Salix arizonica Dorn (Arizona willow): A Technical Conservation Assessment

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

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COVER PHOTO CREDIT

Salix arizonica (Arizona willow). Photograph by Phil Tonne, used with permission.

SUMMARY OF KEY COMPONENTS FOR CONSERVATION OF *SALIX ARIZONICA*

Status

Salix arizonica (Arizona willow) is a subalpine species of wet meadows, streamsides, and cienegas in Utah, Arizona, New Mexico, and Colorado. The NatureServe global conservation status rank for *S. arizonica* is G2; state Natural Heritage Program rankings are S1 for Colorado and New Mexico, and S2 for Arizona and Utah. At one time this species was considered a candidate for listing as an endangered species, but the listing proposal was withdrawn in 1995 following the development of an interagency Conservation Agreement and Strategy. Due to the discovery of many new populations outside Arizona, this agreement was allowed to expire. *Salix arizonica* is currently considered a sensitive species in the USDA Forest Service (USFS) Rocky Mountain Region (Region 2), and in USFS Regions 3 and 4. The species was first found in Colorado on the Rio Grande National Forest in Conejos County in 2001, and this remains the only known occurrence in Region 2 despite the fact that *S. arizonica* is known from dozens of occurrences in Arizona, New Mexico, and Utah. Other Region 2 occurrences may yet be discovered, however, through expanded search efforts. Rangewide, the majority of known occurrences of *S. arizonica* are on National Forest System lands.

Primary Threats

Primary threats to the persistence of *Salix arizonica* in Region 2 are grazing by domestic and wild ungulates, hydrologic alterations, impacts from timber harvesting, impacts from recreational use, consequences arising from small population sizes, and global climate change. The detrimental effects of grazing and altered hydrology have been documented in occurrences outside Region 2. Information on the incidence and potential severity of other threats is less well known, due to the relatively recent discovery of both the species and many of its occurrences.

Primary Conservation Elements, Management Implications and Considerations

The high elevation wetland habitats where *Salix arizonica* is found are relatively rare in the Intermountain West. Ultimately, the survival of this species in Region 2 depends on future habitat trends as well as on the conservation efforts of land managers and owners. As currently known, most *S. arizonica* occurrences, including that in Region 2, are most vulnerable to ungulate herbivory and habitat loss or degradation. Any management activities that reduce utilization of *S. arizonica* by ungulate herbivores and/or maintain intact hydrologic function for its subalpine riparian habitats will contribute to the persistence of the species. The primary information need for *S. arizonica* is the determination of population numbers and trends over time for known occurrences throughout the range of the species, especially in Region 2. Conservation efforts would be greatly enhanced by cross-region, interagency review of the species' status on a periodic basis.

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INTRODUCTION

This assessment is one of many being produced to support the Species Conservation Project for the USDA Forest Service (USFS) Rocky Mountain Region (Region 2). *Salix arizonica* (Arizona willow) is the focus of an assessment because it is a regional endemic species whose population viability is identified as a concern based on its extremely limited regional distribution. USFS Region 2 currently lists *S. arizonica* as a sensitive species (USDA Forest Service 2005). Within the National Forest System, a sensitive species is a plant or animal whose population viability is identified as a concern by a Regional Forester because of significant current or predicted downward trends in abundance and/or significant current or predicted downward trends in habitat capability that would reduce its distribution (USDA Forest Service 2003). A sensitive species may require special management, so knowledge of its biology and ecology is critical. This assessment addresses the biology, ecology, conservation status, and management of *S. arizonica* throughout its range, but it focuses on the single known occurrence in Region 2. This introduction defines the goal of the assessment, outlines its scope, and describes the process used in its 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 available scientific knowledge. The assessment goals limit the scope of the work to critical summaries of scientific knowledge, discussion of broad implications of that knowledge, and outlines of information needs. The assessment does not seek to develop specific management recommendations. Instead, it provides the ecological background upon which management must be based and focuses on the consequences of changes that result from management (i.e., management implications). Furthermore, it cites management recommendations proposed elsewhere and examines the success of those recommendations that have been implemented.

Scope of Assessment

The assessment examines the biology, ecology, conservation status, and management of *Salix arizonica* with specific reference to the geographic and ecological characteristics of the USFS Rocky Mountain Region. Although essentially all of the literature on this species and its congeners is derived from field investigations outside the region, this document places that literature in the ecological context of the southern Rocky Mountains. Similarly, this assessment is concerned with reproductive behavior, population dynamics, and other characteristics of *S. arizonica* in the context of the current environment rather than under historical conditions.

In producing the assessment, I reviewed refereed literature, non-refereed publications, research reports, and data accumulated by resource management agencies and other investigators. The majority of known publications that specifically treat *Salix arizonica* are referenced in this assessment. Because basic research has not been conducted on many facets of the biology of *S. arizonica*, literature on its congeners was used to make inferences. The refereed and non-refereed literature on the genus *Salix* and its included species is more extensive and includes other regionally rare species. Element occurrence records were obtained from the Arizona Natural Heritage Program, Colorado Natural Heritage Program, and New Mexico Natural Heritage Program. Utah Conservation Data Center element occurrences records have not been updated to reflect the most current information (Franklin personal communication 2005), so locations in Utah were obtained from Mead (1996), Clark (2002 and 2003), and Groebner (2004). Additional location information was derived from herbarium specimen labels and inventory reports. Specimens of *S. arizonica* were viewed at University of Colorado Herbarium (COLO) and Rocky Mountain Herbarium (RH), and specimen records were obtained from herbaria in New Mexico and Arizona. An exhaustive search for all extant specimens was beyond the scope of this document; however, all known localities are represented to some degree. The assessment emphasizes refereed literature because this is the accepted standard in science, and refereed literature is used to address general biological and ecological concepts. Non-refereed publications or reports were regarded with greater skepticism, but they were used in the assessment since they are the primary source of information about *S. arizonica* occurrences.

In this assessment, the term population is used to refer to a discrete group of *Salix arizonica* individuals that is separated from the next nearest known group of *S. arizonica* individuals by at least one kilometer. Within a population, individual plants may be distributed in a more-or-less patchy fashion, but all are within the minimum separation distance. This usage is synonymous with "element occurrence"

as used by NatureServe and state Natural Heritage Programs. In this usage, population/occurrence implies that members of such a group are much more likely to interbreed with one another than with members of another group. To lessen confusion, I have used the term "occurrence" to refer to such a discrete group, and "population" to refer to groups of occurrences that may or may not interbreed. In this document, the term population is not used to refer to the entire complement of *S. arizonica* individuals present in Region 2 or worldwide (the meta-population).

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, so often observations, inference, critical thinking, and models must be relied on to guide our understanding of ecological relations. For most aspects of the biology and ecology of *Salix arizonica*, it is important to note that available information has been gathered from populations outside Region 2. In addition, information on the biology and ecology of other *Salix* species has been used to draw inferences regarding similar characteristics for *S. arizonica*. 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, Web publication facilitates revision of the assessments, 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 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 arizonica is currently considered a sensitive species in Region 2 of the USFS (USDA Forest Service 2005). It is also on the sensitive species list for USFS Region 3 (New Mexico and Arizona) and Region 4 (Utah). Although *S. arizonica* is known from dozens of occurrences in Arizona, New Mexico, and Utah, there is currently only a single known occurrence in Region 2, in southern Colorado (**Figure 1**). Occurrences in Arizona, Colorado, and New Mexico are generally much smaller than those in Utah. In the four states in which it is found, *S. arizonica* is primarily on National Forest System lands or (in Arizona) on Tribal lands. In Region 3, Arizona occurrences are limited to the Apache-Stigreaves National Forest and the adjacent Fort Apache Indian Reservation. One Arizona occurrence is on the Phelps Cabin Research Natural Area. New Mexico occurrences are on the Carson and Santa Fe national forests. In Region 4, the species is known from more than 30 occurrences in Utah, on the Dixie, Fishlake, and Manti-La Sal national forests (Mead 1996, Clark 2002 and 2003, Groebner 2004), on National Park Service lands at Cedar Breaks National Monument, and on private lands. The single Colorado occurrence is on the Conejos Peak Ranger District of the Rio Grande National Forest in Conejos County. The current management prescription for the immediate area of the Region 2 occurrence is for Forest Products, in this case commercial harvest in Engelmann spruce and Engelmann spruce-subalpine fir stands. The intent of this prescription is to allow a full range of activities, with an emphasis on the production of commercial wood products (USDA Forest Service Rio Grande National Forest 1996). As of this writing, there are no known plans to harvest timber in the immediate vicinity of the *S. arizonica* occurrence (Erhard personal

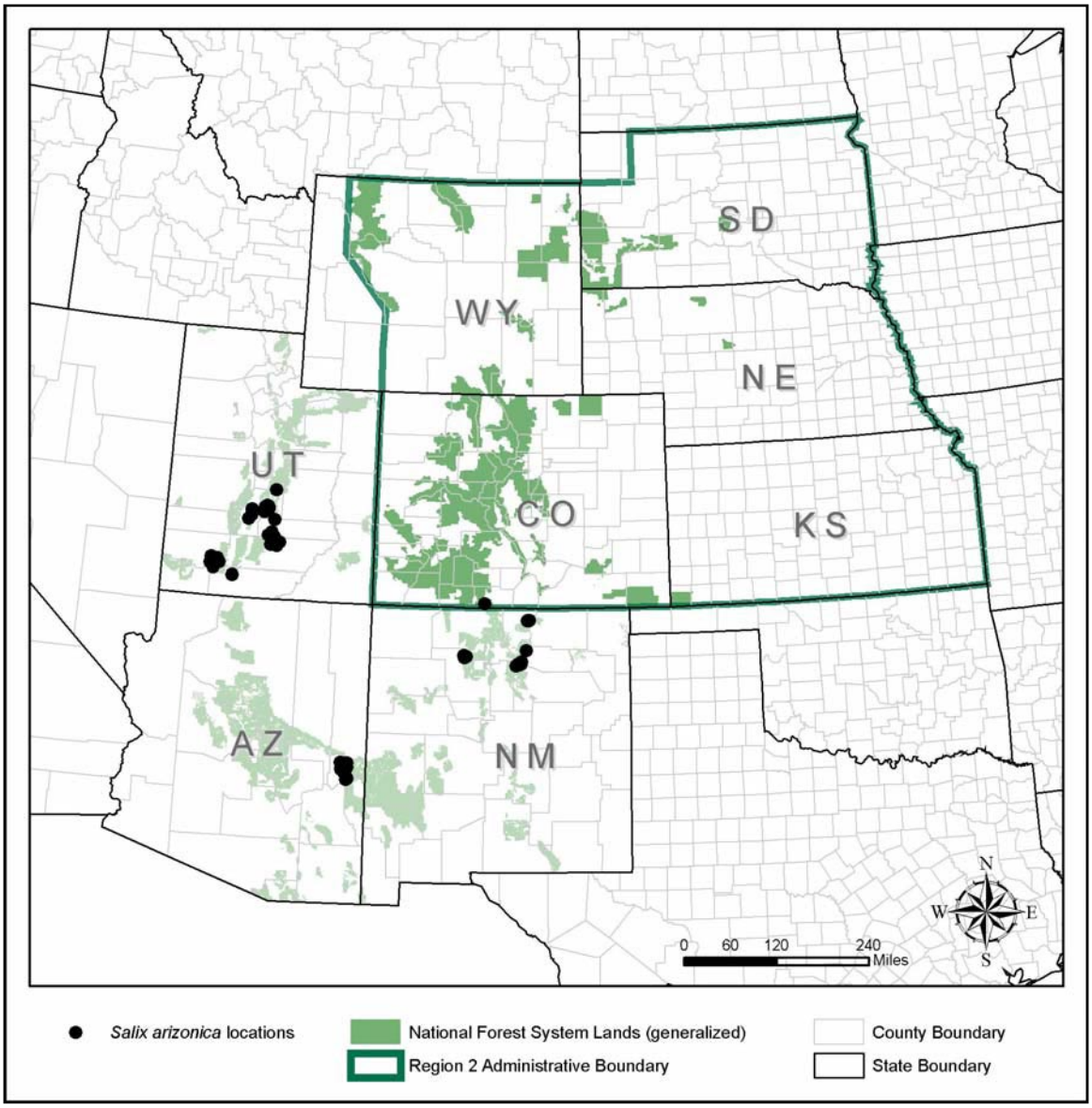


Figure 1. Distribution of *Salix arizonica* in USDA Forest Service Region 2.

communication 2006). Adjacent areas are under a Backcountry management prescription, with a theme of maintaining plant and animal habitats that are shaped primarily through natural processes and providing backcountry experiences to the public in areas where there is little evidence of human activities (USDA Forest Service Rio Grande National Forest 1996).

In 1992, the U.S. Fish and Wildlife Service (USFWS) proposed listing *Salix arizonica* as an endangered species under the Endangered Species Act (57 FR 54747). At that time the species was known only from the vicinity of Mount Baldy in Apache County, Arizona. Following the publication of the proposal, additional occurrences of *S. arizonica* were located in Utah, and in 1995 an interagency conservation agreement and strategy was published (Arizona Willow Interagency Technical Team 1995, Prendusi et al. 1996). The USFWS determined that the implementation of this plan would provide sufficient protection for the species and withdrew the listing proposal in 1995 (60 FR 20951). There are currently no *Salix* species that are federally listed as threatened or endangered.

The current NatureServe global conservation status rank for *Salix arizonica* is G2G3 (with a rounded rank of G2). The global (G) rank is based on the status of a taxon throughout its range. A G2 ranking is defined

as "Imperiled - At high risk of extinction due to very restricted range, very few populations (often 20 or fewer), steep declines, or other factors," while the G3 ranking is "Vulnerable - At moderate risk of extinction due to a restricted range, relatively few populations (often 80 or fewer), recent and widespread declines, or other factors" (NatureServe 2005). State Natural Heritage Program rankings for this species are S1 for Colorado and New Mexico, and S2 for Arizona and Utah (NatureServe 2005). The state (S) rank is based on the status of a taxon in an individual state. The S1 rank signifies that the species is "critically imperiled in the state because of extreme rarity (often 5 or fewer occurrences) or because of some factor(s) such as very steep declines making it especially vulnerable to extirpation from the state." A rank of S2 is indicates that the species is "imperiled in the state/province because of rarity due to very restricted range, very few populations (often 20 or fewer), steep declines, or other factors making it very vulnerable to extirpation from the nation or state/province" (NatureServe 2005).

Existing Regulatory Mechanisms, Management Plans, and Conservation Strategies

Salix arizonica is not currently listed as a candidate for Threatened or Endangered status under the Endangered Species Act. The 1996 elimination of the Category 2 Candidate Species List left *S. arizonica*, along with hundreds of other species, in something of an uncertain state with regard to their status as Federal species of concern. There appears to be little Federal provision for maintaining continued interagency oversight of species for which conservation efforts have forestalled listing, but whose status is still potentially subject to change if such efforts are not maintained.

In Arizona, *Salix arizonica* is protected under the Arizona Native Plant Law as a Highly Safeguarded Species (Arizona Revised Statutes 1999). This law prohibits collection without a permit for educational or scientific purposes from the Arizona Department of Agriculture (Arizona Willow Interagency Technical Team 1995), but it does not apply to Tribal lands, nor does it protect *S. arizonica* habitat. *Salix arizonica* has no similar protection under state statutes in the other three states in which it is found.

In 1995, the Arizona Willow Conservation Agreement and Strategy was signed (Arizona Willow Interagency Technical Team 1995), to be effective for a period of 10 years. This document included administrative responsibilities and procedures, a summary of short and long-term actions to be implemented, and commitments of the participating agencies for the conservation of *Salix arizonica*. At that time it was considered that the conservation of *S. arizonica* would require the removal of threats, improvement of degraded habitat conditions, maintenance and/or expansion of populations, and restoration of many of the natural functions of the riparian systems associated with known occurrences. The Agreement designated eight watershed-based "conservation units", with the objectives that each conservation unit sustain viable populations or populations on a significant upward trend toward viability for at least 10 years, and that unfragmented and high quality habitat sufficient to ensure long-term survival and recovery be protected within each conservation unit (Arizona Willow Interagency Technical Team 1995). Short-term actions were prescribed that were intended to stabilize populations of *S. arizonica* by reducing immediate threats that inhibited growth, reproduction, and seedling establishment, and contributed to mortality (Arizona Willow Interagency Technical Team 1995). In 2002, the signatory agencies met to review the progress of the Agreement. Since the inception of the Agreement, extensive survey efforts had lead to the discovery of several major populations and expanded the known range of the species, and many of the conservation items had been successfully implemented. In light of this information, the interagency team recommended to the U.S. Fish and Wildlife Service that the Team be dissolved, and the Service agreed that the Agreement had fulfilled its purpose (Clark 2003, Prendusi personal communication 2005). The team was dissolved, and the agreement was allowed to expire at the end of its original 10-year term. The group determined that there was no merit in listing the species. Each of the participants was encouraged to work within agency guidelines to promote the sustainability of *S. arizonica* (Clark 2003).

During the same time that the Conservation Agreement and Strategy was produced, a management plan consistent with the strategies and intent of the Interagency Agreement was developed for *Salix arizonica* on the Fort Apache Indian Reservation in Arizona (Arizona Willow Interagency Technical Team 1995). In addition, a number of Tribal laws and regulations governing land management, livestock grazing, health and safety, timber harvest, road construction, collection of biological materials, wildlife management, and recreation use serve to protect *S. arizonica* and its habitat (Arizona Willow Interagency Technical Team 1995).

There are several Federal laws, executive orders, and policies that have the potential to provide protection for *Salix arizonica* habitat and, indirectly, for individual plants. The National Environmental Policy Act of 1969 requires Federal agencies to prepare environmental compliance documents for Federal actions, including consideration of the effects of proposed actions on the environment. Section 404 of the Federal Water Pollution Control Act of 1948 (Clean Water Act), as amended, and Federal Executive Orders 11988 (Floodplain Management) and 11990 (Protection of Wetlands), also provide protection of *S. arizonica* habitat under certain conditions.

The National Forest Management Act (NFMA) of 1976 (16 U.S.C. 1600-1602, 1604, 1606, 1608-1614) charges the USFS with the responsibility of protecting natural resources, especially wetlands, streams, lakes, and riparian areas, from damage. Management activities that could negatively affect wetland habitat should be avoided (36 CFR 219.27). The NFMA regulations require the USFS to manage lands so as to provide sufficient habitat to maintain viable populations of native species such as *Salix arizonica*. A viable population is defined as having "the estimated numbers and distribution of reproductive individuals to insure its continued existence." The Regional Foresters of the three USFS regions in which *S. arizonica* occurs maintain lists of sensitive plant species on National Forest System lands, and these lists currently include *S. arizonica*. Any proposed action on USFS lands must be evaluated for possible negative effects to sensitive species, and personnel are directed to use a variety of approaches to prevent sensitive species from becoming designated Threatened or Endangered by the U.S. Fish and Wildlife Service. USFS policy also requires a permit to collect sensitive species on the National Forest System lands. Finally, the Forest Service Watershed Conservation Practices Handbook (FSH 2909.25) provides guidance on the protection of soil, aquatic, and riparian systems.

Adequacy of current laws and regulations

The above-mentioned plans and regulations provide powerful tools for the conservation of *Salix arizonica* and its habitat, especially on National Forest System lands. However, many of these regulatory mechanisms have exemptions and exceptions that could preclude the protection of *S. arizonica* and its habitat from a variety of project actions. For occurrences on privately owned lands, current laws and regulations may be inadequate to prevent damage or destruction. Furthermore, the lapse of the Interagency Conservation Agreement and Strategy diminishes the potential for coordinated, rangewide protection for the species.

Adequacy of current enforcement of laws and regulations

There are no confirmed cases in which an occurrence of *Salix arizonica* in Region 2 was extirpated due to human activities or due to the failure to enforce any existing regulations. However, occurrences could have been unknowingly eliminated by human activities prior to the discovery of *S. arizonica* as a distinct species. In addition, the adequacy of current regulations and their enforcement for as-yet undiscovered populations cannot be evaluated. Occurrences outside Region 2 have been eliminated by construction activities associated with reservoir and ski area development. Population sizes may have been reduced by human activities, especially range management practices. Due to the lack of repeat observations or monitoring, current knowledge is insufficient to determine the adequacy of current enforcement of laws and regulations for most occurrences.

For known occurrences, isolated incidents of extirpation do not appear to have threatened the persistence of *Salix arizonica*. However, a steady but gradual loss of individual occurrences over time through a variety of causes could easily contribute to a contraction of its known range. For actions proposed on federal land, agency personnel are required to determine whether the action will impact a sensitive species and/or its habitat and cause a trend toward federal listing or a loss of viability. If these determinations are not treated additively across the range of the species, gradual erosion of habitat and population viability could occur. Although monitoring is frequently recommended in such actions, it is also frequently under-funded and implemented only on a cursory basis, if at all. Loss of populations in one area could reduce the genetic diversity of the species as a whole, as well as depress its resilience in the face of genetic, demographic, and environmental stochasticity (Huenneke 1991, Millar and Libby 1991).

Biology and Ecology

Classification and description

Salix arizonica is a member of the willow family (Salicaceae). The Salicaceae is generally regarded as consisting of the genera *Populus* and *Salix*. Two additional genera have been recognized in treatments

of Asian material but do not occur in North America (Argus 1997). The genus *Salix* includes some 450 species worldwide, and these are distributed primarily in the Northern Hemisphere (Argus 1997).

The classification of the genus *Salix* at a worldwide level has been fraught with confusion and discarded names. The primary difficulties have been the tendency for authors to produce regional or continental classifications rather than to treat the genus as a whole, and difficulty in assembling a suite of characters that is useful for classification across the entire group. Argus (1997) provides a comprehensive review of classification efforts from Linnaeus to the present (and see also Neid et al. 2004). The most recent treatment of the entire genus (Andersson 1868) is now well over a century old although it still provides the foundation for more modern treatments. The North American *Salix* were treated more recently by Dorn (1976) and later by Argus (1997), who recognized four subgenera, 28 sections of native species, three sections represented only by naturalized species, and a total of 104 species present in the New World. In his original description, Dorn (1975) places *S. arizonica* in subgenus *Vetrix*, section *Cordatae*, together with 13 other species (*S. barclayi*, *S. boothii*, *S. commutata*, *S. eastwoodiae*, *S. farriae*, *S. hastata*, *S. monochroma*, *S. monticola*, *S. myrtillifolia*, *S. orestera*, *S. pseudomonticola*, *S. wolfii*, and the *S. lutea* complex). Argus (1997) placed *S. arizonica* in the subgenus *Vetrix*, section *Hastatae*, in company with the North American species *S. ballii*, *S. barclayi*, *S. boothii*, *S. commutata*, *S. cordata*, *S. eastwoodiae*, *S. farriae*, *S. hastata*, *S. monticola*, *S. myricoides*, *S. myrtillifolia*, *S. orestera*, *S. pseudomonticola*, and *S. wolfii*. *Salix arizonica* is also known by the common names Arizona willow and manzanita willow.

History of knowledge

Salix arizonica has been recognized as a distinct species for only a few decades. It was described by Dorn in 1975 from a specimen collected by Carl-Eric Granfelt in 1969 on the Fort Apache Indian Reservation in Arizona. Although *S. arizonica* was at first thought to be endemic to its namesake state, a 1913 specimen of *S. pseudomyrsinites* from Utah's "Sevier Forest" (now Dixie National Forest) was later identified as *S. arizonica*. The discovery of this specimen resulted in extensive survey efforts for the species in Utah and the location of numerous occurrences in that state. Dorn (1975) suggests that *S. arizonica* was often confused with *S. pseudocordata* (=*S. boothii*) prior to its recognition as a new species. Specimens from New Mexico collected in the mid 1980's have also been identified as *S. arizonica*, and subsequent survey work has confirmed the existence of several occurrences in that state. *Salix arizonica* was first found in Colorado by Dorn in 2001, and in Colorado it is still known from only this single location in Conejos County.

Description

The following description is based on Dorn (1975), Arizona Willow Interagency Technical Team (1995), Arizona Game and Fish Department (2002), and Argus (1995 and 2004). *Salix arizonica* is a perennial, deciduous shrub with a variable growth habit from low to tall. A variety of growth forms have been reported, including rounded shrub; spindly, ragged shrub; large hedge or thicket; and prostrate mat. Heights may vary from a few centimeters to 3 m. Some sources suggest that the species does form colonies by vegetative reproduction (Arizona Game and Fish Department 2002, Clark 2002), but it is more likely that the appearance of colonies is a result of stems gradually being covered by sediment and not due to subterranean rhizomes (Maschinski personal communication 2005). The young twigs are yellow-green, red-brown, or brown in color, with dense hairs. Branches of previous years are often bright red, giving it a resemblance to manzanita (*Arctostaphylos*). The mature leaves are ovate to broadly elliptic or obovate, with a rounded or heart-shaped base, 1 to 5 cm in length and 0.5 to 3 cm wide, with serrulate (finely toothed) margins (**Figure 2**). Upper leaf surfaces are generally shiny, without hairs, except at the mid-rib, and the underside of the leaf is not glaucous (i.e., without a white bloom or waxy covering).

All *Salix* species are dioecious, meaning that male flowers and female flowers are produced on separate plants (**Figure 2**). *Salix* flowers are produced in dense spikes called catkins or aments. *Salix arizonica* catkins generally appear before the leaves. Female (pistillate) catkins of *S. arizonica* are densely flowered, 1 to 4.5 cm long, with glabrous capsules and brown or black floral bracts. The fruits (capsules) are mostly 5 to 10 mm long when mature. The male (staminate) catkins are somewhat shorter at 1 to 3 cm long with anthers 0.3 to 0.6 mm in length. *Salix arizonica* is most likely to be confused with the taxonomically similar *S. boothii*, with which it is frequently associated and reported to hybridize (Clark 2002). The two species are distinguished by differences in leaf size, shape and base, stem internode length, and catkin length; these differences are summarized in **Table 1**.

(A)

(B)

Figure 2. Male (A) and female (B) catkins of *Salix arizonica*. Photographs by Phil Tonne, used with permission.

Table 1. Distinguishing characters of *Salix arizonica* and *S. boothii*. Adapted from Tonne (2002).

	Salix arizonica	***Salix boothii***
Mature leaf blade shape and size:	❋ eliptic to broadly eliptic	❋ ligulate to narrowly oblong, or narrowly eliptic to broadly so
	❋ 20 to 50 mm long	❋ 26 to 102 mm long
	❋ 10 to 31 mm wide	❋ 8 to 30 mm wide
	❋ 1.6 to 3.6 x long as wide	❋ 2 to 5.2 x long as wide
Leaf blade base:	usually round or cordate	Acute to rounded
Staminate catkin length:	5 to 15 mm	20 to 25 mm
Pistillate floral bract apex:	acute to obtuse	rounded
Adaxial floral nectary, pistillate catkin:	slender, as long as stipe	Broad, shorter than stipe

Published descriptions and other sources

Pending the completion of the treatment of the genus *Salix* by Dr. G.W. Argus in the forthcoming Volume 7 of the *Flora of North America*, the most complete technical descriptions to date are found in Dorn (1975), Argus (1995), and Arizona Willow Interagency Technical Team (1995). The fairly recent discovery of *S. arizonica* and constantly expanding knowledge of its range means that it is not yet included in most regional floras. A drawing and photograph of the plant and its habitat are available in the *Arizona Rare Plant Field Guide* (Arizona Rare Plant Committee, no date). Additional illustrations or photographs are available in Arizona Willow Interagency Technical Team (1995), New Mexico Rare Plant Technical Council (1999), and Utah Native Plant Society (2003-2005).

Distribution and abundance

The known distribution of *Salix arizonica* is shown in **Figure 1** and summarized in **Table 2**. It is a subalpine species of high elevation wet meadows, streamsides, and cienegas whose occurrences are concentrated near the margins of the Colorado Plateau in Utah, Arizona, New Mexico, and Colorado. The species is confined to North America. In Region 2, a single occurrence is known from the southern San Juan Mountains in Conejos County, Colorado.

Known occurrences are confined to three primary centers of distribution in the White Mountains of east-central Arizona, the High Plateaus of south-central Utah, and the Southern Rocky Mountains of northern New Mexico and southern Colorado. These distribution centers are separated by distances of 300 to 500 km (200 to 300 miles). In Arizona, *S. arizonica* occurrences are restricted to 15 to 20 drainages flowing north, east, or south from Mount Baldy (Arizona Willow Interagency Technical Team 1995). New Mexico and Colorado occurrences are concentrated in the southern Sangre de Cristos, Nacamiento Mountains, and southern San Juan Mountains. Utah occurrences are found on the Markagunt Plateau near Brian Head Peak, the Paunsagunt Plateau along the East Fork of the Sevier River, the vicinity of Boulder Mountain, the Monroe Mountains, and Fishlake Mountain (Groebner 2004). Within these distribution clusters, occurrences are separated by distances of 1 to 200 km (1 to 125 miles). Utah and Arizona occurrences in particular are concentrated on highlands of volcanic origin that were isolated by erosion after the uplift of the Colorado Plateau, beginning some 5 million years ago. Genetic differences between populations of *S. arizonica* in Utah and Arizona suggest that their evolutionary history extends back to this period (Long 2004). Long (2004) hypothesized that additional occurrences may be found in other volcanic highlands at the edges of the Colorado Plateau, especially in the San Juan Mountains. The cooler climate and higher precipitation of the Pleistocene resulted in glaciation of higher elevations and shaped the Quaternary alluvial substrates on which many occurrences are found. These higher elevation locations continue to experience cooler, wetter conditions than the adjacent lowlands of the Colorado Plateau (**Figure 3**) and provide subalpine habitat for *S. arizonica*.

The number of genetic individuals present in the single *Salix arizonica* occurrence in Region 2 is not known. Plants are reported to be concentrated in two dense clumps, covering an area of 5 to 18 m^2 (50 to 200 $ft.^2$). The Region 2 population is among the smallest of reported populations, at least in terms of area covered. Population sizes for occurrences outside Region 2 vary from a single stem to several thousand plants, but most appear to be between 10 and 1000 plants (Arizona Willow Interagency Technical Team 1995, Clark 2002, Tonne 2002, Clark 2003, Groebner 2004). Because of the difficulty in determining what constitutes a genetic individual in the field, the total number of plants can

Table 2. Summary of occurrences of *Salix arizonica* in USDA Forest Service (USFS) Regions 2, 3, and 4.

USFS Region	State and County	Land Ownership/Management	Locations	Elevation (ft.)	Number of plants
2: Rocky Mountain	Colorado Conejos	USFS: Rio Grande National Forest	Vicinity of La Manga Pass	10,320	unknown 2 clumps
3: Southwestern	New Mexico Mora Rio Arriba Taos	USFS: Carson National Forest USFS: Santa Fe National Forest	San Pedro Mountains Santa Fe Mountain Taos Mountain	9,560-11,680	3,500-4000
3: Southwestern	Arizona Apache	USFS: Apache-Sitgreaves National Forest Fort Apache Indian Reservation Private	15 to 20 drainages in the vicinity of Mount Baldy	8,500-10,000	689 “plant units”
4: Intermountain	Utah Iron Kane Sanpete Sevier	USFS: Dixie NF USFS: Fishlake NF USFS: Manti-La Sal NF NPS: Cedar Breaks Nat’l Monument Private	Markagunt Plateau Paunsagunt Plateau Boulder Mountain Monroe Mountains Fishlake Plateau	8,000-10,800	18,000 to over 50,000?

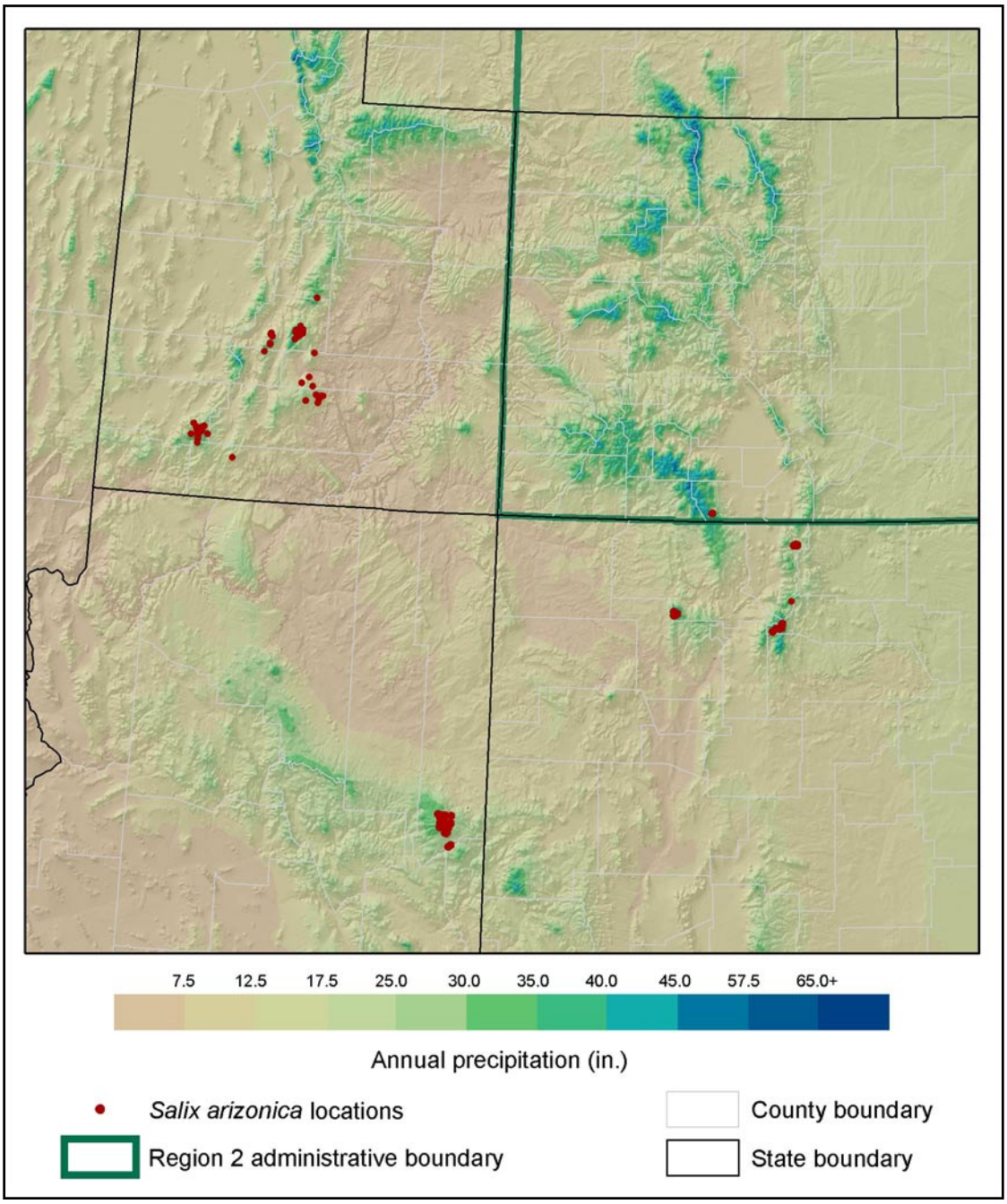


Figure 3. Annual precipitation patterns in the range of *Salix arizonica*.

only be very roughly estimated. *Salix arizonica* appears to be most abundant in the Utah portion of its range, where total numbers of individuals reported from the Fishlake National Forest in Utah are between 6,800 and 18,000 in more than 70 locations that represent several dozen occurrences (Clark 2002, USDA Forest Service Fishlake National Forest 2004). Mead (1996) reported 16 locations with a combined area of over 100 hectares comprising an unknown number of individuals on or near Utah's Dixie National Forest, and later surveys added 20 or more locations that included a total of 100 to 600 plants (Clark 2003, Groebner 2004). Some of the occurrences studied by Mead (1996) are estimated to contain thousands or tens-of-thousands of plants (Arizona Willow Interagency Technical Team 1995). New Mexico occurrences total between 3,500 and

4,000 plants in 15 to 20 occurrences (Tonne 2002). Arizona sites are reported as "plant units", or clumps of plants separated by more than 1 m. Plant units may contain many individuals of different sexes, or they may be a single individual. The Arizona Willow Interagency Technical Team (1995) reported 689 known plant units from 15 sites, with a range of one to 363. Total numbers of individuals and/or plant units reported from all four states are between 22,000 and 55,000.

Population trend

Population trends have not been rigorously determined for *Salix arizonica*, but the species appears to be primarily declining throughout its range. Arizona populations were reported to be declining, in some cases severely, and habitats degraded prior to the implementation of the Conservation Agreement; the species' range is thought to have contracted from that occupied historically (Arizona Willow Interagency Technical Team 1995). Trends may be improving as a result of implementing more conservation-oriented management practices (Arizona Rare Plant Committee, no date); however, no publicly available data support this contention. New Mexico occurrences are reported to be noticeably impacted by grazing and altered hydrology (Tonne 2002). Utah occurrences in the vicinity of Boulder Mountain are generally small and heavily browsed (Clark 2003, Groebner 2004), which may threaten their long-term viability. In contrast, several of the Monroe Mountains occurrences on the Fishlake National Forest and many of the Markagunt Plateau occurrences on the Dixie National Forest are sizable (thousands to tens-of-thousands) and substantially less impacted by browsing ungulates (Arizona Willow Interagency Technical Team 1995, Mead 1996, Clark 2002).

The single Region 2 occurrence has only been known for a few years and is thought to have remained stable during this time (Erhard personal communication 2005). An exclosure was erected around this occurrence in 2002 to protect it from browsing by cattle. Although the plants are currently protected, it is not known whether large ungulate grazing in the area will prevent the occurrence from expanding beyond the protection of the fencing. Although extensive survey work has greatly increased our knowledge of the abundance and distribution of *Salix arizonica*, the same cannot be said for monitoring populations over time. Most documented occurrences are not accompanied by repeated population counts; hence, there is insufficient information to allow an assessment of current rangewide population trends.

Habitat

Throughout its range, *Salix arizonica* is typically associated with high elevation wet meadows, streamsides, and cienegas. Habitat often occurs as a narrow, linear strip associated with perennial water in seeps, springs, stream sides, and wet meadows. Plants are also sometimes found in drier sites adjacent to forest edges or within the riparian zone where subsurface channels provide moisture (Arizona Willow Interagency Technical Team 1995). Although it is not believed to be a strict substrate specialist (Long and Medina 2004), *S. arizonica* is frequently associated with substrates of volcanic origin, and it appears to favor coarse-textured and well-watered soils, including those associated with alluvial deposits. Arizona occurrences are generally associated with felsic, coarse-textured Mount Baldy formations (Long and Medina 2004). In south-central Utah, Mead (1996) found that parent materials were often Tertiary age volcanics but also could be limestone or Pleistocene glacial deposits. Utah occurrences were about equally divided between those with peat overlaying the parent material (histosols), and mineral soils (molisols) on a variety of parent materials. Aspects are variable, but slopes are generally flat to moderate (less than 5 to 9 percent). Observations suggest that the occurrence and growth form of *S. arizonica* depend in part on soil moisture and aeration, temperature, and nutrient availability. Plants growing in boggy meadows with saturated soils low in oxygen content tend to have a stature of less than 1/3 m. In more aerated, but moist soils, plants typically reach heights of 1 to 2 m (Groebner 2004). Mead (1996) found that plant growth was greatest at high elevations on mineral soils of volcanic origin where soil pH is moderate and nitrogen, phosphorus, potassium, and copper are abundant. Peat depth, soil temperature, and water table depth explained nearly 40 percent of the height variation in his sampled populations. Conversely, plant vigor (on a subjective scale of 1 to 4) was highest in sites with the greatest peat depth and shallowest water table where plants were short-statured (Mead 1996). Elevations of Arizona occurrences reported by Argus (1995) range from 2,590 to 3,050 m (8,500 to 10,000 ft.). Utah elevations have been reported from 2,440 to 3,290 m (8,000 to 10,800 ft.; Clark 2002, Groebner 2004). Tonne (2002) reported New Mexico occurrences at elevations of 2,910 to 3,560 m (9,560 to 11,680 ft.). The single Colorado occurrence is comparable to the New Mexico elevations at 3,145 m (10,320 ft.). These higher elevations receive substantially more annual precipitation than the adjacent lowlands (**Figure 3**), and plants may lie dormant beneath heavy snowpack for many months (Mead 1996).

Salix arizonica is associated with plant communities that are characteristic of subalpine wetlands and meadows. Although few species are associates of *S. arizonica* in all four states, the assemblages are regional variations of typical subalpine meadows (**Table 3**). The most common associates include *Dasiphora* (=*Pentaphylloides*) *floribunda*, *Caltha leptosepala*, *Carex* species, *Deschampsia caespitosa*, *Pedicularis groenlandica*, *Picea engelmannii*, and various other willows, especially *S. monticola* and *S. planifolia*. The non-native Kentucky bluegrass (*Poa pratensis*) is also commonly present. Dorn indicated that *S. wolfii* has similar moisture requirements to *S. arizonica* (Erhard personal communication 2005).

The Region 2 occurrence (**Figure 4**) is found along a small rivulet in a meadow community. Dominant species include *Salix wolfii*, *Dasiphora floribunda*, *S. monticola*, *Caltha leptosepala*, and *Carex aquatilis* (see **Table 3** for common names). Other associated species at this site are *Poa pratensis*, *Phleum commutatum*, *C. utriculata*, *Deschampsia cespitosa*, *Geum macrophyllum*, *Swertia perennis*, *Clementsia rhodantha*, and *Potentilla pulcherrima*. Within the population area, total shrub cover is approximately 75 percent, graminoid cover is 15 percent, forb cover is 5 percent, and moss cover is 5 percent. The area is south-facing, with a very gentle slope (1 percent). The substrate is alluvial, moist to saturated loamy soil. Water in the small tributary where the plants are found has a pH of 7.5 to 7.7 (Erhard personal communication 2005).

Reproductive biology and autecology

Although *Salix arizonica* has been the subject of several research efforts in recent years, many facets of its biology and ecology remain unaddressed. As a long-lived perennial species that devotes several years to vegetative growth before reproducing, *S. arizonica* can be regarded more or less as a *K*-selected species in the classification scheme of MacArthur and Wilson (1967). *Salix* species of high elevation riparian and wet meadow habitats, such as *S. arizonica*, are probably best described as competitors in the strategic schema of Grime (2001). *Salix arizonica* occupies fairly productive and stable habitat, is a deciduous perennial, and is probably capable of rapid growth. Although *S. arizonica* and other willows have many competitor characters, other characteristics suggest elements of stress-tolerance (growing in waterlogged soils, low temperatures) or ruderal strategies (copious seed production, not highly clonal).

Salix arizonica is a perennial, deciduous shrub that reproduces sexually by seed. Plants also form dense thickets when stems are buried by alluvial sediments, making identification of genetic individuals difficult. However, plants are not producing subterranean rhizomes (Maschinski personal communication 2005). Nearly all willows, including *S. arizonica*, are dioecious; an individual plant has either male flowers or female flowers, but not both. Although the Salicaceae appear to be almost exclusively dioecious, at least one regularly hermaphrodite species (*S. martiana*) has been reported (Rohwer and Kubitzki 1984), and the production of mixed-sex catkins or fertile bisexual flowers has been occasionally observed in unseasonably flowering individuals (Smith 1942, Glisson 2003). This type of sex lability has not been reported in *S. arizonica*, and dioecy appears to be more or less stable for the majority of the North American Salicaceae. One important implication of the dioecious condition is that many species exhibit sex differential response to environmental conditions. This character could be important in evaluating the consequences of management actions.

The catkins of *Salix arizonica* generally appear before the leaves (precocious flowering) or at the same time (coetaneous flowering). Throughout its range, *S. arizonica* is reported to flower from April or May to June or July. In Region 2, *S. arizonica* has been reported with catkins in early July (Colorado Natural Heritage Program 2005). The timing of flowering and leaf emergence depends on elevation and local climate (Arizona Willow Interagency Technical Team 1995). Fruits mature from June through August (Arizona Willow Interagency Technical Team 1995).

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

Karrenberg et al. (2002a) investigated pollen vectors in four floodplain willow species (*Salix alba*, *S. daphnoides*, *S. elaeagnos*, and *S. triandra*). Their

Table 3. Species associated with *Salix arizonica* throughout its range. Sources: Herbarium labels and element occurrence records.

Species Name	Common Name	CO	AZ	NM	UT
Abies concolor	white fir		X		
Abies lasiocarpa	subalpine fir		X		
Achillea millefolium	common yarrow			X	X
Achnatherum (=*Stipa*) *lettermanii*	Letterman's needlegrass				
Agropyron spp.	common yarrow				X
Agrostis scabra	rough bentgrass				X
Agrostis stolonifera	creeping bentgrass			X	X
Allium geyeri	Geyer's onion		X	X	
Allium macropetalum	largeflower onion		X		
Allium rubrum	bulbil onion		X		
Allium spp.	onion			X	
Angelica pinnata	small-leaf angelica				X
Antennaria pulcherrima	showy pussytoes				X
Antennaria spp.	pussytoes				X
Argentina anserina	silverweed cinquefoil			X	
Artemisia cana	silver sagebrush				X
Artemisia spp.	sagebrush				X
Aster spp.	aster				X
Bromus carinatus	California brome				X
Caltha leptosepala	white marsh marigold	X	X	X	
Campanula parryi	Parry's bellflower				X
Cardamine californica var. *cardiophylla*	milkmaids			X	
Cardamine cordifolia	heartleaf bittercress		X		
Carex aquatilis	water sedge	X			X
Carex nebrascensis	Nebraska sedge				X
Carex rossii	Ross' sedge				X
Carex utriculata	Northwest Territory sedge	X			
Carex spp.	sedge		X	X	X
Castilleja linariifolia	Wyoming Indian paintbrush				X
Castilleja miniata	giant red Indian paintbrush				X
Castilleja spp.	Indian paintbrush			X	
Chenopodium spp.	goosefoot				X
Cirsium spp.	thistle				X
Conioselinum scopulorum	Rocky Mountain hemlockparsley				X
Conium maculatum	poison hemlock				X
Dasiphora (=*Pentaphylloides*) *floribunda*	shrubby cinquefoil	X	X	X	X
Delphinium barbeyi (*D. occidentale*)	subalpine larkspur				X
Delphinium spp.	larkspur			X	
Deschampsia caespitosa	tufted hairgrass	X	X	X	X
Deschampsia spp.	hairgrass			X	
Dodecatheon alpinum	alpine shootingstar		X		
Dodecatheon pulchellum	darkthroat shootingstar			X	

Table 3 (cont.).

Species Name	Common Name	CO	AZ	NM	UT
Dodecatheon spp.	shootingstar			X	
Epilobium ciliatum	fringed willowherb			X	X
Epilobium saximontanum	Rocky Mountain willowherb				X
Epilobium spp.	willowherb		X		X
Equisetum hyemale	scouringrush horsetail				X
Erigeron spp.	fleabane			X	X
Erigeron speciosus	aspen fleabane				X
Festuca ovina	sheep fescue				X
Festuca spp.	fescue		X		
Fragaria virginiana	Virginia strawberry				X
Geranium richardsonii	Richardson's geranium				X
Geranium spp.	geranium				X
Geum macrophyllum	largeleaf avens	X		X	X
Geum spp.	avens				X
Glyceria striata	fowl mannagrass				X
Heracleum maximum (*H. lanatum*)	common cowparsnip				X
Hordeum brachyantherum	meadow barley		X		X
Hymenoxys (=*Helenium*) *hoopesii*	owl's-claws				X
Hypericum formosum	St. Johnswort				X
Juncus arcticus (*J. balticus*)	Baltic rush			X	
Juncus halli	Hall's rush				X
Juncus longistylis	longstyle rush				X
Juncus spp.	rush		X	X	X
Lathyrus spp.	pea				X
Lupinus argenteus	silvery lupine				X
Luzula parviflora	smallflowered woodrush			X	
Mertensia arizonica	aspen bluebells			X	
Mertensia spp.	bluebells			X	
Mimulus guttatus	seep monkeyflower		X	X	X
Mimulus primuloides	primrose monkeyflower		X		
Moss			X	X	X
Oxypolis fendleri	Fendler's cowbane			X	
Packera streptanthifolia (=*Senecio streptanthifolius*)	Rocky Mountain groundsel			X	
Parnassia palustris	marsh grass of Parnassus				X
Pedicularis groenlandica	elephanthead lousewort			X	X
Phleum alpinum (*P. commutatum*)	alpine timothy	X	X	X	X
Picea engelmannii	Engelmann spruce		X	X	X
Picea pungens	blue spruce		X		
Polygonum spp.	knotweed			X	
Poa alpina	alpine bluegrass				X
Poa pratensis	Kentucky bluegrass	X	X	X	X
Polemonium caeruleum	charity				X

Table 3 (cont.).

Species Name	Common Name	CO	AZ	NM	UT
Polemonium spp.	Jacob's-ladder			X	X
Polygonum bistortoides	American bistort			X	
Polygonum spp.	knotweed			X	
Populus angustifolia	narrowleaf cottonwood				X
Populus tremuloides	quaking aspen		X	X	X
Potentilla diversifolia	varileaf cinquefoil		X		
Potentilla gracilis	slender cinquefoil			X	X
Potentilla pulcherrima	beautiful cinquefoil	X			
Potentilla spp. (annual)	cinquefoil				X
Pseudotsuga menziesii	Douglas-fir		X		
Pyrrocoma (=*Haplopappus*) *lanceolata*	lanceleaf goldenweed				X
Ranunculus aquatilis	white water crowfoot		X		
Ranunculus cardiophyllus	heartleaf buttercup			X	
Ranunculus cymbalaria	alkali buttercup		X		
Ranunculus flammula	greater creeping spearwort				X
Ranunculus macounii	Macoun's buttercup		X		
Ranunculus spp.	buttercup				X
Rhodiola rhodantha	redpod stonecrop	X		X	
Ribes cereum	wax currant				X
Ribes inerme	whitestem gooseberry				X
Ribes leptanthum	trumpet gooseberry		X		
Ribes montigenum	gooseberry currant				X
Rosa woodsii	Woods' rose				X
Rubus idaeus	American red raspberry				X
Salix bebbiana	Bebb willow		X		
Salix boothii	Booth's willow		X	X	X
Salix brachycarpa	shortfruit willow			X	
Salix drummondiana	Drummond's willow			X	
Salix exigua	narrowleaf willow				X
Salix geyeriana	Geyer willow		X		X
Salix irrorata	dewystem willow		X		
Salix monticola	park willow	X	X	X	
Salix planifolia	diamondleaf willow		X	X	X
Salix wolfii	Wolf's willow	X			
Salix spp.	willow				X
Sambucus racemosa	red elderberry				X
Scirpus spp.	bulrush			X	
Senecio bigelovii	nodding ragwort		X		
Senecio spp.	ragwort			X	
Senecio triangularis	arrowleaf ragwort			X	
Swertia perennis	felwort	X			
Symphyotrichum (=*Aster*) *foliaceum*	alpine leafybract aster				X

Table 3 (concluded).

Species Name	Common Name	CO	AZ	NM	UT
Taraxacum lyratum	harp dandelion				X
Taraxacum officinale	common dandelion			X	X
Thalictrum fendleri	Fendler's meadow-rue				X
Trifolium repens	white clover				X
Trifolium spp.	clover			X	X
Trisetum spicatum	spike trisetum				X
Veratrum californicum	California false hellebore			X	
Veratrum spp.	false hellebore			X	
Veronica americana	American speedwell				X
Veronica spp.	speedwell			X	
Viola spp.	violet			X	X

Figure 4. Habitat of *Salix arizonica* in Colorado. Photograph by Dean Erhard, used with permission.

results show that while seedless fruit developed in some instances, pollination is generally necessary for seed set and maximum seed set is associated with insect vectors. Reported insect visitors to *Salix* flowers include a variety of Dipteran, Hymenopteran, and Lepidopteran species (Sacchi and Price 1988, Totland and Sottocornola 2001, Karrenberg et al. 2002a). Pollen vectors for *S. arizonica* have not been investigated but are likely to be primarily insects that frequent subalpine riparian habitats. Wind pollination is a potential vector for gamete dispersal between populations of *S. arizonica* within each state, but successful inter-population pollination is likely to be much less frequent than within-population anemophily. Even within a state,

many occurrences are separated to an extent that makes insect pollination between them unlikely.

Few specifics are known about the reproductive capacity of *Salix arizonica*. Willows are generally characterized as producing large numbers of rapidly developing seeds. Even when the percentage of filled seeds per catkin is low, the numbers of catkins produced and number of fruits per catkin often result in very large numbers of seeds per individual plant. Karrenberg et al. (2002a) reported seed production of four *Salix* species (*S. alba*, *S. daphnoides*, *S. elaeagnos*, and *S. triandra*). Individuals produced several hundred to several thousand catkins. Catkins had anywhere from 35 to 150 fruits each, and fruits contained 2 to 22 seeds. The average number of seeds produced per individual over all four species was over 200,000. Under laboratory conditions germination rates for many *Salix* species are high (close to 100 percent), but temperature requirements vary (Densmore and Zasada 1983, Young and Clements 2003) and seeds typically loose viability soon after being released from the parent plant. Germination rates are typically lower under natural conditions. Sacchi and Price (1992) noted that *S. lasiolepis* reached seedling densities of up to 25,000 per square meter. Clearly, fertility and seed viability of *Salix* species can be extremely high. However, seed set and seedling survival depend on a variety of factors, including pollination rates, resource availability, and weather conditions.

The seeds of *Salix* are surrounded by a spreading coma of fine, silky hairs that are longer than the seed itself, and that facilitate dispersal by wind (Argus 1986). The 'drag chute' function of the plume of hairs allows the tiny seeds to gain height in even very gentle convective air currents, and spreading seed hairs allow many seeds to cluster together. When seeds are wetted, the hairs quickly collapse and release the seed (Karrenberg et al. 2002a). Seeds of *S. arizonica* are reported to be very lightweight and are thought to disperse by both wind and water (Arizona Willow Interagency Technical Team 1995). Seed production and germination rates of *Salix* species are generally high, and seedling mortality is correspondingly great. Available research is primarily on floodplain species. Sacchi and Price (1992) recorded mortality of first year seedlings at nearly 100 percent for *S. lasiolepis* in northern Arizona, and they found that the lack of soil surface moisture was the primary cause of seedling mortality. McBride and Strahan (1984) found similar results for *S. hindsiana* and *S. laevigata* in northern California. In densely vegetated wet meadow habitats, open sites for establishment of seedlings may be rare and produced by localized disturbance such as trampling by domestic or wild ungulates. For *S. arizonica*, the disturbance produced by streambank scouring may be important for opening bare space for seedling establishment (Maschinski personal communication 2005). Seedlings of *S. arizonica* are rarely observed (Arizona Willow Interagency Technical Team 1995).

Although synthetic hybrids are easily formed between many *Salix* species, natural hybridization in willows is apparently rare in North America as a whole (Argus 1974, Dorn 1976). *Salix arizonica* is apparently able to hybridize with a variety of co-occurring *Salix* species. At least 10 other *Salix* species have been reported as co-occurring with *S. arizonica* (**Table 3**), so the possibility for hybridization is present in many populations. Individuals that are morphologically intermediate between "true" *S. arizonica* and other *Salix* species are routinely reported as hybrids or introgressed forms in inventory and survey work (Clark 2002 and 2003, Groebner 2004). Putative hybrids between *S. arizonica* and *S. brachycarpa*, *S. boothii*, *S. geyeriana*, *S. planifolia*, and *S. wolfii* have been reported in Utah (Arizona Willow Interagency Technical Team 1995, Clark 2002, Groebner 2004), and possible intermediate forms between *S. arizonica* and *S. boothii* have been reported from New Mexico (Tonne 2002). Hybridization has not been documented in Arizona, but some plants appear to have sufficiently variable morphology to be hybrids with *S. boothii* or *S. monticola* (Arizona Willow Interagency Technical Team 1995). No hybrids have been reported from Region 2. Because most willows also exhibit phenotypic variations in plant stature, leaf size, shape, hairiness, and toothing, as well as other characters, in response to environmental variables such as moisture, nutrients, shade, and wind (Argus 2001), it is important to use mature, typical branches for identification.

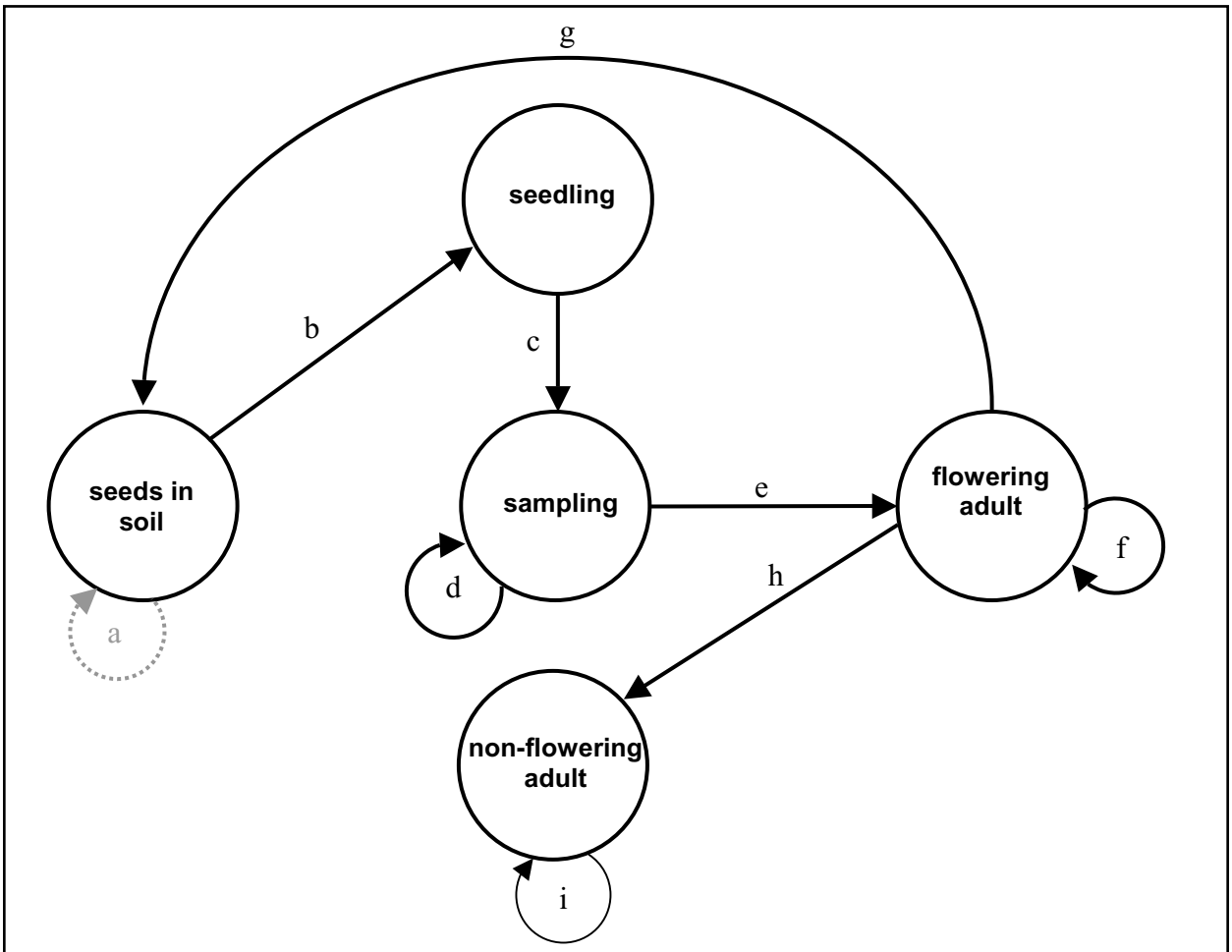
Mycorrhizal associations have been documented in many *Salix* species. Endomycorrhizal fungi belonging to the taxonomic order Glomales are a key component of one of the most common underground symbioses. These endomycorrhizae are characterized by inter-and intracellular fungal growth in the root cortex where they form fungal structures known as vesicles and arbuscles (Quilambo 2003). Vesicular-arbuscular mycorrhizae (VAM) occur in about 80 percent of all vascular plants (Raven et al. 1986), and the association is geographically widespread. Association with VAM has been reported for a variety of *Salix* species (Harley and Harley 1987, Newman and Reddell 1987, Dhillion 1994). Ectomycorrhizal associations have also been reported in many *Salix* (Dhillion 1994, Thormann et al. 1999),

and some species are able to support both conditions simultaneously (Dhillion 1994). The mycorrhizal status of *S. arizonica* has not been investigated.

Demography

Most willows, regardless of habitat, appear to produce large numbers of seeds. These seeds are either non-dormant, or in Arctic species, they have conditional dormancy that allows them to over-winter in the seed bank. Seedling mortality is high, and recruitment rates are closely tied to the frequency and duration of disturbance events that create open sites. Mortality of established plants is presumably much lower, and plants are likely to survive for decades. Age at first flowering can be as low as 2 years for colonizing riparian species like *Salix exigua* (Ottenbreit and Staniforth 1992) while other species require up to 10 years of growth before becoming reproductive (Haeussler and Coates 1986). **Figure 5** shows a hypothetical lifecycle diagram for *S. arizonica*. Because there are no demographic studies of this species, transition probabilities are left unquantified.

Recruitment, survival, reproductive age, and other vital rates for *Salix arizonica* are largely unknown



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

Figure 5. Lifecycle diagram for *Salix arizonica* (after Caswell 2001).

although a few studies have indirectly addressed demographic parameters and population structure. Based on methodology modified from USDI Bureau of Land Management (1996), Mead (1996) classified individuals of *S. arizonica* at 25 study sites in Utah into four age/stage classes:

- **Seedling:** Plant up to 3 years old that has become firmly established; stems usually less than 3 mm (1/8 in.) in diameter.

- **Young:** Larger, with more complex branching and more fibrous bark than the seedling; not showing signs of maturity [i.e., not reproductive]; stems usually between 3.0 and 5.0 mm (1/8 and 1/4 in.) in diameter.

- **Mature:** Complex branching, rounded growth form, larger size; shows signs of reproduction; stems larger than 5 mm (¼ in.) stem diameter.

- **Decadent:** Any plant, regardless of age, that is in a state of decline as evidenced by 25 percent or more dead branches.

Due to the difficulty of distinguishing between the seedling and young classes, these categories were combined in his analysis and not reported separately. Mead's data show that within individual sites, distribution of individuals between these classes ranged from predominantly young plants (four sites) to predominantly mature plants (17 sites). The remaining four sites were approximately equal in numbers of young and mature plants. No sites were dominated by decadent plants. The average distribution of classes across all sites was 28 percent young, 63 percent mature, and 9 percent decadent individuals (Mead 1996). Arizona occurrences observed on the Apache-Sitgreaves National Forest and Fort Apache Indian Reservation were reported to contain almost no seedlings, and they appeared to be heavily skewed toward older, less vigorous plants (Arizona Willow Interagency Technical Team 1995).

Taylor et al. (1996) found that stem diameter was strongly correlated with age in Utah populations of *Salix arizonica*. Sampled stems ranged from 1 to 19 years in age, and age could be predicted within 3 years by stem diameter measurement. In addition, there was little variation in growth rates over a range of site conditions. This technique provides a useful monitoring tool, giving insight into the population age/class structure at various locations. Their results indicated that at least one Utah population was dominated by very young stems, with no older stems present. Other populations showed a more normal distribution of classes (Taylor et al. 1996). Populations of transplanted cuttings have shown very low survival rates over a three-year period. Mortality was attributed to elk browsing and extremely dry conditions (Arizona Willow Interagency Technical Team 1995).

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

Although the potential problems for small, isolated populations are numerous, a variety of studies have concluded that small and peripheral populations can still be viable conservation targets (Lesica and Allendorf 1992 and 1995, Lammi et al. 1999, Matthies et al. 2004). There are no Population Viability Analysis (PVA) models available for *Salix arizonica*. Morris et al. (1999) discuss general classes of data sets and methods suitable for PVA including:

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

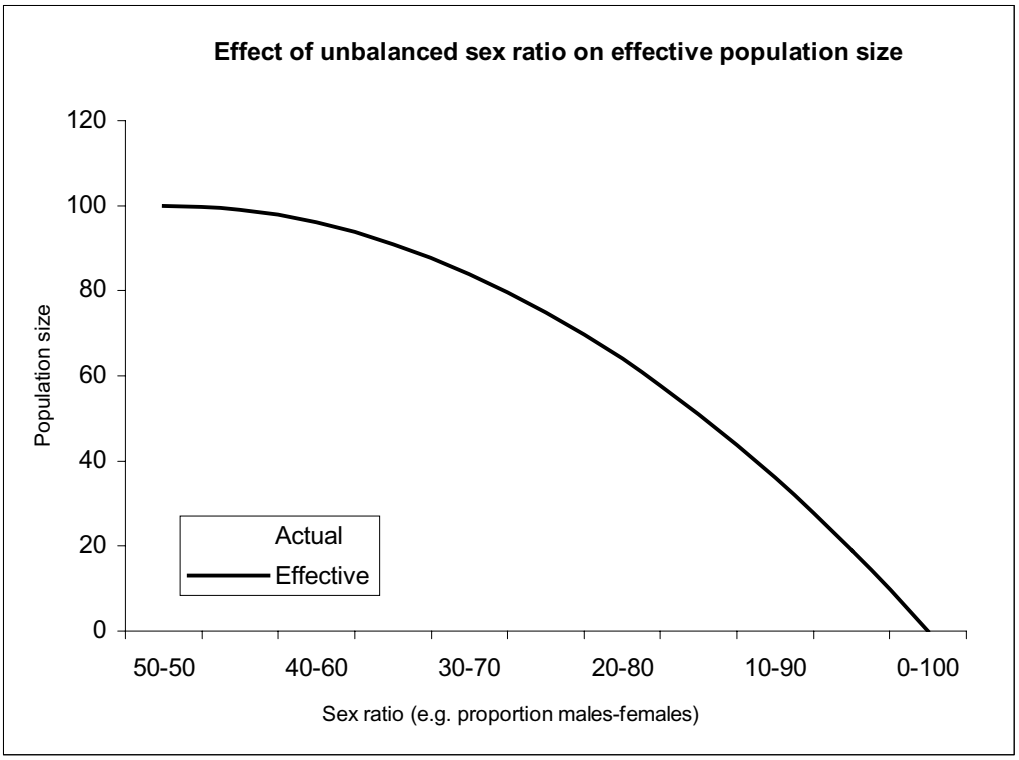
2) Multi-site extinction analysis: requires counts from multiple populations, including a multi-year census from at least one of those populations.

3) Projection matrix modeling: requires detailed demographic information on individuals collected over 3 or more years (typically at only 1 or 2 sites).

There may be data sets for Arizona populations that could be used for PVA of *Salix arizonica*, but publicly available data do not include any multi-year sets. Basic research on lifecycle stages of this species would greatly facilitate viability analysis.

Community ecology

The community ecology of *Salix arizonica* includes its interactions with populations of co-



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

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

existing species, the effects of herbivory, parasites, and disease, and any competitive, mutualistic or symbiotic interactions between *S. arizonica* and other species. **Table 3** provides a list of plant species associated with *S. arizonica*.

Effects of competition have not been investigated in *Salix arizonica*, but some inferences can be made from studies of its congeners and from its habitual association with subalpine riparian and wet meadow communities. Subalpine riparian habitats are often densely vegetated, and species may have highly specialized niches along a micro-topographic or hydrologic gradient. However, mixed willow stands are apparently common where *S. arizonica* is found, and any micro-topographic or hydrologic requirements that separate *S. arizonica* from other willows are unknown. The tendency for willow species to rely on disturbance to open sites for seedling establishment means that *S. arizonica* is likely to compete with other plants for this resource as well.

Mead (1996) reported that both deer and elk browsed *Salix arizonica* in Utah occurrences on the Dixie National Forest. Beaver use of *S. arizonica* was also observed in two sites. Mead also compared willow use on cattle allotments to use on sheep allotments, and he found that cattle use of *S. arizonica* is higher than use of *S. planifolia* when the two species grow together while sheep had a (non-significant) tendency to prefer *S. planifolia* over *S. arizonica*. Utilization increased with increasing duration of exposure to cattle, and two sites showed over 40 percent utilization on 97 percent of the monitored branches.

Strohmeyer and Maschinski (1996) and Maschinski (2001) have reported on the effects of ungulate herbivory on *Salix arizonica*. Observations confirmed that both cattle and elk utilize this species, and that utilization by either herbivore significantly reduces aboveground biomass, height, survival, and sexual reproduction (Maschinski 2001). Furthermore, the intensity of grazing effects depended on the types

of herbivores present, the duration of exposure to herbivory, and the amount of recovery time between grazing episodes. The greatest reduction of total branch length and the highest mortality occurred under conditions when both wild and domestic grazers were present. Severe use in the first year of the study appeared to depress mean total branch length to the extent that plants were unable to recover to control levels during the next 2 years of the study, even with less grazing pressure.

Herbivory and root clipping by rodents, especially voles (*Microtus* spp.), has been reported for Arizona occurrences (Arizona Willow Interagency Technical Team 1995). However, plants exposed to rodent herbivory in Maschinski's (2001) control group did not show adverse effects in comparison to plants that were also grazed. Willows are also subject to attack by a variety of insect herbivores (e.g., Stein et al. 1992, Kendall et al. 1996, Sipura 2002). Insect herbivores reported on *Salix arizonica* include caterpillars of the mourning cloak butterfly (*Nymphalys antiopa*), beetles (*Coleoptera*), and grasshoppers (*Orthoptera*) (Arizona Willow Interagency Technical Team 1995, Colorado Natural Heritage Program 2005). Insect herbivory is apparently variable across the entire range of *S. arizonica* (Maschinski 2001). In some reported instances, defoliation by caterpillars was heavy enough to cause branch die-back, but such effects appear to be generally localized (Arizona Willow Interagency Technical Team 1995). Insect galls have been observed in at least two occurrences on Utah's Dixie National Forest (Arizona Willow Interagency Technical Team 1995).

The genus *Salix* apparently displays the spectrum of strategies between resistance to and tolerance of herbivory; plants that develop chemical defenses (resistance) against herbivory are presumed to pay a price in reduced growth while plants that evolve tolerance to herbivory escape the metabolic costs of manufacturing secondary compounds and spend resources on regrowth instead. The rapid regrowth of some pioneering willow species is interpreted as tolerance to herbivory (e.g., Kudo 2003) while the characteristic phenolic glucoside salicylate produced by many *Salix* species acts as a defense against herbivory (e.g., Kendall et al. 1996). The strategy of *S. arizonica* is not known.

Nearly all *Salix* species, including *S. arizonica*, have some degree of susceptibility to infection by fungal rust belonging to the species complex *Melampsora epitea* (Smith et al. 2004). However, resistance to infection is highly variable between species and between pathogen populations (Pei et al. 2004). Susceptibility to infection has also been reported to be highly variable between individual *S. arizonica* plants and is believed to have a genetic component (Fairweather 1993). Arizona occurrences have been reported to be infected by *M. epitea* at 11 sites, both on the Apache-Sitgreaves National Forest and on the Fort Apache Indian Reservation (Fairweather 1993, Arizona Willow Interagency Technical Team 1995). The effects of *Melampsora* infection are premature leafdrop, loss of plant vigor, and a reduction of stored carbohydrates, which delays regrowth the following spring. Severe infections may cause die-back, or delay the onset of dormancy, making shoots susceptible to frost damage. Infected plants produce almost no flowers or seeds (Fairweather 1993). At least one *S. arizonica* occurrence on the Fort Apache Indian Reservation was severely affected by a rust infection in the late 1980's and experienced 20 percent mortality over the 5-year period following the onset of the infection (Arizona Willow Interagency Technical Team 1995). There are no reports of fungal infection of the *S. arizonica* occurrence in Region 2. Willows are also susceptible to a variety of insect borers and gall-forming species (e.g., Froiland 1962, Collet 2002, Sipura 2002), and although insect galls have been reported from two Utah occurrences, there are no reports of such infections for *S. arizonica* in Region 2.

CONSERVATION

Although monitoring for Arizona and Utah populations of *Salix arizonica* was prescribed in the 1995 Conservation Agreement, it is not clear to what degree this item was implemented. Technical team members from Utah and Arizona did not respond to inquiries about the implementation or results of monitoring. In consequence, there are no publicly available data on the effects of management activities or natural disturbances on *S. arizonica*. However, some inferences can be drawn from knowledge of its preferred high elevation riparian habitat. *Salix arizonica* depends on a functional hydrologic regime to maintain suitable habitat. Any management activity or natural disturbance that disrupts the hydrologic dynamics of its habitat is likely to have an effect on habitat quality for *S. arizonica*. In general, management activities or natural disturbances that affect habitats are likely to have similar or parallel effects on individuals or subpopulations. In particular, hydrological modification resulting from livestock grazing, timber harvest, road building, or recreation is likely to directly impact individuals and populations of *S. arizonica*. Plants may be killed or

damaged as a result of these activities, and population remnants may be unable to recolonize disturbed areas. Surface disturbance may also affect the survival and reproductive success of individuals by altering local patterns of erosion and drainage and by eliminating safe sites for germination.

There are no known commercial uses for *Salix arizonica*, other than as forage for domestic grazers. *Salix arizonica* is occasionally collected in botanical surveys or for research purposes, but there is no evidence to suggest that past levels of collecting have endangered any occurrences, and it is appropriate to approve limited collecting whenever it will enhance current knowledge of the species' abundance and distribution.

Threats

Based on the available information, there are a variety of threats to the persistence of *Salix arizonica* in Region 2. In approximate order of decreasing concern, threats include grazing by domestic and wild ungulates, hydrologic alterations, impacts from timber harvesting, impacts from recreational use, consequences arising from small population sizes, and global climate change.

Grazing

Major impacts of grazing include removal and reduction of vegetation, soil compaction, and increased erosion. These impacts have been shown to affect hydrology, water chemistry, and other variables (Menke 1977, Johnston and Brown 1979, Chadde et al. 1998). Grazing may also cause changes in riparian community species composition (Schulz and Leininger 1990). For individual plants, the loss of plant material through herbivory may reduce plant vigor and reproductive success, decrease plant height, and affect plant growth habit (Maschinski 2001). Severe grazing that removes much of the plant's aboveground biomass can also result in the destruction of individuals plants. Trampling by large herbivores may contribute to the formation of open sites for seedling establishment, but it may also have a detrimental effect on the hydrology, soil structure, microtopography, and canopy structure of the habitat (Stammel and Kiehl 2004). The trampling action of large grazers can also physically damage *Salix arizonica* plants and retard normal growth and reproduction. Domestic livestock and native grazers may also both contribute to the spread of invasive species.

The declining status of many *Salix arizonica* occurrences is often attributed to the effects of ungulate herbivory, especially from cattle and elk (Arizona Willow Interagency Technical Team 1995 and citations therein, Tonne 2002). Livestock grazing of *S. arizonica* habitat in Arizona and Utah was heavy during the late 1800's and early 1900's, and in some cases continuing to the present day (Arizona Willow Interagency Technical Team 1995). Galeano-Popp (1988, as cited in Arizona Willow Interagency Technical Team 1995) attributed the lower density of *S. arizonica* at sites on National Forest System lands compared to sites on the Fort Apache Indian Reservation sites to the prevalence of heavier grazing on the former. Utah occurrences in the vicinity of Boulder Mountain were reported to be heavily browsed, and active cattle use was confirmed at eight of 15 sites in 2004 (Groebner 2004). Many New Mexico occurrences are also reported to have heavy cattle use (Tonne 2002).

Other reported large herbivores include sheep, deer, pronghorn, and, in one Utah location, moose. In addition to the effects of herbivory, sheep have been reported to severely impact *Salix arizonica* in holding-bedding areas near Cedar Breaks National Monument (Arizona Willow Interagency Technical Team 1995). Nearly all *S. arizonica* occurrences on public lands are part of active sheep or cattle grazing allotments (Arizona Willow Interagency Technical Team 1995, Mead 1996, Tonne 2002), including the single Region 2 occurrence on the Rio Grande National Forest, which was subject to cattle grazing before the construction of an exclosure in 2002 (Erhard personal communication 2005). The construction of fences, livestock exclosures, and plant cages in Arizona and Utah was prescribed by the Conservation Strategy and Agreement to protect occurrences from the effects of grazing.

Observations suggest that many native herbivores will browse *Salix arizonica* to some degree, but most non-livestock use is attributed to elk. In some portions of the range of *S. arizonica*, elk numbers have increased to levels significantly above those known in the past. Severe elk browsing on *S. arizonica* occurrences has been reported from the Fort Apache Indian Reservation (Arizona Willow Interagency Technical Team 1995), and Maschinski (2001) reported that Arizona plants in areas of high elk concentration were generally less than 10 cm in height. Noticeable elk use has also been reported for occurrences in Utah, New Mexico, and Colorado (Mead 1996, Tonne 2002, Colorado Natural Heritage Program 2005). Record herd sizes in Colorado

are likely to contribute to herbivory on *S. arizonica* for individuals that are not protected by exclosures. An important consideration in the evaluation and management of grazing impacts is the additive effect of herbivory from a variety of sources. Although *S. arizonica* certainly evolved with native herbivores, the effect of domestic livestock in combination with increasing pressure from wildlife means that the plants may frequently be exposed to levels of herbivory beyond their presumed tolerance.

Altered hydrology

Due to the specialization of *Salix arizonica* on riparian and wet meadow habitats, hydrologic alteration is one of the foremost threats to the species, and this threat interacts to some degree with other threats. Hydrologic alteration can result from numerous natural and human impacts to watersheds supporting *S. arizonica* occurrences, including diversions and impoundments, long-term drought, fire, and elimination of beaver populations. Other threats, such as grazing, timber harvest, road construction activities, recreational use, and global climate change can influence hydrology of *S. arizonica* habitat in addition to their direct effects on populations and individual plants. Changes in hydrologic regimes can influence nutrient cycles, sedimentation, fragmentation, and habitat quality in wetland systems.

In Arizona, the construction of high elevation reservoirs and ponds for recreational fishing and/or for livestock and wildlife water has resulted in both the permanent loss of *Salix arizonica* occurrences and habitat as well as habitat alteration (Arizona Willow Interagency Technical Team 1995). *Salix arizonica* habitat was inundated by the construction of Sunrise Lake, White Mountain Reservoir, and other impoundments. Because these impoundments were constructed before the discovery of *S. arizonica*, it is not known if plants were destroyed in the process. Once in place, dams continue to affect stream hydrology and alter the natural flood regime. The reduction in stream flow energy due to dams leads to the buildup of sediment and organic deposits that may affect adjacent *S. arizonica* habitat (Arizona Willow Interagency Technical Team 1995). The vicinity of the Region 2 occurrence is currently not directly impacted by impoundments, but there is one small reservoir nearby, and potential habitat in the area may be threatened.

Fire suppression and the subsequent increase of woody vegetation in the surrounding uplands can affect the hydrology of riparian habitat. Conversely, a rare catastrophic fire could easily damage or destroy a small occurrence of *Salix arizonica*. Catastrophic fires could also lead to massive erosion and sedimentation that could adversely affect the hydrology of *S. arizonica* habitat. Fire frequency and severity are likely to be different for populations of *S. arizonica* in different states. Locations where *S. arizonica* occurs are typically in spruce-fir forest. Moisture and temperature conditions at these elevations are often less favorable for fire development, and catastrophic fires are correspondingly rare.

Beaver activities can have a variety of effects on the local abundance and distribution of *Salix arizonica*. Although beaver cutting of *S. arizonica* in Utah has been observed, impacts from beaver herbivory are not believed to threaten the persistence of the species directly (Mead 1996). The ongoing process of beaver dam construction and abandonment alters stream hydrology by flooding riparian areas, draining previously wet areas, creating new channels, and altering deposition areas. Although these processes can kill individual plants, the overall process also contributes to the renewal of potential habitat. If such activities are occurring at a natural level that allows the local population of *S. arizonica* to keep pace with hydrological changes, the presence of beaver will be largely beneficial. Conversely, if beaver are eliminated from drainages that are suitable for *S. arizonica*, hydrology may be adversely affected and a gradual loss of habitat result. Beaver are likely to be present in the vicinity of the Region 2 occurrence.

Timber harvest and associated activities

For most *Salix arizonica* occurrences the effects of timber harvest are undocumented. Timber harvesting and associated activities such as skid trail and road construction may result in excessive runoff, increased erosion and sedimentation, and downcutting of stream channels, contributing to habitat degradation (Arizona Willow Interagency Technical Team 1995). Some downcutting of stream channels in *S. arizonica* habitat have been noted in conjunction with logging on the Fort Apache Indian Reservation in Arizona (Arizona Willow Interagency Technical Team 1995). Roads and trails impact wetlands by affecting key physical processes such as water runoff and sediment yield. Roads, even at some distance from a wetland, can concentrate water flows, increase flow rate, increase erosion, and reduce percolation and aquifer recharge rates (Forman and Alexander 1998). In most cases, the presence of roads can also facilitate the spread of invasive species. Riparian buffers for timber harvest have been prescribed on the Reservation and in Utah (Arizona Willow Interagency Technical Team 1995), but their effectiveness is

unreported. The single Region 2 occurrence for *S. arizonica* is under a "Forest Products" management prescription, and improperly designed logging activity in the area could indirectly affect this occurrence. While effects are possible, risks of *S. arizonica* being affected are low. Forest Plan direction states: "In the water influence zone (WIZ) next to perennial and intermittent streams, lakes, and wetlands, allow only those land treatments that maintain or improve long-term stream health (p. III-5). Also, since this plant is designated sensitive, mitigations are used to ensure the plant and habitat are not impacted during Forest projects (Erhard, personal communication 2006).

Recreational use

Wherever recreational use results in concentrated impacts in riparian areas, there is potential for detrimental effects to *Salix arizonica* occurrences. The extent of threats from recreational activities varies with the type and intensity of use, and it is often difficult to predict and control. Localized impacts from recreational activities (primarily ruts from off-road vehicle use) have been reported for occurrences of *S. arizonica* outside Region 2. Recreational development, especially ski area construction and expansion, has resulted in the loss of *S. arizonica* plants and habitat in Arizona. *Salix arizonica* occurrences near ski areas are also known from Utah and New Mexico. The Region 2 occurrence is located in a roaded drainage that gives access to the popular Red Lake trailhead. The area is heavily used for fishing and camping, but it is not known if this use has resulted in habitat degradation.

Small population effects

In small populations the effects of stochastic processes are increased relative to larger populations. Demographic stochasticity, or the chance variation in vital rates such as reproduction and survival, is thought to be relevant only to populations of fewer than 50 individuals (Menges 1991), and it may be a concern for some smaller *Salix arizonica* populations. Reported numbers of individuals at some *S. arizonica* occurrences in Utah, New Mexico, and Arizona appear to be sufficient to buffer against the probability that a fluctuation in vital rates will take the species to the extinction threshold. However, numbers are either unknown or below the generally accepted minimum of 50 for many occurrences, including the single Region 2 occurrence. As a dioecious plant, *S. arizonica* is also vulnerable to chance variation in the sex ratio that could drastically reduce effective population sizes, or even eliminate one sex from the population altogether. Although sex ratios are not known for any *S. arizonica* occurrences, at least one other sensitive *Salix* species in Region 2 has an occurrence consisting of only female plants (Neid et al. 2004), and the possibility of a similar occurrence for *S. arizonica* can not be ruled out at this time. Although this type of demographic stochasticity could eliminate a few of the smallest *S. arizonica* occurrences, it is not likely to be a threat to its persistence across the range.

In addition, the potential genetic consequences of small population size include increased inbreeding, loss of genetic variation due to genetic drift, and the accumulation of deleterious mutations (Matthies et al. 2004). Inbreeding depression, or a loss of fitness due to decreased heterozygosity, results from an increased number of matings between closely related individuals. Although inbreeding through selfing is not a concern for *Salix arizonica*, in isolated populations, matings are necessarily between individuals that are more closely related than two randomly chosen members of the species. It is not clear that metapopulation dynamics are in fact operating among the three extremely disjunct distribution centers, but it is likely that gene flow is occurring between discrete occurrences within these centers. This distribution pattern appears to have resulted in substantial genetic differentiation between populations in Utah and Arizona (Thompson et al. 2003) and presumably the New Mexico/Colorado populations as well. In isolated populations, loss of genetic variation by drift is not compensated for by immigration of seeds or pollen from other populations (Oostermeijer et al. 2003). Because *S. arizonica* is primarily insect pollinated, it is unlikely to have regular gene flow via biotic vectors between populations separated by distances of more than a few miles. Although wind pollination can occur, most pollen is deposited close to its source (Levin and Kerster 1974). Under certain weather conditions, large amounts of pollen may be carried some considerable distances from the source (Procter et al. 1996), but if such long-distance pollen dispersal events do occur in *S. arizonica*, they are likely to be extremely rare and virtually non-existent between centers of distribution. In addition, areas of unsuitable habitat for *S. arizonica* act as barriers to successful dispersal of seeds between populations.

Environmental stochasticity, or temporal variation in reproduction and survival as a consequence of changing environmental conditions (e.g., weather, herbivory, pollinator availability), can also lead to local extinction (Lande 1998, Oostermeijer et al. 2003) and is of potential concern for small, isolated *Salix arizonica* occurrences. For a single population, this includes

natural events happening at random intervals that cause the deaths of a large proportion of individuals in the population. Such events may occur very rarely yet still have a large impact on the persistence of the population (Menges 1991). For *S. arizonica*, potentially important environmental events might include catastrophic fire, severe or prolonged drought, or extreme flood events. Multiple populations can have a mitigating effect against the operation of environmental stochasticity. However, for disjunct populations, catastrophic local events have the potential to eliminate the species from part of a region. Impacts of demographic, environmental, and genetic stochasticity on *S. arizonica* are unknown, but are important considerations in conservation, management, and restoration planning.

Global climate change

Global climate change is potentially the most serious threat to the persistence of *Salix arizonica* throughout its range. There is great uncertainty, however, regarding its regional effects and severity. While global climate change is likely to have wide-ranging effects in the near future for all habitats, changes will be most obvious in ecosystems where the structure and composition are strongly influenced by limiting conditions of temperature or rainfall (Walker 1991), such as subalpine riparian areas and wet meadows. Peters and Lovejoy (1992) summarized characteristics of species or populations that are expected to be most susceptible to climate change:

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

Populations of *S. arizonica* have several of these characteristics; they are geographically localized on the edges of the Colorado Plateau, have specialized habitat requirements, and are restricted to subalpine areas. Predicted effects of climate change include loss of species diversity, changes in phenology, increases in incidence of species invasions or disease, and changes in correlations between ecological factors that are important for species survival (Gates 1993, McCarty 2001, Walther et al. 2002). Temperature changes due to climate change could also alter the duration and frequency of insect herbivory for many species (Bale et al. 2002).

For *Salix arizonica*, climate change is most likely to have an impact through changes in hydrology and temperature that affect the extent of its high elevation wetland habitat rather than directly affecting individual plants. Projections based on current atmospheric CO_2 trends suggest that average temperatures will increase while precipitation will decrease in the West (Manabe and Wetherald 1986). These changes will have significant effects on hydrology, nutrient cycling, vapor pressure gradients, and a suite of other environmental variables. In particular, a decrease in precipitation (snowpack) would lead to lower water tables and reduced wetland habitat. Finally, the effects of climate change could also result in shifts in vegetation dominance that would eventually eliminate *S. arizonica* from its habitat. Because of the disjunct nature of *S. arizonica* occurrences, and the fact that these populations will be unable to retreat to more suitable conditions nearby, this threat is pertinent to all occurrences, including the one in Region 2.

Conservation Status of Salix arizonica in Region 2

A lack of repeat observations of *Salix arizonica* occurrences and the fact that new occurrences have recently been discovered make it difficult to give a firm picture of the distribution and abundance of the species throughout its range. Occurrences outside Utah are generally small, are often reported to be heavily impacted by grazing, and are likely to be declining if current trends continue. The recent discovery of *S. arizonica* in Colorado means that we have no real data on population trends or distribution in the Region 2. Although USFS personnel have begun to search likely areas in the Conejos Peak Ranger District of the Rio Grande National Forest, no additional occurrences have been located (Erhard personal communication 2005). The single occurrence has been visited yearly for several years, and plants appear to be vigorous and producing catkins (Erhard personal communication 2005); however, there is no evidence that the occurrence is expanding.

The high elevation wetland habitats where *Salix arizonica* is found are relatively rare in the Intermountain West and are often separated by large intervening areas

of unsuitable habitat that act as barriers to dispersal. Moreover, occurrences in different portions of the range may have adapted to local conditions that do not apply throughout the range. Ultimately, the survival of this species in Region 2 depends on future habitat trends as well as on the conservation efforts of land managers and owners.

Management of Salix arizonica in Region 2

Implications and potential conservation elements

As a regional endemic species confined to a relatively rare habitat, *Salix arizonica* may never have been widespread. Our current knowledge of its distribution and abundance suggests that each distinct population center (Utah, Arizona, and Colorado/New Mexico) may represent a unique gene pool (Thompson et al. 2003). For the Colorado/New Mexico portion of the distribution, small and scattered populations increase the potential importance of each population to the preservation of the species in that area. Endemic and disjunct populations also provide an important resource for research in biogeography, metapopulation dynamics, population genetics, and other topics.

As currently known, most *Salix arizonica* occurrences, including the one in Region 2, are vulnerable to ungulate herbivory and habitat loss or degradation. Any management activities that reduce the utilization of *S. arizonica* by ungulate herbivores and/or maintain intact hydrologic functioning for its subalpine riparian habitats will contribute to the persistence of the species. Short-term management techniques as outlined in the Conservation Agreement and Strategy focused on stopping population decline or maintaining current population levels. Techniques for managing ungulate herbivory included the maintenance or construction of fences, exclosures, or cages to eliminate grazing, and the implementation of rested pastures to reduce impact from cattle or sheep. These techniques are generally inadequate to restore or preserve natural population dynamics in the long term (i.e., regeneration outside of exclosures, colonization of new sites, restoration of natural hydrology). Long-term preservation of the species may require the regulation and monitoring of domestic grazing, revision of recreational uses, and mitigation of the effects of hydrological modifications, logging, and road construction.

The 1995 Conservation Agreement stipulated the collection of baseline data and population trend monitoring for populations then known in Arizona and Utah. A monitoring protocol (**Appendix A**) was produced by a subgroup of the Interagency Technical team, but apparently no formal monitoring has been implemented. Without these data there is no clear documentation of the effects of management activities on *Salix arizonica*. Small occurrences on National Forest System lands in New Mexico and Colorado make it even more important that baseline data and results of monitoring (if any) are disseminated both within and between USFS regions and forests, especially if the sensitive status is maintained in all three affected regions.

The establishment of protected areas that are managed for the conservation of *Salix arizonica* is a useful conservation strategy for this species. Designation of Special Interest Area or Research Natural Area status for the best occurrences on the Fishlake and Dixie national forests could help to ensure the protection of this species on USFS lands in Utah. Additional information on population sizes and trends is needed to determine the conservation importance of occurrences on USFS lands in New Mexico and Colorado. Due to the dispersed nature of *S. arizonica* population centers, a periodic interagency status review of the species across all three USFS regions in which it occurs is an important conservation tool.

Desired environmental conditions for *Salix arizonica* include an intact natural hydrological regime with little or no evidence of wetland alteration due to increased or decreased drainage, clearing, livestock grazing, anthropogenic nutrient inputs, or logging. Conservation management for *S. arizonica* may require changing livestock or wildlife management, installing protective fencing around occurrences, restoring water tables and drainages, providing open habitat for colonization, and establishing seedlings or cuttings. Landscape management in the area may require controlling exotic species, and limiting roads, development, mining, clearcuts, or heavy grazing. Management activities may need to focus on adjacent land use.

Tools and practices

The census and repeated observation of the single known Region 2 occurrence is a priority for *Salix arizonica*. The identification of potential habitat and the subsequent search for additional occurrences, especially on National Forest System lands, is also a high priority for *S. arizonica*. Although limited searching in the vicinity of the known occurrence has been done (Erhard

personal communication 2006), the possible existence of other Region 2 occurrences has not been ruled out. Tools available to the USFS for conservation of *S. arizonica* in Region 2 include its continued listing as a sensitive species, regulating the use of National Forest System lands where this species occurs, and increasing the protective level of management area designations for *S. arizonica* occurrences. Implementation of these and other tools largely depends on the acquisition of better information on known or suspected occurrences. Continued coordination between agencies managing *S. arizonica* occurrences outside Region 2, and regular data sharing among all interested parties could facilitate management efforts to ensure the persistence of the species throughout its range. In particular, monitoring protocols and results need to be better distributed.

Species and habitat inventory

It is important to make a careful census of the Region 2 occurrence of *Salix arizonica* and to determine the numbers of individuals of each sex present. If feasible, the inventory could note the numbers of plants in each age/stage class, using methods similar to those of Mead (1996) as described above. The presence of seedlings is of particular interest. Census efforts will be most effective during the flowering and fruiting season when the sex of individual *S. arizonica* plants can be determined. If new occurrences are discovered in Region 2, element occurrence record documentation should be submitted to the Colorado Natural Heritage Program.

Suitable habitat on the Rio Grande and San Juan national forests can be targeted for future survey work to check for additional occurrences. Some survey work has already been done on the Rio Grande National Forest (Erhard personal communication 2005). Search areas can be closely linked to digital, georeferenced data, especially aerial photographs (both visual spectrum and infrared images), wetland and riparian area maps, and detailed soil maps, when available. Some digital mapping of wetland and riparian areas in southern Colorado has been completed by the USFWS as part of the National Wetlands Inventory, and by the Colorado Division of Wildlife Wetland and Riparian Mapping Project, and digital vegetation data are available for the entire state. Initial efforts can concentrate on similar habitat near the known occurrence (i.e., high elevation riparian areas with low stream gradients). Although Dorn recommended searching locations from 10,300 to 10,700 ft. in elevation (Erhard personal communication 2005), some lower elevation areas could be included since this range is near the upper range of reported elevations even for New Mexico occurrences. Search maps can be cross-checked and augmented with the expert knowledge of local USFS personnel who are familiar with the area.

Once suitable search areas are located, field surveys should be conducted by trained professionals who are familiar with the taxa in question. The following techniques are used by botanists conducting surveys for *Salix arizonica* in Utah (Clark 2002):

> Surveys consist of wandering transects through meadows or along stream channels looking for suitable habitat and for willows that have Arizona willow characteristics. Suitable Arizona willow habitat consists of moist areas with open cover, a good mix of forbs and grasses, presence of other willows, and a shallow slope gradient. Since identification of Arizona willow depends on leaf size, shape and base, stem internode length and catkin length, it is necessary to examine closely all willows that resemble Arizona willow. Surveyors walk up to any willow one meter or less in height and if it has the general characteristics of Arizona willow, a close inspection of several leaves (and catkin, if available) per plant is done to determine species identification.
>
> Plants with characteristics of Arizona willow mixed with Booth or Plane-leaf willow are determined to be hybrids. If a hybrid is found, intensive searches are done in the immediate area in an attempt to locate a true Arizona willow. If no true Arizona willows are found in the area, the location is marked on a USGS 7½ minute topographic map and information recorded in field notes. The locality is noted in the overall Site Visit Account for that area.
>
> When true Arizona willows are found, the immediate area is thoroughly searched to determine the extent of the occurrence, approximate number of Arizona willows, and to gather a brief list of associated species. The site is marked on a USGS 7½ minute topographic map, photographs are taken to enable relocation of the site, GPS points are taken and a Site Visit Account or Rare Plant Observation Account is completed. Total surveyed area is recorded on USGS 7½ minute topographic maps. Areas with Arizona willows are also noted on maps for relocation and future monitoring.

In addition, USFS personnel who visit likely habitat in the course of other work can be alerted to

check for the presence of *Salix arizonica* and to record possible occurrences carefully. If a new occurrence of *S. arizonica* is located, a completed element occurrence report form and a copy of the appropriate portion of a 7.5-minute topographic map with the occurrence mapped should be submitted to the Colorado Natural Heritage Program. It is also appropriate to collect voucher specimens from new occurrences. It is important to document areas that were searched unsuccessfully; however, negative results are not a guarantee that the plant is absent from an area. Conclusions about the need for further inventory, the extent of the occurrence, and critical habitat characteristics should be shared among state and federal agencies, natural heritage programs, local and regional experts, and interested members of the public.

Population and habitat monitoring

Monitoring that tracks population trends could also be an important tool for the conservation of *Salix arizonica*. A monitoring protocol that was developed for populations originally targeted under the Conservation Agreement is presented in **Appendix A**. There are no records indicating that this protocol has been used for any occurrences. The apparent small size of the Region 2 occurrence means that it may be possible to monitor all individuals, and even to collect demographic data with a slight additional effort. Additional techniques for population monitoring are presented in Elzinga et al. (1998).

Until more exact habitat characterization can be obtained, it is appropriate to monitor the immediate habitat of the known Region 2 occurrence, rather than larger tracts of potential habitat. More research is needed to determine the effects of various management practices and natural disturbances on occurrences of *Salix arizonica* throughout its range. Habitat monitoring of the known occurrences will alert managers to new impacts such as damage from anthropogenic activities or grazing, and it will allow proactive management changes to be implemented in time to prevent serious damage to the occurrence. Change in environmental variables might not cause observable demographic repercussions for several years, so resampling the chosen variables may help to identify underlying causes of population trends. Geographic Information System (GIS) technology can provide a powerful tool in the analysis of the scope and severity of habitat impacts. Mapping the circumference of the Region 2 population with a Global Positioning System (GPS) devise could provide an indication of its expansion or contraction.

Seed banking and restoration methods

No seeds or genetic material are currently in storage for *Salix arizonica* at the National Center for Genetic Resource Preservation (Miller personal communication 2005), but its germplasm is maintained vegetatively by The Arboretum at Flagstaff as part of the National Collection of Endangered Plants (Center for Plant Conservation 2004). Because *S. arizonica* seeds are recalcitrant (unable to survive drying and storage at low temperature), embryonic storage of *S. arizonica* germplasm is appropriate (Maschinski personal communication 2005). USFS Region 2 personnel may want to consider an *ex situ* backup of the Colorado population's germplasm at The Arboretum at Flagstaff, and the eventual possibility that the population will need to be augmented through reintroduction.

Guidelines for propagating and transplanting *Salix arizonica* are presented in **Appendix B**. Restoration methods developed for other riparian willow species (Dreesen et al. 2002, Dreesen 2003) are likely to be suitable for *S. arizonica* as well. Southwestern riparian species (including *S. arizonica*) can be grown from seed or established by cuttings. Seeds may be collected from wild plants on an annual basis, or nursery stock may be established from seeds or cuttings. Effective wild collection requires prior identification of female plants in the field and frequent trips to observe catkin development; thus cultivation of a seed orchard may be more efficient for large-scale restoration efforts. Catkin harvest will normally coincide with the appearance of cotton emerging from partially opened capsules (Dreesen 2003). Because seeds of *S. arizonica* quickly loose viability, it is easiest to propagate the plant by cuttings.

The need to protect young plants from grazing and to transplant them into appropriate habitat is shown by the results of some early transplant efforts on the Apache-Sitgreaves National Forest in Arizona, where nearly all transplanted cuttings died within a few years, and mortality was attributed primarily to elk browsing and extremely dry conditions (Arizona Willow Interagency Technical Team 1995). In 1995 The Arboretum at Flagstaff introduced 130 *Salix arizonica* plants to Stinky Creek on the Apache-Sitgreaves National Forest. Establishment of *S. arizonica* was complicated by difficulties in watering the plants for several weeks after planting. The plants were caged as part of the study reported by Maschinski (2001), and some plants were killed by herbivory during the experimental exposure to cattle. As of June 2002, 84 of the original plants had survived (Maschinski personal

communication 2005). Some mortality at the site has been due to increasing drought conditions (Maschinski personal communication 2005).

Information Needs

The primary information need for *Salix arizonica* is the determination of population numbers and trends over time for known occurrences throughout the range of the species. Trends should also be linked to management practices. Regular reporting on monitoring protocols used by various agencies together with their results and observations is lacking, and this could lead to duplicated efforts or delayed implementation of effective conservation actions. It would be useful to survey for additional occurrences in Colorado, especially on public lands, and to consider additional conservation measures for the Colorado population. Conservation efforts would be greatly enhanced by cross-region, interagency review of the species' status on a periodic basis.

Definitions

Ament – same as catkin.

Capsule – a dry, dehiscent fruit with more than one carpel (Harris and Harris 1994).

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

Cienega – a southwestern United States, non-forested wetland; dominated by graminoids and may be seasonally dry (Horton 1999).

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

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

Endemic – confined to a particular region (Weber and Wittmann 2001).

Felsic – igneous rock rich in light-colored minerals such as feldspar and quartz; opposite of mafic.

Glabrous – smooth, without hairs.

Glaucous – covered with a whitish or bluish waxy coating (bloom), as on the surface of a plum (Harris and Harris 1994).

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

Obovate – inversely ovate, attached at the narrow end (Harris and Harris 1994).

Ovate – of leaves, egg-shaped in outline and attached at the broad end (Harris and Harris 1994).

Rank – used by Natural Heritage Programs, Natural Heritage Inventories, Natural Diversity Databases, and NatureServe. Global imperilment (G) ranks are based on the rangewide status of a species. State-province imperilment (S) ranks are based on the status of a species in an individual state or province. State-province and Global ranks are denoted, respectively, with an "S" or a "G" followed by a character (NatureServe 2004). <u>These ranks should not be interpreted as legal designations</u>.

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

Scour – the erosive action of running water in streams that excavates and carries away material from the bed and banks (Horton 1999).

Wet meadow – graminoid-dominated area with waterlogged soil near the surface but without standing water for most of the year (Horton 1999).

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APPENDIX A

Data Sheets and Instructions for Salix arizonica Monitoring

Courtesy of The Arboretum at Flagstaff and Joyce Maschinski

Site _____ Date _____
GPS Coordinates _____ Observer _____
No. of Transects _____
Comments: (Note any impacts or changes since last evaluation)_____
_____
_____
_____
_____

SUMMARY OF POPULATION TRENDS
Average Plant Height _____% of pop flowering _____
Average Current Year Growth (cm) _____
Total Stems Sampled _____
Total Stems Insect Damage_____ % Insect _____
Total Stems with Rust _____ % Rust _____
Total Stems Browsed_____ % Browsed _____
Live to Dead Ratio_____

Plant ID	Alive?	Live: Dead Stems	Whole Plant Height	Whole Plant Width	Sex	Current Year Length (Sample 3 Stems)			Current Year # Catkins/ Stem			Size 3rd Fully Developed Leaf Width			Size 3rd Fully Developed Leaf Length			Foliage Damage/ Herbivory		Comments
						1	2	3	1	2	3	1	2	3	1	2	3	type	%	

Foliage damage will be estimated as **0**, **1** = 1 –20%, **2** = 21 - 40%, **3** = 41-60%, **4** = 61-80%, **5** = 81-100% of foliage affected. **Type**: **F**ungus, **A**phid, **L**eaf **H**opper, **L**eaf **G**all, **S**tem **G**all, **S**tem **B**orer, **C**aterpillars, **V**ertebrate, **H**ail. Browsing = **V**ertebrate herbivory and is recorded as a percentage of the terminal and lateral twigs that have been nipped by vertebrates.

June 5, 1999

FORM 1. ARIZONA WILLOW MONITORING
1) Site _____ 2) Date _____
3) GPS Coordinates _____ 4) Observer _____
5) Patch Size: Length, Width _____
6) Mean Frequency *Salix arizonica* in plot _____
7) Mean Stem Density in Plot:_____ 8) Mean Stem Density of Live AZ Willows:_____
Comments: (Note any impacts or changes since last evaluation)_____
_____
_____
_____

SUMMARY OF POPULATION TRENDS
9) Total Live Stems Sampled _____
10) Average Live to Dead Ratio _____
11) Total Stems Insect Damage_____12) % Insect _____
13) Total Stems with Rust _____ 14) % Rust _____
15) Total Stems Browsed_____ 16) % Browsed _____
17) Average Plant Height _____18) % of pop flowering _____
19) Average Current Year Length (cm) _____
20) Average Leaf Area _____

Plant ID or Tran. No.	*SA NO, SP, O	# Live Stems 0.25 m plot	#Dead Stems 0.25 m plot	**Foliage Damage/ Herbivory 0.25 m		Whole Plant Height	Sex	Current Year Length (Sample 3 Stems)			Current Year # Catkins/ Stem			Size 3rd Fully Developed Leaf Width			Size 3rd Fully Developed Leaf Length			Comments
				type	#			1	2	3	1	2	3	1	2	3	1	2	3	

***SA** = *Salix arizonica*, **NO** = no shrub is present, **O** = other shrub, **SP** = *Salix planifolia;* if possible, identify target species of concern i.e., *Poa pratensis*
Foliage damage will be counted on stems in the 0.25 m x 0.25 m plot placed at each transect point. **Type: **F**ungus, **A**phid, **L**eaf **H**opper, **L**eaf **G**all, **S**tem **G**all, **S**tem **B**orer, **C**aterpillars, **V**ertebrate, **H**ail. Record the number twigs that have been nipped by vertebrates or damaged by other herbivores in the 0.25 m x 0.25 m plot.

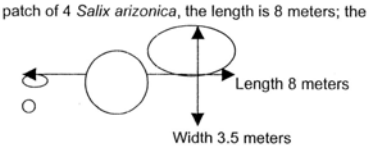
INSTRUCTIONS FOR CONDUCTING ARIZONA WILLOW MONITORING AND COMPLETING FORM 1 (Page 1 of 2).
The monitoring protocol outlined in Form 1 addresses the following questions about Arizona willow. How are Arizona willow plants growing and reproducing? How is the patch of Arizona willow growth and reproduction changing? Small Discrete Patches and Large Patches and/or Large Patches interspersed with other species can be compared with this format.

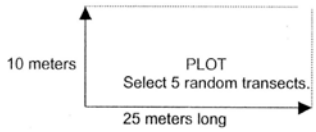
EQUIPMENT NEEDED: GPS (If possible), 25 M TAPE, METER STICK, COMPASS, WIRE SQUARE (0.25 m X 0.25 m in dimension), tally meter, random number table, coin

1) Complete Site, Date, GPS Coordinates, Observer Information

2) A **PATCH** is a group of continuous plant units or discrete plant units spaced no more than 5 meters apart. To determine **Patch Size**, place a meter tape N-S through the longest portion of the patch and record the length. Measure the width at the longest portion of the patch perpendicular to the "length" tape.

Example 1. For this patch of 4 *Salix arizonica*, the length is 8 meters; the width is 3.5 meters.

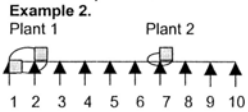




3) PLOTS WITHIN PATCHES: To compare *Salix arizonica* in different patches, the following measurements are taken within a plot that is 10 m X 25 m. Note that the plot may have few or many *Salix arizonica* plants. Find the approximate center of the patch and randomly place 5 ten-meter transect tapes in the plot. You can determine placement of the transect by tossing a stick for placement and spinning it for cardinal orientation or by using a random number table to randomly place the transect along a set boundary of the plot. Note that some transects may not have *Salix arizonica* present. Each year new random transects are chosen.

4) Along the transect at each meter point indicate the plant ID or plant transect number in **Column 1** and the identity of the plant in **Column 2**. SA = *Salix arizonica*, NO = no shrub is present, O = other shrub, SP = *Salix planifolia*. If you wish to target a species of concern, such as Kentucky bluegrass, *Poa pratensis*, indicate the presence of *Poa* in this column.

Example 2.



Arrows indicate meters along transect. Note that plants occur only at meters 1, 2, and 7.

5) At each meter point, place a 0.25 m X 0.25 m square made of wire on the right or left side of the transect tape. Toss a coin to determine on which side of the tape to place the square. Note: plants greater than 1 meter in width may have more than 1 sample (See example at left.) When *Salix arizonica* is present in the square measure the following: **Columns 3 & 4)** the number of live and dead stems present within the square, **Column 5)** the number of stems with foliage damage or vertebrate herbivory (If possible, identify the type of damage), **Column 6)** the maximum plant height of the stems and **Column 7)** the sex of the catkins. **Columns 8, 9, 10, 11)** Select 3 stems within the square to measure current year length, # catkins, and width and length of 3rd fully developed leaf from the tip. This technique will work with small discrete patches and large patches too.

CALCULATIONS FOR SUMMARY OF POPULATION TRENDS: This portion of the form is a tally of the information gathered that can be used to compare from one plant unit to another or from one year to another.

#1-4 are self-explanatory.
5) PATCH SIZE: Assume the patch is a square or rectangle. Calculate area by multiplying length by width.

6) MEAN FREQUENCY OF *SALIX ARIZONICA* WITHIN A PLOT: Add up the number of *Salix arizonica* per transect. Divide by sample points per transect. (For example, 3 plants along one transect with 10 sample points = .3) Add up frequencies in the 5 ten-meter transects and divide by 5 for grand mean frequency in the 10 m. X 25 m. plot. You can compare frequency of *Salix arizonica* across areas and time using this measurement.

7) STEM DENSITY: Count the number of stems per transect. Divide the number of stems by the number of samples. For example, along one transect the following number of stems were counted in the 0.25 m X 0.25 m squares at 10 sample points 6, 25, 100, 0, 5, 15, 0, 75, 40, 10. When no *Salix arizonica* was present a 0 is recorded for the stems. Total stems = 276. Total density of stems = 276/ 10 = 27.6 stems / 0.0625 m^2. To convert to mean stem density per meter squared divide 27.6 by 0.0625 m^2 = 441.6. Add up stem density in the 5 ten-meter transects and divide by 5 for grand mean stem density in the 10 m. X 25 m. plot. You can compare stem densities of *Salix arizonica* across areas and time using this measurement.

8) MEAN LIVE *SALIX ARIZONICA* STEM DENSITY IN PLOT: Perform the same calculation as above, but use only measures where *Salix arizonica* was present. Using the same example as above, add 6, 25, 100, 5, 15, 75, 40, 10 = 276. Divide by 8 (There were 8 willows along the transect). 276/8 = 34.5 stems/ 0.0625 m^2. Thus, the stem density of Salix arizonica in this transect was 552. To get the average for all transects in the plot, add each transect density and divide by 5.

9) TOTAL LIVE STEMS SAMPLED: Add the total number of live stems in each of the 5 transects.

10) AVERAGE LIVE TO DEAD RATIO: For each transect, divide the total live stems by the dead stems. Add ratio for each transect and divide by 5. For example: Note that zeros are treated such that the ratio favors the live stems. Total 29.585/10 = 2.9 is the average.

LIVE	DEAD	RATIO
7	2	3.5
25	40	0.625
14	30	0.46
0	1	0
5	0	5
0	0	0
20	10	2
8	4	2
30	2	15
10	10	1
Total		29.585

11, 12) TOTAL STEMS INSECT DAMAGE, % INSECT = Add total stems with insect damage. Divide by the total stems.
13, 14) TOTAL STEMS WITH RUST, % RUST = Add total stems with rust. Divide by the total stems.
15, 16) TOTAL STEMS BROWSED, % BROWSED = Add total stems browsed. Divide by the total stems.

15, 16) TOTAL STEMS BROWSED, % BROWSED = Add total *Salix arizonica* stems browsed. Divide by the total stems (#9).

17) AVERAGE PLANT HEIGHT: Calculate an average by adding all *Salix arizonica* height measurements and dividing by total measurements. For example, whole plant heights measured in one transect were 10, 9, 7, 8, 5, 3, 2, 4, 3.5, and 6. To determine the average, sum plant heights and divide by the total of Arizona willow measured (57.5/ 10 = 5.75). Sum all 5 transect averages and divide by 5 to get the average plant height for the plot.

18) % of POP FLOWERING: Divide total plants in flower by the total number of Arizona willow plants measured in the plot.

19) AVERAGE CURRENT YEAR LENGTH (CM): For measurements taken in the current year growth, 3 stems are measured at each meter point when Arizona willow is present. The total measurements could equal 30 for a 10-meter transect if there are Arizona willows present at each meter point. Within the plot there are 5 transects or a total of 150 measurements if there are Arizona willows present at each meter point. For calculating average current year growth, only use measures where live Arizona willows are present. Sum the current year growth measurements and divide by total stems measured.

20) AVERAGE LEAF AREA: Assume the area of the leaf is an ellipse. Calculate average leaf area by multiplying the width and length of leaves X ¼ pi (¼ lw) and dividing by the total leaves measured in the plot. This calculation only *estimates* leaf area, but it will serve as a valid comparison across sites or years.

APPENDIX B

Propagation Protocol for Salix arizonica

Courtesy of The Arboretum at Flagstaff and Joyce Maschinski

Guidelines for Propagating and Transplanting Arizona Willow

In order to maintain genetic integrity of populations, it is advisable to obtain material for transplanting from the population existing at the site. Genetic distances between sites of some populations are reported in Harper and Van Buren (1998).

Propagation of Arizona willow is relatively easy using fresh seed or stem cuttings. The seed is relatively short-lived, therefore it must be sown soon after it is fully ripe. Surface sow seeds onto a sterile medium, such as perlite or vermiculite, and keep constantly moist. Germination will occur within 24 hrs if the seed is viable. Allow seedlings to grow to approximately 2 cm or 1 inch in height before you attempt to transplant them. Transplant them into potting soil in conifer seedling tubes to promote deep root growth.

Stem cuttings can be taken at any time of the year, though we have had the best success with early or mid-growing season cuttings. Collect a stem at least 10 cm or 5 inches in length. Dip the freshly cut stem into a rooting hormone such as Hormex #3 and place the stem into a moist, sterile medium, such as perlite. Keep the media moist until the stems have produced roots. Root production will be greater at temperatures warmer than 65 °F. Once the stems have produced substantial roots, transplant them into potting soil in conifer seedling tubes to promote deep root growth.

Allow plants to become well established in the tubes with root growth along the entire length of the tube. Keep plants well watered.

The best time to transplant to the field is during the monsoon period due to relatively high humidity levels. Like any plant that is transplanted, dessication is a big threat. Dig a hold that is 3 inches deeper than your growing tube. Water the willow in the tube before you transplant. Place the willow into the hole and fill with moist soil. Make sure that the soil is thoroughly wet. Water the new transplants on a daily basis for a 3-4 week period following the transplant. Protect the new transplant with caging to exclude herbivores.

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