at Swamp Lake in Wyoming lacks male plants, thus eliminating any progression through the life cycle, which is arrested at mature plants.

In general, willows exhibit rapid early growth. They are often early producers; some species begin to flower after two years, some after approximately ten years of age (U.S. Department of Agriculture 1974). *Salix exigua*, a species of relatively ephemeral river bar habitat, produces seed after two years (Ottenbreit and Staniforth 1992). On the other hand, *S. bebbiana*, which grows in poorly drained or seasonally inundated meadows, optimally produce flowers and set seed between 10 and 30 years of age (Haeussler and Coates 1986). *Salix myrtillifolia* likely is more similar to *S. bebbiana* and reaches reproductive maturity after approximately ten years.

Growth and biomass accumulation in willows have been generalized for two groups of willows based on height and habitat (Kovalchik 2001). Short shrub willows that grow at high elevations or in peatlands, like *Salix myrtillifolia*, tend to have basal stem diameters that do not exceed half an inch. Individual stem ages in Washington do not appear to exceed ten years of age due to insect or disease mortality. Dead stems, however, re-sprout from the base, making the life span of an individual genet potentially indefinite. Total shrub biomass for short-statured willows in bogs ranges from 5,000 to 10,000 pounds dry weight per acre, with roots comprising about 75 percent of the biomass (Kovalchik 2001).

Given a lack of specific information on the demography of *Salix myrtillifolia*, general tenets of population viability analysis are applicable. As summarized by Nelson (2000), minimum viable populations (MVP) are those assumed to be large enough to maintain evolutionary potential in the face of various stochastic risks. Four basic kinds of stochasticity are environmental stochasticity (the normal range of environmental variability at a site), natural catastrophe (disastrous local events affecting entire populations), demographic stochasticity (chance events affecting survival and reproduction of individuals), and genetic stochasticity (founder effects, inbreeding depression) (Menges 1991). Various estimates of MVP size are suggested by various authors (Frankel and Soule 1981, Menges 1991, Given 1994). Suggested MVP for environmental stochasticity and natural catastrophe is one thousand to one million individuals, whereas for demographic and genetic stochasticity suggested MVP is fifty and fifty to five hundred, respectively. Environmental stochasticity and natural catastrophe dictate MVP's substantially greater than demographic and genetic stochasticity. As cited in Nelson (2000), Constance Miller, Geneticist for the USFS Pacific Southwest Research Station (Albany, CA) suggests that there is no rule of thumb for choosing absolute numbers for viable population sizes other than more is better. Miller assesses the value in classifying the four classes of stochasticity as providing a framework for evaluating different risks. Demographic and genetic concerns will be easily assuaged by conserving populations sufficient for surviving environmental and catastrophic stochasticity.

Community ecology

The multitude of species within *Salix* gives the genus wide ecological amplitude. However, in general, New World *Salix* species are shade-intolerant and grow best on moist soils. Germination and seedling establishment maximally occur at sunny sites with moist substrate (Argus 1986).

In Region 2, *Salix myrtillifolia* is inextricably linked to the unusual hydrology and water chemistry of its extremely rich fen habitat found at Swamp Lake in Wyoming and in localized areas of South Park in Colorado. Calcium, sodium, and magnesium are abundant nutrients in these fens and are derived from limestone and dolomite bedrock through which the groundwater percolates before reaching the fen surface (Cooper 1996, Sanderson and March 1996, U.S. Fish and Wildlife Service 1998, Heidel and Laursen 2003,

Johnson and Steingraeber 2003). Although greater in species diversity, extremely rich fens are lower in overall plant productivity relative to fens of lower pH because certain essential plant nutrients are rendered unavailable at biological extremes of the pH scale (McBride 1994). Lower plant productivity plus cool temperatures found in intermountain basins lead to very slow accumulation of peat, especially relative to peatlands elsewhere. The overall rate of peat accumulation in Region 2 exhibits a range of values estimated between 10 and 41 cm per 1,000 years (U.S. Fish and Wildlife Service Region 6 1997).

Cooper (1996) and Johnson and Steingraeber (2003) describe the species diversity and microtopographic features of extremely rich fen habitat in Colorado, and Fertig and Jones (1992) and Heidel and Laursen (2003) describe it in Wyoming. The overall species diversity in these habitats agglomerates in several microhabitats that comprise extremely rich fen habitat. In Colorado, these microhabitats consist of hummocks, hollows, springs, water tracks, meadows, and salt flats (Cooper 1996). Vegetation is distributed across these microhabitats along environmental gradients that correspond to water table height and microtopography (Johnson and Steingraeber 2003). Fertig and Jones (1992) and Heidel and Laursen (2003) identify eight different vegetation zones at Swamp Lake. Microtopography influence small scale plant distribution at this site.

Herbivory of *Salix myrtillifolia* by large ungulates has been suspected in Region 2 and documented and studied elsewhere. Studies in Alaska on the Tanana floodplain, where *S. myrtillifolia* is common, demonstrate heavy utilization by moose (Wolff 1976). Palatability of *S. myrtillifolia* was also rated high in restoration planning documents from British Columbia (Yoho National Park 1999). In general, willows provide forage, cover, and nesting for small mammals, and all willows appear to be preferred food for beaver (Kovalchik 2001).

In Alaska, several insects and fungi produce galls and disease in *Salix myrtillifolia*. Gall midges (*Rabdophaga*) induce various vegetative abnormalities, or galls. *Rabdophaga rigidae* produces beaked galls while *R. rosaria* induces "willow rose" formation, and *R. salicis* induces stem swelling. Pouch galls are formed by insects in the Eriophyiida. Fungal infection by *Rhystima salicinum* (tar spot fungus) has also been documented on *S. myrtillifolia* (Collett 2002). Studies on the interaction of herbivory and pathogen effects in a willow hybrid (*Salix* x *cuspidata*) demonstrated negative, or exacerbating, effects between these two stresses. Herbivory led to an increased susceptibility to fungal infection, and previous fungal infection systemically enhanced susceptibility toward subsequent fungal infection (Simon and Hilker 2003).

Although there are no specific studies of the mycorrhizae of *Salix myrtillifolia*, *Salix* species can have mycorrhizal relationships with several fungal species including *Inocybe*, *Cortinarius*, *Laccaria*, and *Tricholoma*, and *Cenococcum* (Cripps 2004). *Salix* is known to have both ectomycorrhizal and vesicular-arbuscular mycorrhizal associations (Harley and Harley 1987).

Many species of *Salix* produce salicylate, a compound that is the basis of aspirin. The hypothesized evolutionary significance of salicylate is that it has allelopathic properties that reduce interspecific composition. Schmidt et al. (2000) demonstrated that salicylate-producing plants have salicylate-mineralizing microorganisms in the soils beneath them, and these microorganisms preclude salicylate from persisting or accumulating in soils. However, Bowman et al. (2004) demonstrated that phenolic compounds, such as salicylate, produced by vascular alpine plants provided a carbon source for soil microorganisms but did not have inhibitory properties. The potential mutualistic relationship between *S. myrtillifolia* and soil microorganisms, and the potential habitat specificity of these relationships has yet to be fully elucidated.

Salix myrtillifolia, like most *Salix* species, is generally well-adapted to fire (Viereck and Little 1972, Haussler and Coates 1986, Uchytil 1992, Kovalchik 2001). Plants are top-killed by light to moderate fire, which then leads to re-sprouting from roots or basal stems and crowns. *Salix myrtillifolia* exhibits increased vigor following fires in spruce lowlands (Viereck and Little 1972). However, deep, lingering peat fires or any fire that removes upper soil layers would produce more severe damage and likely kill individual plants directly or indirectly through exposing roots (Kovalchik 2001). In Region 2, *S. myrtillifolia* occurs in wet habitats that will not readily burn under average circumstances.

CONSERVATION

Threats

Major threats to *Salix myrtillifolia* in USFS Region 2 directly affect its habitat and therefore indirectly affect populations. The primary and overarching threat to *S. myrtillifolia* and its habitat is hydrologic alteration.

Peat mining, a destructive extraction practice that leads to hydrologic alteration, is a second major threat to *S. myrtillifolia* habitat. Other site-specific impacts to *S. myrtillifolia* include livestock grazing and fire. As with all species and habitats, *S. myrtillifolia* is likely impacted by regional and landscape scale threats like acid rain, nitrogen deposition, habitat fragmentation due to anthropogenic development, and global climate change. Of these, global climate change will be discussed as the threat with the greatest potential to impact *S. myrtillifolia*. The habitat occupied by *S. myrtillifolia* in Region 2, extremely rich fens, is highly specialized and very restricted in distribution and abundance. Fens are intricate, groundwater-fed systems that form under highly stable hydrological conditions over thousands of years. Extremely rich fens are further specialized by being fed by groundwater that becomes enriched after percolating through specific types of bedrock, including limestone and dolomite. Constant saturation by cold, enriched groundwater over thousands of years has produced the organic peat substrate of these fens. Peat soils act like sponges, holding water *in situ* relatively longer than mineral soils, slowing water movement through these unique wetlands. Once damaged, recovery is slow, if it is possible at all (Cooper and MacDonald 2000, Johnson 2000, Sanderson et al. in prep.).

Hydrologic alteration

Hydrologic alteration is the greatest threat to the extremely rich fen habitat, and incidentally to *Salix myrtillifolia* occurrences, in Region 2. Hydrologic alteration encompasses any impact to water flow through fen systems or to the water balance supplied by surface and groundwater. The two primary impacts to hydrology in Region 2 are at opposite ends of the water supply spectrum; they are flooding of fen habitat and water diversion from fen habitat. Alterations can result from either anthropogenic or natural causes. Straightening or diverting streams, digging ditches, building stock ponds and reservoirs, and road building alter both the volume of water flow through the systems and the proportion of the water supply contributed by groundwater relative to surface flow. Transportation corridors and pumping groundwater for municipal use may also alter the hydrology of fen systems. Alteration to vegetative cover within the watershed can increase the amount of surface flow into the fen, shifting the balance between surface and groundwater sources.

Flooding of fen habitat has been a primary cause of extremely rich fen habitat loss in Region 2. Creation of reservoirs inundates vegetation and dramatically changes the hydrology, thereby destroying the intricate balance that maintains these fens. For example, based on the remaining fen vegetation at the upper end of Antero Reservoir in Park County, Colorado, the flooding of the valley to build the reservoir destroyed an unknown amount of well-developed extremely rich fen habitat that has a population of *Salix myrtillifolia* in the remnant vegetation (Sanderson and March 1996). Flooding by the reservoir created different edge effects to the remaining fen area. The Antero Reservoir provides drinking water to the Denver metropolitan area. Water usage in this area has steadily increased. Any further expansion of this reservoir, which has been proposed, will likely destroy the fen. Livestock ponds are smaller versions of the same impact, although coupled with the further impacts of grazing and trampling by livestock.

Alternatively, reduced water volume to these wetlands also has a significant detrimental impact. Straightening or diverting streams and ditch digging moves water through these systems more quickly and can lead to drying out of the wetlands. Incremental drying of the peat substrate also creates oxidizing conditions instead of anaerobic conditions, shifting the substrate dynamics to a loss of peat due to decomposition from conditions that favor slow peat accumulation. As ditches and diversions lower the water table, vegetation composition will shift. Different species of shrubs may colonize areas previously occupied by more hydrophytic herbs adapted to fen conditions (Glaser et al. 1981). These types of alterations also remove vegetation through the physical construction of the diversion, impacting populations and individuals directly.

Groundwater removal in the vicinity of fen systems would alter the water balance. Development pressure increased dramatically in the South Park area of Colorado with an eight-fold increase in population between 1970 and 2000. Residential development is the greatest projected source of growth in the future (Pikes Peak Area Council of Governors 2004). The demand for water will only increase. Surface waters have diminished in the drought period in Colorado between 2001 and 2004; Antero Reservoir, a water storage reservoir for Denver drinking water, was dry in the summer of 2004. The loss of surface water leads to a greater reliance on groundwater resources, which themselves are noticeably lower due to regional drought. Groundwater pumping has not yet had a discernibly significant impact to water sources feeding many fens in South Park, but it remains an important long-term threat that will require monitoring (Sanderson and March 1996).

Transportation corridors near or in wetlands alter site hydrology. Roads and railroad grades can increase

and intensify water flow due to higher runoff from relatively impervious surfaces. This reduces percolation and aquifer recharge as well as increases erosion (Forman and Alexander 1998). Alternatively, roads and railways can impede drainage, backing up water flow and increasing surface water levels. This has occurred at Swamp Lake in Wyoming where a culvert was placed above local water levels during highway reconstruction and has likely increased water retention in the wetland basin (Heidel and Laursen 2003). This has also occurred at the Old Railroad site (Sanderson and March 1996) northwest of Antero Reservoir where an old abandoned railroad was pushed through the wetland. The area between the railroad and the reservoir still maintains extremely rich fen conditions, but the opposite side has been lost to drying and mining of substrate. Further, roads and railroads are anthropogenic features that fragment and degrade habitat. They can be conduits for alien species and can increase pollutant inputs.

Disturbance within the watershed can also affect hydrology of fen systems. Removal of trees in the immediate vicinity of wetlands can increase surface runoff and cause erosion, both of which affect nutrient cycles within the fen. Past logging practices caused significant erosion implicated in major stream degradation in the South Platte River drainage, causing downcutting and sedimentation (Pikes Peak Area Council of Governors 2004).

In general, management activities or natural disturbances that affect the habitat of *Salix myrtillifolia* are likely to have confounding and cumulative effects on individuals or populations. Some threats that degrade habitat may cause similar degrading effects to *S. myrtillifolia* individuals or populations, but in many cases, effects to individuals or populations can be more severe. In particular, flooding associated with road building and reservoir or livestock pond creation is likely to eliminate individuals and populations of *S. myrtillifolia* by making the fen habitat too wet for these woody shrubs. However, the fen habitat may not be eliminated entirely, only set back to a different successional phase dominated by graminoids, depending on the severity of the hydrologic alteration.

Peat mining

Peat mining has significantly impacted the habitat of *Salix myrtillifolia* in Region 2. Commercial peat mining is permitted and is ongoing only in Colorado in Region 2 (USDI Bureau of Mines 1994, U.S. Fish and Wildlife Service Region 6 1998, Colorado Division of Minerals and Geology 2004). Mountain peat is primarily mined for horticultural use as well as to reclaim land for pasture and to create fishing ponds (Cooper and MacDonald 2000, Sanderson et al. In prep.). The purchase and use of mountain peat has been boycotted in Colorado by the Denver Water Board, Colorado Garden Club, and others. The boycott is based on the poor quality of mountain peat as a soil amendment and the recognition that the mining practices destroy critical and sensitive habitat (U.S. Fish and Wildlife Service Region 6 1997).

Peat mining has severely detrimental impacts to peatlands. It destroys fen habitat through removal of substrate and irrevocably alters its hydrology. These effects alter soil and groundwater chemistry and impair wetland functioning (Johnson 2000). Peat mining reduces vegetation cover and species richness, alters species composition and edaphic properties, and eliminates microtopography. The elimination of microtopography removes hummocks that are the primary microhabitat within fens where *Salix myrtillifolia* occurs. Hummocks are a product of decades of plant growth. Due to its slow accumulation rates (10 to 41 cm per 1,000 years; U.S. Fish and Wildlife Service Region 6 1998), peat in USFS Region 2 should not be considered a renewable resource.

Other site-specific threats

As described in Sanderson and March (1996), livestock grazing has demonstrably impacted some peatlands in Colorado. Although cattle tend to avoid the softest, wettest substrate areas, where *Salix myrtillifolia* occurs, vegetation is damaged or diminished by trampling and consumption. Over-grazing degrades surface water quality through the sheet, rill, and bank erosion it causes (Pikes Peak Area Council of Governors 2004). These detrimental effects can be mitigated by reducing the grazing pressure during early and mid-summer, when soils are wettest and highly vulnerable to compaction and disruption (Sanderson and March 1996) and by fencing for grazing management and alternative water supply structures (Pikes Peak Area Council of Governors 2004). Greater impacts were noted in smaller fens with more limited groundwater resources; larger fens generally are not utilized as heavily by livestock if sufficient pasture is available (Sanderson and March 1996).

Frequent or heavy levels of grazing can cause a shift in species composition as a secondary effect; cattle prefer grasses, sedges, and willows, reducing the abundance if not frequency of these taxa. Disturbance to peat soils by trampling also creates opportunity

for invasive plants, like Canada thistle (*Cirsium canadensis*). As *Salix myrtillifolia* occupies hummocks in the wettest portions of fens, it is likely protected somewhat from direct grazing pressure. Grazing impacts to *S. myrtillifolia*, if present, would be a secondary effect of habitat quality degradation.

Currently, *Salix myrtillifolia* occurrences in Region 2 are largely free of invasive, non-native plant species. Dandelion (*Taraxacum officianale*) and Kentucky bluegrass (*Poa pratensis*) have been reported from the Sweetwater Ranch population on the South Fork of the South Platte River in Colorado. This population had been heavily grazed. However, it was not discerned that these exotic species were problematic (Colorado Natural Heritage Program 2000). Cattle grazing can cause soil disturbance in *S. myrtillifolia* habitat, but it is likely that the high pH and anaerobic conditions preclude establishment of many weed species. However, certain hydrologic alterations may create more favorable conditions for exotic plant invasion. Drawdown of the water table and consequent drying of the soil may allow less hydrophytic species to colonize and establish. Nutrient loading from fertilizer or pollutant run-off can alter the pH of a fen, making it more vulnerable to invasion by exotic plants.

Forest fires affect surface water quality. A forest fire in the Clarks Fork Ranger District on the Shoshone National Forest burned much of the Swamp Lake watershed in 1988, including the cliffs above Swamp Lake. Debris flows from subsequent erosion have had notable impacts to the wetland below (Heidel and Laursen 2003). Likewise, the Hayman Fire has increased sediment loads reaching the South Platte River in the southeast portion of Park County, Colorado (Pikes Peak Area Council of Governors 2004). The impact area of the Hayman Fire is downstream of known extremely rich fens; however, it can serve as a model of the effects of forest fires on erosion and the impacts of base-level lowering on stream headwaters and associated wetlands (Heede et al. 1980; Neary et al. 2000).

Global climate change

Although global climate change is arguably the most serious potential threat to the persistence of *Salix myrtillifolia* in USFS Region 2, there remains uncertainty about its regional effects and severity. Climate fluctuations lead to vegetation change through species migration and/or evolution. Individual species have different responses to such changes due to different capabilities for migration. Further, migration corridors between suitable habitat must be present and intact in the face of long-term climate change for certain species to survive in a region. Region 2 populations of *S. myrtillifolia* are presumably glacial relicts. The constant supply of groundwater and the relatively high elevations of Region 2 occurrences have maintained conditions more similar to boreal regions. The habitat occupied by *S. myrtillifolia* in Region 2 is very restricted in distribution and abundance, and there is relatively little suitable habitat in the surrounding areas of either disjunct location. Further, each disjunct area has nearly impervious barriers to dispersal (mountain ranges), which makes these populations, in a sense, stranded where they occur. Without other suitable habitat or the means of reaching it, *S. myrtillifolia* may be completely eliminated from its current range by the inexorable force of global climate change.

Global climate change is likely to have wide-ranging effects in the near future for all habitats. However, the direction of projected trends is yet to be determined, and predictions vary based on environmental parameters used in predictive models. For example, Manabe and Wetherald (1986) demonstrate projections based on current atmospheric CO_2 trends that suggest that average temperatures will increase while precipitation will decrease in the western United States. However, Giorgi et al. (1998) showed that temperature and precipitation increased under simulated doubling of atmospheric carbon dioxide levels. Either scenario could significantly affect the hydrology of extremely rich fens in Region 2. Temperature increase, predicted by both models, could cause vegetation zones to climb 350 feet in elevation for every degree F of warming (U.S. Environmental Protection Agency 1997). This type of change is likely to result in a decline in habitat availability, moving *Salix myrtillifolia* populations to even higher elevations or eliminating them entirely. Changes in precipitation patterns would also result in a loss of habitat. Decreased precipitation will dry out water sources, making fens susceptible to invasion by shrubs, trees, and less hydrophytic herbs. Increased precipitation will reduce the aridity that promotes evapotranspiration and maintains high concentrations of minerals in extremely rich fens (see Cooper 1990 as cited in Sanderson and March 1996). Changes in element concentrations can subtly alter substrate pH, making fens a relatively less harsh environment and more available to competitive species. Because of the disjunct nature of *S. myrtillifolia* populations in the southern extent of the species' range and the fact that these populations will be unable to retreat to more suitable conditions nearby, this threat is pertinent to all occurrences in Region 2.

Jones et al. (1999) demonstrated differential response of dioecious species to climate change in *Salix arctica*, a prostrate, arctic and alpine tundra species also found in Region 2. Physiologic response (net assimilation) to artificial summer warming was positive in female plants and negative in male plants. As resources become limiting, this is a mechanism to minimize intraspecific competition and to optimize fitness (Jones et al. 1999). Although the final outcome is impossible to predict, rapid and continued atmospheric warming may alter sex ratios and potentially eliminate male plants if selection response does not keep up with the selection pressure. Alteration of sex ratios would affect the capacity for sexual reproduction within populations. Whether male plants ever existed at the Swamp Lake population of *S. myrtillifolia* is not known. However, the pattern demonstrated by Jones et al. (1999) presents a theory that may explain the absence of male plants.

Conservation Status of Salix myrtillifolia in Region 2

Is distribution or abundance declining in all or part of its range in Region 2?

Although no specific prescribed monitoring of individual populations of *Salix myrtillifolia* has occurred in Region 2, the distribution and abundance of *S. myrtillifolia* can be considered to be in decline within both disjunct areas. Habitat degradation and loss have been well-documented in South Park in Colorado, with areas immediately adjacent to *S. myrtillifolia* populations notably lost due to removal via peat mining as well as from drying due to water diversion and to flooding by reservoir creation (Sanderson and March 1996). The single Wyoming population of *S. myrtillifolia* has only female plants and thus is unable to reproduce sexually. Its population numbers will not increase without intervention. The Swamp Lake population is within a USFS Special Botanical Area, which protects it from certain land uses (e.g., *de novo* road building). However, the population is restricted to a small area within a large wetland complex. It cannot colonize areas that are any distance away, leaving it vulnerable to observed stochastic events (e.g., erosional debris fields noted in the area) and to any alteration of habitat due to land management (e.g., maintenance of water levels in wetland basins).

Do habitats vary in their capacity to support this species?

Salix myrtillifolia appears to occupy a distinct niche within well-developed extremely rich fens in Region 2; it grows on well-developed hummocks that raise the plants above the water table enough to support their growth. *Salix myrtillifolia* apparently does not tolerate persistent inundation. This microtopographic niche only occurs in larger peatlands where time and stable environmental processes have allowed sufficient peat accumulation to support necessary variation. Smaller fens are subject to greater edge effects and possibly to greater fluctuations in water levels that preclude sufficient peat development.

Vulnerability due to life history and ecology in Region 2 at risk

Although dioecious breeding systems are presumably an evolutionary adaptation to ensure outcrossing (Charlesworth and Charlesworth 1978), this characteristic of *Salix myrtillifolia* has made it vulnerable to extirpation in one of the two disjunct areas with the species in Region 2. The Swamp Lake population of *S. myrtillifolia* in Wyoming has no male plants, relegating the remaining female plants solely to vegetative reproduction. As such they are highly vulnerable to environmental stochasticity as well as to alterations in land management. The low numbers of plants at this site is also of concern.

The extremely rich fen habitat occupied by *Salix myrtillifolia* is very limited in its distribution and abundance. It is also sensitive to any impacts in hydrology as well as to certain land uses such as grazing as reviewed in the Threats and Community Ecology sections of this document.

Management of Salix myrtillifolia in Region 2

Implications and potential conservation elements

Two of the eight known occurrences of *Salix myrtillifolia* in Wyoming and Colorado (Swamp Lake in Wyoming and South Park, Colorado) occur on National Forest System lands. Total numbers of individual plants

at these sites, and therefore, the proportion of the total number within Region 2 boundaries that occurs on National Forest System lands, is unknown. Since the conservation status of occurrences outside National Forest System jurisdiction is to a large extent unknown and unpredictable, management of the two occurrences on USFS lands is critical for the persistence of the species. However, much of the responsibility for conservation of this species in Colorado lies with private landowners and the State of Colorado Division of Wildlife. Given the fact that the population trend for the species may already be in decline, its viability and survival in Colorado may depend on the coordinated efforts of landowners and land managers with occurrences on their property.

Disjunct and peripheral populations of *Salix myrtillifolia* have scientific and conservation significance even though the survival of the species may not depend on these populations. *Salix myrtillifolia* is part of a unique relictual community that has lingered in small pockets on the landscape following glacial retreat (Wells and Stewart 1987, Mitton et al. 2000). As such, this community can provide valuable information about the natural history of the North American continent during the Quaternary period. Disjunct populations can be important genetic reserves since outlier populations often contain atypical genetic variation in response to different environmental conditions outside of the main ecological range for the species. Disjunct populations can also be an important resource for research in biogeography, metapopulation dynamics, and population genetics. In Region 2, *S. myrtillifolia* can provide information on its unique and highly specialized habitat.

Occurrences of *Salix myrtillifolia* in Region 2 are probably most vulnerable to any environmental change that affects their extremely rich fen habitat. Management activity that maintains the natural hydrologic regime for these fens will benefit populations of *S. myrtillifolia*.

Strict regulation of hydrological modifications and resource consumption as well as monitoring of domestic grazing of occupied habitat will allow current populations of *Salix myrtillifolia* to persist. Unfortunately, hydrologic modifications are common throughout the range of *S. myrtillifolia* in Region 2 where water is an important commodity and drainage has been altered for a variety of historical and modern land uses. Natural environmental changes have affected the wetland and extremely rich fen habitat favored by *S. myrtillifolia* where it occurs in Region 2. Natural disturbance, such as forest fires, higher in the watersheds occupied by *S. myrtillifolia* have lead to altered hydrology that may be detrimental to its persistence. In these areas, land management policies focusing on the mitigation of these effects where at all possible would be beneficial. Any land management strategies that focus on maintaining or restoring natural hydrologic regimes would be a positive contribution to the conservation of *S. myrtillifolia*. See Beneficial Management Actions below for potential tools that may be applicable in achieving this goal.

Rondeau (2001) outlines desirable environmental parameters for extremely rich fen systems, and thus *Salix myrtillifolia* occurrences. The most important feature for the persistence of extremely rich fens is an intact natural hydrologic regime, ideally in a large area of unfragmented habitat that is comprised of unmodified natural ecological systems. Several authors describe desirable vegetation composition and structure of extremely rich fens (Cooper 1996, Carsey et al. 2003, Johnson and Steingraeber 2003). Fens that have similarly high diversity of native species are desirable. An intact natural hydrologic regime is indicated by a site with little or no evidence of wetland alteration. There would be no drainage modifications (increased or decreased), mining, clearing, or unnatural nutrient inputs. Certain native species (e.g., *Deschampsia cespitosa* and *Carex aquatilis*) increase with disturbance or with changes in hydrology or nutrient status. These species naturally occur in fens at a particular frequency and abundance typical of diverse communities. If these species are present in expansive stands, it may indicate hydrologic alteration. Unfragmented habitat, where roads or other anthropogenically-induced fragmentation is very limited (ideally impacting less than 1 percent of the wetland), provides ideal conditions for maintenance of fen habitat. As discussed in the Threats section, transportation corridors and any kind of development can alter the hydrology of an area and impede water flow connecting wetland complexes. In Region 2, the uplands surrounding *S. myrtillifolia* occurrences are primarily rugged mountain ranges that are forested. A surrounding landscape that is free of recent clearcuts, mining activity, heavily grazed pasture, or roads or municipal development will eliminate the potential impacts that these land uses may have on fen habitat.

Tools and practices

Species and habitat inventory

Ideally, species inventories would thoroughly search all potential habitats, locate and map all occurrences, accurately census each population, and

repeat this effort at regular intervals. Because this process is usually prohibitively expensive and time consuming, inventory work normally concentrates on obtaining reasonable estimates of population numbers and species distribution. Inventory methods based on a standard, repeatable protocol suitable for the scale and purpose of the project are desirable. The National Park Service Guidelines for Biological Inventories (National Park Service 1999) provides an excellent protocol for both species and habitat monitoring. Elzinga et al. (1998) is another comprehensive reference on monitoring plant populations. Brand and Carpenter (1999) devised a vegetation, habitat, and groundwater monitoring program for High Creek Fen in Colorado, which can serve as a model for *Salix myrtillifolia* monitoring.

Vegetative characteristics are diagnostic for *Salix myrtillifolia*, so inventory efforts need not take place while plants are flowering or fruiting. However, the clonal, layering habit of *S. myrtillifolia* makes collecting detailed data on each population – measuring numbers of individuals, as well as proportions of the population that are flowering versus vegetative – extremely difficult and time consuming. However, even rough population estimates based on spatial extent would be useful in determining population trends.

Extremely rich fens have been intensively studied in Colorado (Cooper 1990, Cooper 1996, Sanderson and March 1996, Johnson and Steingraeber 2003), and the Swamp Lake site has been mapped and characterized in Wyoming (Fertig and Jones 1992, Heidel and Laursen 2003). However, since their discovery in the early 1990's, many populations of *Salix myrtillifolia* have not been revisited. Ideally, these populations would be revisited and re-evaluated by trained professionals who are familiar with the nuances of *S. myrtillifolia* identification. Collection of voucher specimens has occurred at all known populations except for the site on Michigan Creek in Colorado where the population may not be large enough to support collection.

Personnel who conduct the surveys ideally would be familiar with *Salix* taxonomy and *S. myrtillifolia* identification, as well as detailed methods of soil and habitat characterization. They would also be able to use topographic maps and/or Global Positioning System units for accurate data collection of location and population and habitat extent. Recognizing that the extremely rich fen habitat that supports *S. myrtillifolia* is sensitive to perturbations, care should be taken to limit trampling of these fragile areas during surveys. Sharing information about the extent of occurrences and critical habitat characteristics will prevent duplication of survey effort and will allow multiple stakeholders (i.e., state and federal agencies, natural heritage programs, local and regional experts, interested members of the public) to devise protection and management strategies.

Population monitoring

Information on basic population size, structure, sex ratio, and density is lacking for *Salix myrtillifolia*. A population monitoring program that addresses growth patterns, recruitment, seed production, plant longevity, and population variability would generate data useful to managers and the scientific community. Population monitoring would allow the detection of population trends under different management prescriptions and land use patterns. Monitoring sites under a variety of land use scenarios (including sites in boreal regions outside of USFS Region 2) will help managers to identify appropriate management practices for *S. myrtillifolia*, and to understand its population dynamics and structure.

Repeated monitoring of established plots or transects every one to five years over the course of several decades would be a useful method of generating quantitative data on population dynamics of *Salix myrtillifolia*. Commitment to such a long time frame is suggested since *S. myrtillifolia* is a long-lived, woody, perennial shrub species. Further, this species is likely to be relatively slow-growing due to the non-productive habitat in which it occurs. The frequency of monitoring is suggested due to the sensitive nature of the extremely rich fen habitat and the development pressure occurring around all of Colorado's occurrences. South Park populations may need to be visited as often as possible in order to note any environmental perturbations prior to any subsequent impact on *S. myrtillifolia*. Although the habitat of the Swamp Lake population is relatively pristine, this population would likewise benefit from being visited as often as possible given the potentially precarious nature of the unisexual population found at that location. However, quantitative studies are time consuming and can be expensive. If agency resources are limiting, a minimal level of effort to acquire broad population estimates or photopoint data collection could provide a qualitative measure of habitat condition and population condition over time (see Elzinga et al. 1998).

Habitat monitoring

For sites occupied by *Salix myrtillifolia*, extremely rich fen habitat monitoring would ideally be

conducted concurrently with any population monitoring that may be conducted. Habitat monitoring alone is preferred if population monitoring is deemed too costly or time consuming. Because the fen habitat of *S. myrtillifolia* often supports other regionally rare species and communities (Sanderson and March 1996), habitat monitoring would be the most efficient way to detect impacts and population trends for a suite of important biological resources. Monitoring soil moisture, water table, and water chemistry would be useful for this habitat since it relies on a narrow range of hydrologic conditions. Documenting the scope and severity of any habitat disturbance would be useful for documenting potential impacts to *S. myrtillifolia* populations. Correlation of this sort of habitat information with population trends would greatly enhance our present understanding of the habitat requirements and management needs of *S. myrtillifolia*.

Habitat monitoring of sites with known occurrences of *Salix myrtillifolia* will alert managers to any new impacts from grazing or off-road vehicle use. Early detection of damage will allow proactive management changes to be implemented in time to prevent serious damage to *S. myrtillifolia* populations. Demographic response to changes in environmental variables may not be immediate, so repeated sampling of select environment 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, photopoints can also be used for habitat monitoring as a powerful technique that can be performed quickly in the field (see Elzinga et al. 1998). Practical details of photographic monitoring are exhaustively covered in Hall (2001). Although it does not provide detailed cover or abundance data, photopoint monitoring can clarify patterns observed in quantitative data.

Beneficial management actions

At the species level, continuing to list *Salix myrtillifolia* as a sensitive species will maintain an effective conservation tool. In terms of *S. myrtillifolia* habitat, the primary consideration for any management action is to preserve the natural hydrology of the fen containing the population as well as its surrounding watershed. In general, management actions that maintain the hydrology of fens and promote natural levels of connectivity between them will tend to benefit populations of *S. myrtillifolia*. Specific management actions beneficial to *S. myrtillifolia* and/or its habitat include:

- implementing and improving standards and guidelines in USFS Land and Resource Management Plans
- changing management area allocation to one with more protection
- limiting or eliminating grazing access by domestic animals whenever possible to decrease trampling of sensitive fen habitat
- examining the effects of off-road vehicle use in the immediate habitat and in the surrounding watershed may reveal a potential need for restricting recreational use in these areas
- evaluating the effects of other management activities, such as logging, mining, road construction, and ditching or other water diversions that may impact hydrology and/or cause sedimentation of wetland habitat, both in the immediate habitat as well as the surrounding watershed
- creating buffers or no-management zones surrounding wetlands
- investigating land exchange or purchase with willing partners
- designating additional protected areas that are managed for the conservation of *S. myrtillifolia*.

Seed banking

The ephemeral nature of *Salix* seeds precludes seed banking as a demonstrably practical conservation tool although improvements are developing for some *Salix* species (Maroder et al. 2000, Wood et al. 2003). Live specimens of both sexes would need to be maintained for production of seed for any restoration projects. Propagation of cuttings is also a possible means of producing material for restoration. Baskin and Baskin (2002) list propagation protocols for *S. myrtillifolia*.

Information Needs

Distribution

The geographic distribution of *Salix myrtillifolia* in Region 2 is reasonably clear. *Salix myrtillifolia* occurs in two disjunct areas in Region 2 that are both disjunct from the main boreal range of the species. Occurrences of *S. myrtillifolia* in the intervening area in Montana, Idaho, Oregon, and Washington, which would reduce the geographic distance between known occurrences in Region 2 and the main boreal range of the species, are possible but not confirmed. Difficulties with identification and with taxonomy have likely precluded the confirmation of this taxon in these areas. However, taxonomic resolution is eminent and will lay the ground work to complete distribution and habitat expression of this taxon throughout its geographic range (Volume 7, FNA, "Under construction"). Some populations have only been identified recently, and it may be possible to locate additional populations. *Salix myrtillifolia* is known from approximately 30 percent of the known fens in South Park, Colorado. Searching these fens for additional populations may provide further information on the size and condition of habitat needed to support *S. myrtillifolia*.

Life cycle, habitat, and population trend

Characteristics of the extremely rich fen habitat where *Salix myrtillifolia* is found are well documented. However, the intricacy of interaction among environmental parameters is still under investigation. These characteristics are complex and require continued study in order to achieve a comprehensive understanding from which to devise conservation strategies. Groundwater monitoring protocols are on-going at High Creek Fen in Colorado, the largest and best example of extremely rich fen and the largest *S. myrtillifolia* population in Colorado (Brand and Carpenter 1999). Establishing similar studies on smaller fens may elucidate important parameters for these smaller wetland systems where the dynamics between surface and groundwater fluctuations may be different.

The specific niche occupied by *Salix myrtillifolia* within montane fen ecological systems has been observed but not specifically studied. Research to clarify the exact hydrologic, chemical, and microtopographic tolerances of the species, and how to recognize these in the field would advance our knowledge and ability to understand and manage these fen ecological systems.

The relative importance of reproduction through vegetative growth compared to sexual reproduction in this species will have important implications for the population dynamics and persistence of the species in disjunct areas in USFS Region 2. It is important to develop practical but accurate methods for estimating population numbers, methods that preferably do not rely on the identification of individual plants. Additional information on growth and recruitment patterns, specific pollination vectors, and disturbance mechanisms responsible for creating suitable sites for establishment would also contribute to our ability to understand population trends in *Salix myrtillifolia*.

Response to change

The effects of environmental variation on the success of *Salix myrtillifolia* have not been investigated. Variation in environmental parameters presumably affects plant growth, reproductive rates, dispersal mechanisms, probability of establishment, plus its interaction with herbivores, pollinators, and exotic species to an unknown degree. Without knowing these effects, implications of habitat change in response to management or disturbance is difficult to evaluate. Detailed information on the microhabitat requirements of *S. myrtillifolia* will provide a basis for understanding the potential effects of disturbance and management actions in extremely rich fens. Of particular interest in Region 2 is the response of *S. myrtillifolia* to various hydrological disturbance produced by domestic grazing, trampling, or drought.

Metapopulation dynamics

Metapopulation dynamics may be important for the Colorado occurrences of *Salix myrtillifolia*, especially if additional small populations are discovered. Metapopulation dynamics are not relevant to the Wyoming site as there is only one known occurrence. Research has not been performed on populations of *S. myrtillifolia* to determine the importance of metapopulation structure and dynamics for its long-term persistence at both local and regional scales. Emigration, immigration, colonization rates, and extinction rates are unknown for *S. myrtillifolia*.

Demography

Currently, only the broadest generalizations can be made regarding the demography of *Salix myrtillifolia* populations in Region 2. Studies on other *Salix* species

in other, very different habitats do not provide a good generalized model with which to approach the demography of *S. myrtillifolia* populations occurring in extremely rich fen habitat. *Salix myrtillifolia* is likely quite different in growth rates and resource allocation patterns than the other *Salix* species that have been studied. The detailed investigation required to develop a life-cycle projection matrix may not be feasible in Region 2. These sorts of studies generally require destructive sampling that should not occur in these limited disjunct occurrences. However, this may be a viable option for populations in the main boreal distribution range of the species. In the absence of more complex studies, it may still be useful to collect growth and longevity data in Region 2 by following marked individuals in their natural habitat over several consecutive years and at different sites.

Population trend monitoring methods

The clonal, rhizomatous growth habit of *Salix myrtillifolia* complicates the use of existing population trend monitoring methods. Standard methods usually rely on counting individual plants, which is difficult with clonal species. Modified methodology would need to be employed. Depending on the level of information desired, possible alternatives are to use individual stems as a sampling unit, or to use some sort of density per unit area estimate.

Restoration methods

Certain impacts to the highly specialized extremely rich fen habitat of *Salix myrtillifolia* are dire and cause irreparable damage considering a reasonable time frame and budget. Peat mining causes severe damage to the substrate and hydrological dynamics at a site. Sanderson et al. (In prep) and Cooper and MacDonald (2000) describe restoration protocols attempted for restoring fen habitat after peat mining. In Sanderson et al. (In prep), mined sites were regraded, seeds were broadcast, and limited live plant material was transplanted over the restoration area. After eight years of monitoring, the restoration effort failed to re-establish the characteristic wetland vegetation found in extremely rich fens, but some improvement was noted. Cooper and MacDonald (2000) also designed a study to test techniques for restoring fens along a water table gradient as well as to determine which fen species naturally re-colonized mined peatlands. Hydrologic systems within their mined sites were relatively intact, but the peat layer had been removed. They tested four revegetation techniques: seeding, transplanting greenhouse-grown seedlings, transplanting rhizomes from adjacent sites, and transplanting willow stem cuttings. Each technique used several fen species, mostly sedges and willows. *Salix myrtillifolia* was studied as part of the stem cuttings transplant technique. Direct seeding was not successful; only two of eight species germinated and there was low survival among those individuals that did emerge. Seedling transplants of *Carex aquatilis* were most successful where the water table was within 10 cm of the surface, with fifty percent survival of all transplants after two field seasons. Rhizome transplants showed highly variable results depending on the species and hydrology. Survival of willow stem cuttings after two seasons ranged from 12 to 33 percent, with *S. myrtillifolia* survival at 33 percent, suggesting that this species readily develops an adventitious root system. The results of these experiments suggest that peatland restoration following peat mining is a slow and labor-intensive process. Because of the complexity of the associated relictual plant communities, development of successful restoration methods for this species may need to concentrate on mitigation of damage *in situ*, and not on the creation of new habitat. *Salix myrtillifolia* has been used in restoration projects in Canada (Uchytil 1992), and it may be transplantable to other wetland habitats (Cooper and MacDonald 2000).

Less damaging impacts to fen habitat, such as those from high levels of grazing, can be mitigated. A reduction in grazing pressure has led to the recovery of *Salix myrtillifolia* at one site in Colorado (Colorado Natural Heritage Program 2000). Investigating specific parameters of rotational and deferred grazing and their effect on extremely rich fen habitat in Region 2 would provide useful management information. Further, impacts to surficial water quality from excessive grazing can severely reduce riparian vegetation cover and increase erosion. If this happens upstream from fen habitat, evaluation of land management practices may be warranted. At Antero Reservoir, cattle exclusion has led to a slow recovery of woody species cover. Also, below the reservoir, the Colorado Division of Wildlife created a new meander channel in 2001 to augment the channelized stream drainage. The new meander mimics natural riparian characteristics with deep areas dug at outside turns, the addition of point bars, plus placement of boulders and woody debris in the channel for habitat complexity (Pikes Peak Area Council of Governors 2004). Effects of this restoration on water quality have yet to be determined.

The Swamp Lake population of *Salix myrtillifolia* in Wyoming could be a case study for restoration. The lack of male plants precludes sexual reproduction in this population, leaving it vulnerable to extirpation.

Importing male plants is likely quite possible. However, if this is attempted, care should be taken when deciding on the source of genetic material, whether from the other disjunct area in Colorado or the more common boreal distribution in Canada.

Research priorities for Region 2

The most important research priority for *Salix myrtillifolia* in Region 2 is the continued investigation of specific water quality and quantity impacts on extremely rich fen hydrology due to drought and to groundwater pumping. Long-term monitoring that studies detailed growth assessments of *S. myrtillifolia* populations in differing hydrogeomorphic settings (i.e., near a stream, at the base of a steep slope, valley floor) would generate useful information. Additional research topics include:

- identifying locations of additional populations
- assessing genetic differences between the relict populations in Colorado and Wyoming versus populations in the boreal range
- quantifying the effects of disturbance and land management practices on the survival and persistence of the species
- investigating the growth and reproductive requirements of individual plants
- developing and utilizing practical population monitoring methods in concert with habitat monitoring.

Definitions

Definitions are drawn from Fertig and Markow (2001) unless noted otherwise.

Anthesis – The time of flowering in a plant.

Artificial classification – Ordering of organisms into groups based on non-evolutionary features, like number and situation of stamens, styles, stigmas, etc. (Allaby 1998).

Bract – A modified, usually reduced leaf associated with a flower or group of flowers.

Branchlet – Small branch, usually referring to second, third, or fourth-year stems.

Bud – Dormant growing tip of a plant covered by a hardened, protective scale.

Capsule – Dry fruit that, at maturity, opens and releases seeds.

Catkin – Structure consisting of a group of flowers (unisexual in willows) arranged along an elongate, flexible axis.

Coetaneous – Flowering as the leaves expand (Radford et al. 1974).

Decumbent – Describes a stem that creeps along the ground, with the tip pointed upward.

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

Ecological amplitude – Range of tolerance of a species, diagrammatically forming a bell-shaped curve. Species with a narrow ecological amplitude often form good indicator species.

Edaphic – Pertaining to soil properties (Allaby 1998).

Endosperm – Stored food materials that are broken down during germination (Allaby 1998).

Entire – Describes leaf margins that lack teeth or other indentations or divisions.

Flark – Low area between strings (or ridges) within a patterned peatland (Crum 1988).

Glabrous – Lacking hairs.

Gland – Small swelling that usually secretes a liquid.

Glaucous – Condition where a surface is coated with a light blue or whitish waxy substance that can be rubbed off with your fingers.

Hybridization – Cross between two different taxa (Allaby 1998).

Hydrophyte – A plant growing in water or in soil too waterlogged for most plants to survive.

Hypocotyl – Part of the embryonic shoot or seedline located below the cotyledon and above the root (Allaby 1998).

***K*-selection –** Selection for maximizing competitive ability. Most typically this is a response to stable environmental resources. This implies selection for low birth rates and high survival rates among the offspring, and prolonged development (Allaby 1998).

Natural classification – Ordering of organisms into groups based on evolutionary relations (Allaby 1998).

Nectary – Small gland that holds or excretes nectar or sap, usually found at the base of floral parts (American Heritage Dictionary 1976).

Phenetic – Basis of grouping on observed physical similarities (Allaby 1998). See Artificial classification.

Phenology – The study of the impact of climate on the seasonal occurrence of flora and fauna (dates of flowering, migration, etc.), and the periodically changing form of an organism, especially as this affects its relationship with its environment (Allaby 1998).

Pistillate – Condition in which a plant or plant part has only female reproductive structures (pistils).

Ploidy – The number of single sets of chromosomes in a cell or an organism.

Primordia – Cells in embryo or bud giving rise to roots, leaves or flowers (Radford et al. 1974).

Pubescent – Condition of having hairs.

Reticulate – Having a network-like pattern of ridges and spaces (Allaby 1998).

Staminate – Condition in which a plant or plant part has only male reproductive structures (stamens).

Stigma – Pollen-receptive portion of pistil (Radford et al. 1974).

Stipules – Small appendages at the base of a petiole.

Stochasticity – Random. A stochastic process is one whose behavior is non-deterministic in that the next state of the environment is not fully determined by the previous state of the environment.

String – Ridges or locally high microtopography in a patterned peatland (Crum 1988). Compare flark.

Sympatric – Applied when species occupy overlapping geographic range (Allaby 1998).

Tomentose – Condition of having short, dense, woolly hairs.

Tricolpate – Describes pollen grains that have three folds, or colpi, which extend from both ends of the grain and are spaced somewhat evenly around it. The colpi serve as germination furrows for the emerging pollen tube during fertilization. (Gifford and Foster 1989).

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