Salix barrattiana Hooker (Barratt's willow): A Technical Conservation Assessment

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

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AUTHOR'S BIOGRAPHY

Juanita A. R. Ladyman received her B.Sc. degree (with First-class honors) in Biochemistry from London University, England. Her first professional position was as plant pathology laboratory technician and, later, as greenhouse research supervisor with the Arid Lands Research Center on Sadiyat Island in the United Arab Emirates. She obtained her Ph.D. degree in Botany and Plant Pathology from Michigan State University where she was also a research assistant with the D.O.E. Plant Research Laboratory. She worked as a plant physiological ecologist and plant scientist for Shell Development Company conducting research on the physiology, ecology, and reproductive biology of economically important plant species and their wild relatives. She then worked for a plant biotechnology company in their Genetic Transformation and Plant Tissue Culture Division. For the last 14 years she has worked in the area of conservation, particularly on rare, endemic, and sensitive plant species in the southwest United States. For three years of that time, she was the botanist with the New Mexico Natural Heritage Program. She has conducted research and monitoring programs on both non-vascular and vascular species. She currently is a partner in *JnJ Associates LLC*, an environmental consulting company in Colorado.

SUMMARY OF KEY COMPONENTS FOR CONSERVATION OF *SALIX BARRATTIANA*

Status

Salix barrattiana (Barratt's willow) is ranked globally secure by NatureServe. Both the Montana Natural Heritage Program and the Wyoming Natural Diversity Database rank this species as critically imperiled (S1) while the Alaska Natural Heritage Program regards it as apparently secure (S4). It is ranked secure (S5) by the British Columbia Conservation Data Center and apparently secure (S4) by the Alberta Conservation Data Center. The USDA Forest Service (USFS) Region 1 and Region 2 designate *S. barrattiana* as a sensitive species.

Primary Threats

The biggest vulnerability of *Salix barrattiana* lies in the small number of disjunct populations in the continental United States of America, where only two small isolated populations are known. The low or no potential for sexual reproduction by the population on the Wyoming-Montana border on the Shoshone and Custer national forests, managed by USFS Regions 2 and 1 respectively, appears to be a significant threat to long-term population sustainability. *Salix barrattiana* is a palatable species and is threatened to various degrees by herbivore activity range-wide. The known populations in Montana and Wyoming are vulnerable to wildlife browsing. That portion of a population that lies within Region 2 might also be threatened by livestock grazing. Some recreational activities may threaten the population on lands managed by the USFS. Any activities or environmental conditions that lead to a drier habitat will adversely impact the species.

Primary Conservation Elements, Management Implications and Considerations

Salix barrattiana is known from only two locations within the continental United States. One population is primarily on the Shoshone National Forest (USFS Region 2) and extends onto the Custer National Forest (USFS Region 1). This population is near but is not enclosed within the legal boundaries of the Line Creek Plateau Research Natural Area (RNA). Thus, users of the area in which the plant occurs are not legally obligated to abide by the more stringent RNA rules. The other population of *S. barrattiana* is on land managed by Glacier National Park in northwestern Montana. Because there are only two populations within the continental United States, the taxon is very vulnerable to environmental, demographic and genetic stochasticity, as well as natural catastrophes. Additional targeted inventory surveys would clarify its rarity. *Salix* species can be difficult to identify, and non-targeted biological surveys frequently describe *Salix* stands only at the genus level. Therefore, there is the potential that *S. barrattiana* stands have been overlooked in the central Rocky Mountains.

The genetic variation within *Salix barrattiana* is unknown. The possibility that the populations in Wyoming and Montana represent hybrid stands with lower conservation status or that they contain genes lost to northern populations, thereby conferring higher conservation value, needs to be explored. Yearly monitoring of the existing population on the Wyoming-Montana border would verify the report that the Region 2 population is unable to reproduce sexually. *Salix barrattiana* has been reported from parts of Alaska, Alberta, British Columbia, the Yukon Territory, and the Northwest Territories. In these northern regions it is not viewed as needing special management consideration because, although uncommon on a range-wide basis, there are areas where it is locally abundant.

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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 barrattiana* (Barratt's willow) is the focus of an assessment because Region 2 of the USFS has designated it as a sensitive species (USDA Forest Service 2003). Within the National Forest System, sensitive species are "those plant and animal species identified by a Regional Forester for which population viability is a concern, as evidenced by (a) significant current or predicted downward trends in population numbers or density, and/or (b) significant current or predicted downward trends in habitat capability that would reduce a species' existing distribution" (Forest Service Manual 2670.5 Definitions 19; USDA Forest Service 1994a). Sensitive species may require special management, and therefore knowledge of their biology and ecology is critical. This assessment addresses the biology of *S. barrattiana* throughout its range. This introduction defines the goal of the assessment, outlines its scope, and describes the process used in its production.

Goal

Technical 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 scientific knowledge accumulated prior to initiating the assessment. The assessment goals limit the scope of the work to critical summaries of scientific knowledge, discussion of broad implications of that knowledge, and outlines information needs. The assessment does not seek to develop specific management recommendations. Rather, it provides the ecological background upon which management must be based and focuses on the consequences of changes in the environment that result from management (i.e., management implications). Furthermore, this assessment cites management recommendations proposed elsewhere and examines the success of those recommendations that have been implemented.

Scope

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

In producing the assessment, peer reviewed (refereed) literature, non-peer reviewed (non-refereed) publications, research reports, and data accumulated by resource management agencies were reviewed. Not all publications on *Salix barrattiana* may have been referenced in this assessment, but an effort was made to consider all relevant documents. Refereed literature is preferred because it is the accepted standard in science, and in some cases, non-refereed publications and reports may be regarded with greater skepticism. Non-refereed literature was used in the assessment because information was unavailable elsewhere. In addition, many reports or non-refereed publications on rare plants are quite reliable, being often 'works-in-progress' or isolated observations on phenology or reproductive biology. For example, demographic data may have been obtained during only one year when monitoring plots were first established. Insufficient funding or manpower may have prevented work in subsequent years. One year of data is generally considered inadequate for publication in a refereed journal but still provides a valuable contribution to the knowledge base of a rare plant species. Unpublished data (e.g., Natural Heritage Program and herbarium records) were important in estimating the geographic distribution and population sizes of this species. These data required special attention because of the diversity of persons and methods used in collection. Records that were associated with locations at which herbarium specimens had been collected at some point in time were weighted higher than observations only.

Treatment of Uncertainty

Although *Salix barrattiana* has been known for almost two centuries, the information on which to base an assessment is incomplete. Generally, science represents a rigorous, systematic approach to obtaining knowledge. Competing ideas regarding how the world works are measured against observations. However, because our descriptions of the world are always incomplete and observations limited, science focuses on approaches for dealing with uncertainty. A commonly accepted approach to science is based on a progression of critical experiments to develop strong inference (Platt 1964). However, strong inference as described by Platt, suggests that experiments will produce clean results (Hillborn and Mangel 1997), as may be observed in certain physical sciences. The geologist T.C. Chamberlain (1897) suggested an alternative approach to science where multiple competing hypotheses are confronted with observation and data. Sorting among alternatives may be accomplished using a variety of scientific tools (i.e., experiments, modeling, logical inference). Statistics, used in experiments and quantitative observation, is a powerful tool to address uncertainty in ecology and systematics. Ecological science is, in some ways, more similar to geology than physics because of the difficulty in conducting critical experiments and the reliance on observation, inference, logical thinking, and models to guide understanding of the world (Hillborn and Mangel 1997).

Confronting uncertainty, then, is not prescriptive. In this assessment, the strength of evidence for articulate ideas is noted and alternative explanations described when appropriate. While well-executed experiments represent a strong approach to developing knowledge, alternative approaches such as modeling, critical assessment of observations, and inference are accepted approaches to understanding.

The inherent variability among willows makes some species difficult to identify, especially where multiple species grow together. *Salix barrattiana* is a clearly defined species, but it is also phenotypically quite variable (Raup 1959). In fact, although not currently recognized as valid, several varieties have been described to distinguish between different phenotypes. This variability has led to misidentification in the past (e.g., Cody et al. 2001). For this particular species of *Salix*, uncertainty in the context of this report has also been generated by an incomplete knowledge of its abundance and the current status of known populations. Information on the distribution of this species has primarily consisted of relatively casual observations such as herbarium specimens, observations in the literature, and personal communications.

Publication of the Assessment on the World Wide Web

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

Peer Review

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

MANAGEMENT STATUS AND NATURAL HISTORY

Management Status

The NatureServe Global[1] rank (2005) for *Salix barrattiana* is secure (G5), but the National Heritage Status Rank for both Canada and the United States is listed as unknown (N?), suggesting that there is some uncertainty with regards to its status.

Salix barrattiana is regarded as a sensitive species in Montana (Lesica and Shelly 1991). It is currently designated critically imperiled (S1) by both the Montana Natural Heritage Program and the Wyoming Natural Diversity Database. Although NatureServe (2005) list it as only reported and unranked in Alaska, the Alaska Natural Heritage Program regards it as apparently secure (S4) (Lipkin personal communication 2004). *Salix barrattiana* is designated a sensitive species by USDA Forest Service Region 2 (2003) and the USDA Forest Service Region 1 (1999).

In Canada, the Alberta Natural Heritage Information Centre ranks *Salix barrattiana* apparently secure (S4) (Rintoul personal communication 2003), and the British Columbia Conservation Data Centre ranks it secure (S5) (Donovan personal communication 2003). It is unranked but has been reported from the Northwest Territories and the Yukon Territory.

[1]For definitions of G and S ranking see Rank in the Definitions section at the end of this document.

Existing Regulatory Mechanisms, Management Plans, and Conservation Strategies

Within the continental United States, *Salix barrattiana* is only known to occur on land managed by the USFS and the National Park Service. Both the Wyoming Natural Diversity Database and the Montana Natural Heritage Program track *S. barrattiana* because they consider the taxon critically imperiled.

The Heritage Program and Conservation Data Centers in Alaska and Canada, respectively, do not track the taxon. In these northern regions, *Salix barrattiana* is not viewed as needing special management considerations because, although uncommon on a range-wide basis, there are areas where it is locally abundant. These areas of abundance are primarily within national parks or wilderness areas. Such locations provide some protection because national parks in both the United States and Canada are managed for their scenic or historical significance. Recreation is recognized as an important use for parks and wilderness areas, and therefore logging, mining, and other such development activities are usually prohibited (Canada National Parks Act 2000, Environmental Media Services 2001). The wilderness areas in which *S. barrattiana* occurs in Canada also prohibit mountain bikes and horses, but livestock grazing may be permitted on a site-specific basis.

Within USFS Region 2, *Salix barrattiana* is only known from the Shoshone National Forest near the Montana border (**Figure 1** and **Figure 2**). This population extends into the Custer National Forest of Region 1. Occurrences of *S. barrattiana* have been reported to be within the Line Creek Plateau Research Natural Area (RNA) (USDA Forest Service 2000b). However, the locations of occurrences reported by the Wyoming Natural Diversity Database, the Montana Natural Heritage Program, and on specimen sheets at the Rocky Mountain Herbarium are actually not within the current borders of the Line Creek Plateau RNA. The RNA boundaries described in the establishment record (USDA Forest Service 2000b) are slightly inaccurate (Armel personal communication 2004), but apparently the current boundaries as designated in USFS records do not encompass any known occurrences.

The other occurrence of *Salix barrattiana* in Montana is within Glacier National Park (**Figure 1**; Lesica 1984). A conservation plan has not been developed for this taxon in Glacier National Park since no management concerns have been identified and anthropogenic threats to the population are considered to be low within the park (Lesica 1984, Carolin personal communication 2004).

Biology and Ecology

Classification and description

Systematics and synonymy

The genus *Salix* belongs to the family Salicaceae, commonly known as the willow family. Members of the genus *Salix* are known from North, Central, and South America, Europe, Asia, India, Africa, the Middle East, and Japan. It is most abundant in the northern hemisphere. China is particularly rich in *Salix* species. In Australia, New Zealand, and Oceania *Salix* exists only through introduction (Argus 1999). It is an extremely variable and taxonomically complex genus that is organized into various sub-genera and sections (Newsholme 2002).

Salix barrattiana belongs to the subgenus *Caprisalix* (Newsholme 2002) or *Vetrix* (Argus 1999, Dorn 2001), both of which include shrubs and small trees. Within these subgenera it has typically been placed in the section *Lanatae* (Argus 1973, Dorn 1976, Dorn 2001, Newsholme 2002). In a relatively recent treatment, Argus (1997) placed it in the section *Villosae*. Although he recognized that it has some similarities to members of section *Lanatae*, he concluded it most typically clusters with section *Villosae* in phenetic analysis (Argus 1997). Interestingly, both section names imply hairiness; “lanatus” means woolly in Latin whereas “villous” means soft and shaggy-haired. Argus (1997) proposed that *S. barrattiana* is a link between the two sections, perhaps through hybridization and introgression or through alloploidy. The chromosome number of *S. barrattiana* is not known. The treatment of Argus (1997) indicates that it is most closely related to *S. alaxensis* (feltleaf or Alaska willow) and *S. silicicola* (feltleaf or blanketleaf willow).

A synonym for *Salix barrattiana* is *S. albertana* Rowlee. Three varieties, var. *angustifolia*, var. *latifolia*, and var. *marcescens*, have been described (Hultén 1968, Argus 1973). These are all now accepted as synonymous with *S. barrattiana* (Kartesz 1994). See Definitions section for authorship of the trinomials. A synonym for *S. tweedyi* is *S. barrattiana* var. *tweedyi* Bebb ex Rose. *Salix tweedyi* (*S. barrattiana* var. *tweedyi*) is a unique taxon and is clearly distinguishable from *S. barrattiana* (Dorn 1977, Dorn 2001, Fertig and Markow 2001).

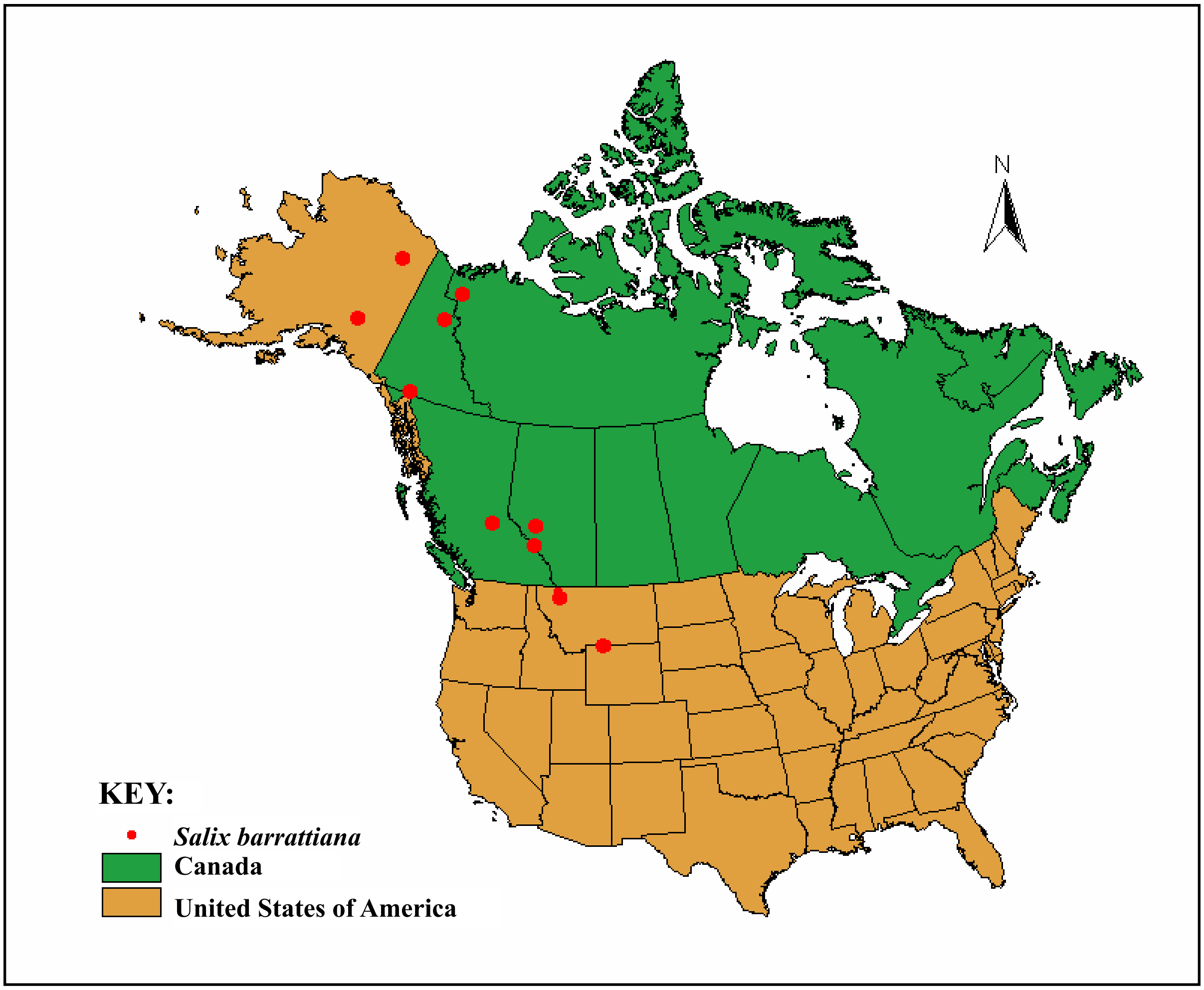

Figure 1. Global range of *Salix barrattiana*.

History of the species

Salix barrattiana appears to have first been collected in Canada by T. Drummond sometime between 1825 and 1828 during the late northern expeditions led by Captain Sir John Franklin, RN (Hooker 1840). Sir William Hooker was responsible for describing *S. barrattiana*, and he named it in honor of an American, Joseph Barratt (1796-1882), who had eclectic botanical interests specializing in the Cyperaceae, the *Eupatorium purpureum* group, and *Salix* (Hooker 1840, Grimes and Keller 1982). *Salix barrattiana* was found more than one century later in disjunct locations in the Rocky Mountains of Montana and Wyoming.

Non-technical description

Salix barrattiana is a low-growing, upright shrub, 0.3 to 1.5 m high. It commonly forms loose clumps, or thickets, several meters across. The twigs are stout, densely hairy when young but also remaining so for many years. Older twigs are reddish-brown to dark brown. The elliptic to ovate-lance shaped leaves are 4 to 7 cm long and are a quarter to one third as wide, with a short pointed apex. On younger leaves, both surfaces appear to be gray-silver from the long-silky hairs. As the leaves age, the surfaces, especially the upper surface, become less hairy. The upper surface of mature leaves can be quite glossy. The leaf margins are entire or minutely serrate and glandular especially toward the leaf base. The petioles are up to 15 mm long, being longest on the upper leaves. All the leaves tend to have a vertical orientation and are packed towards the ends of the twigs. The leaf-like stipules and buds are oily. The silky male, staminate, catkins are 2 to 5 cm long, and without an appreciable stalk. The scales are black, pointed at the tip, and covered by long silky hairs. The female, pistillate, catkins are larger, between 4 to 11 cm long, erect but flexing, and also essentially stalk-less. The seed capsule, which is on a 1.5 mm-long pedicel (stalk) is stout, approximately 6 mm long, and covered by silky white hairs. This description was taken

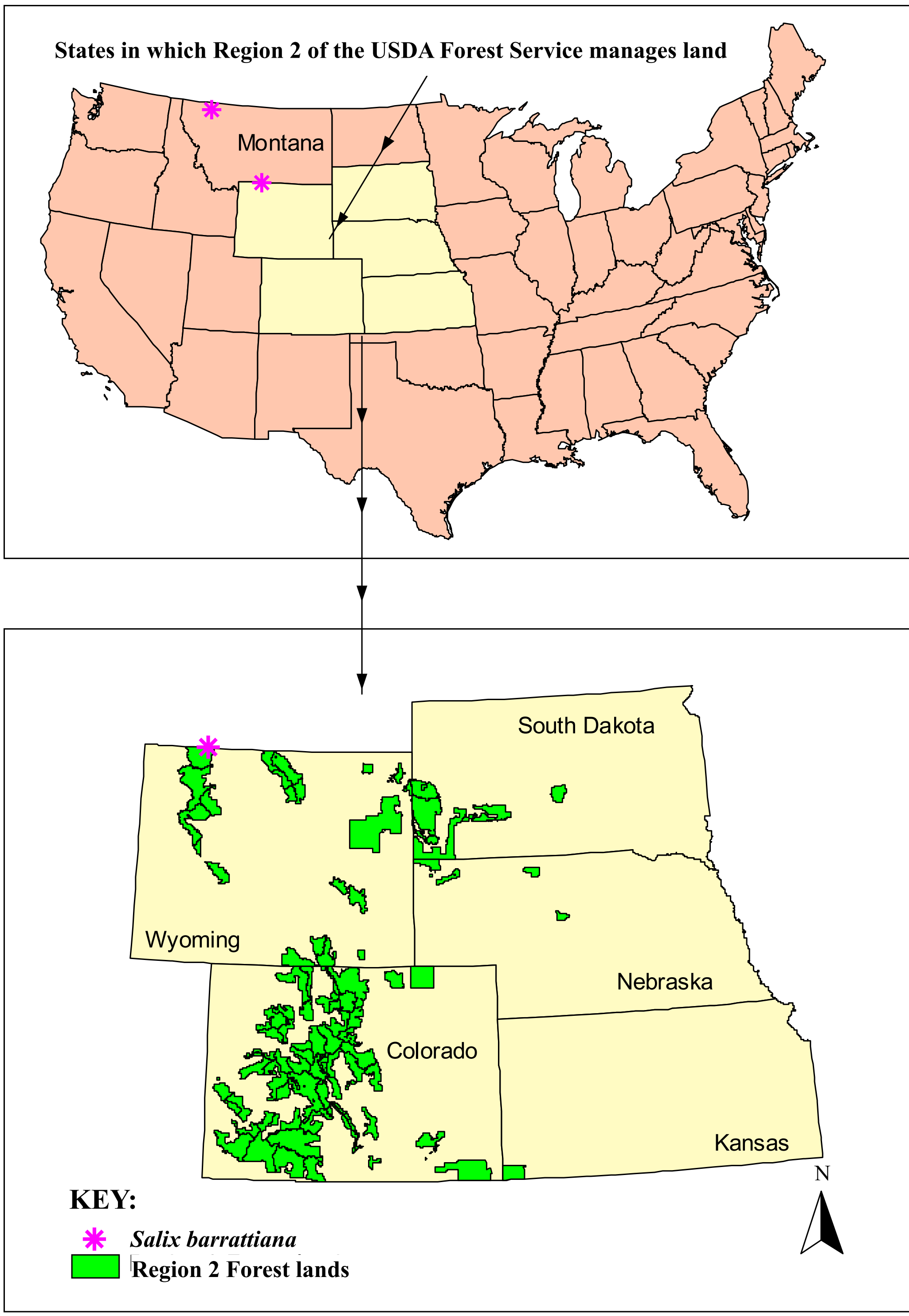

Figure 2. Range of *Salix barrattiana* within the continental United States of America.

from Hooker (1840), Standley (1921), Hultén (1968), Viereck and Little (1972), Welsh (1974), Scott (1995), Dorn (1997), and Newsholme (2002). An illustration of *S. barrattiana* is in **Figure 3**.

The green-silvery appearance of *Salix barrattiana* makes it quite conspicuous in the field, and it was graphically described as a "species equal in beauty to, but not excelled by, the *S. speciosa* and *S. lanata*" (Hooker 1840). The long sessile catkins and oily twigs are principal distinguishing characteristics (Porsild 1951, Lesica 2002). The smell might also be distinctive. The glands on the leaves are described as releasing a "powerful balsamic smell" (Drummond quoted in

Figure 3. Illustration of *Salix barrattiana*. From Viereck and Little (1972).

Hooker 1840, Douglas et al. 2000). When specimens are collected and pressed, the scales, stipules, and young twigs exude a yellowish oily substance that stains the pressing papers yellow or green (Viereck and Little 1972, Dorn 1977). A distinctive type of hairiness, described as sericeous-lanate, covers the undersides of the leaves (Argus 1973). Two superficially similar species, *S. eastwoodiae* and *S. tweedyi*, are within its range in Region 2 (Dorn 1997). A photograph that was taken of plants in the population that extends across the land managed by USFS Regions 1 and 2 is in **Figure 4**.

References to technical descriptions, photographs, line drawings and herbarium specimens

Detailed technical descriptions are in Welsh (1974), Argus (1973), Dorn (1977, 1984, 1988, 2001), and Moss (1983). Other comprehensive technical descriptions, each illustrated with a line drawing, are published in Hultén (1968), Viereck and Little (1972), Scott (1995), Douglas et al. (2000), Fertig and Markow (2000), Hitchcock and Cronquist (2001), Newsholme (2002), and Montana Natural Heritage Program (2004). A particularly beautiful illustration, accompanying the original technical description, is in Hooker (1840). A technical description and photograph are also in Dorn (1997) and Kershaw et al. (1998). Photographs of specimen sheets are also available at the New York Botanical Garden Web site, and collection details of the type specimen are on the Harvard University Herbaria Web site (see References section for Internet addresses).

Distribution and abundance

Salix barrattiana has a relatively wide range and occurs in Alberta, British Columbia, Yukon Territory, and the Northwest Territories in Canada and in Alaska, with substantially disjunct occurrences in Montana and Wyoming in the continental United States (**Figure 1**). The populations at these disjunct occurrences most likely represent relic colonies that were left stranded as temperatures rose relatively rapidly at the end of the most recent glacial event, the Wisconsin glaciation, which ended around 10,000 years ago at the end of the Pleistocene epoch (Daubenmire 1978, Davis 2003).

Salix barrattiana is known from only one location in Wyoming, and two in Montana (**Figure 1** and **Figure 2**). In Wyoming it only occurs on Shoshone National Forest land managed by USFS Region 2. The occurrence is very small. It only "occupies an area of approximately 100 square meters along the Wyoming/Montana State line" (Lesica 1993, Fertig and Markow 2001). In Montana, one occurrence is in Glacier National Park and the other in the Custer National Forest, USFS Region 1 (**Table 1**). The occurrence in the Custer National Forest extends into the occurrence in Wyoming. In this assessment, an occurrence is

Figure 4. Photograph of *Salix barrattiana*. From USDA Forest Service Publication by Dorn (1997).

Table 1. Occurrences of *Salix barrattiana* in the United States of America. For herbaria abbreviations see the footnote to **Table 2**.

State - Arbitrary occurrence no.	Date	Management (County)	Location	Source[1]
WY-1	22 Aug 1964, 23 June 1991, 23 May 1992	USDA Forest Service Region 2, Shoshone National Forest, Clarks Fork Ranger District (Park County)	East of and adjacent to Boundary Lake at the Montana-Wyoming state line on the Beartooth Plateau	*D.L. Pattie #s.n.* 1964 RM. *R. Dorn #5332*, *R. Dorn #5222* RM. Wyoming Natural Diversity Database (2003)
MT-1 - extends into WY-1	1970, 1991, 10 Aug 1993	USDA Forest Service Region 1, Custer National Forest, Beartooth Ranger District (Carbon County)	Beartooth Plateau, headwaters of Wyoming Creek, along Wyoming -Montana border, near south end of Line Creek Plateau. Plants observed on northeast and west sides of unnamed lake that feeds into Wyoming Creek	Montana Natural Heritage Program (2003). *R. Dorn, #1114* 1970. MONTU. *R. Dorn, #1743* 1972. Specimen #390820. RM. *P. Lesica, #6198* 1993. MONTU
Likely sub-occurrence of WY-1	11 Aug 1970	USDA Forest Service Region 2, Shoshone National Forest, Clarks Fork Ranger District (Park County)	Beartooth Plateau: on Wyoming-Montana line 1/4 mi southwest of lake, 1 mile east of highway at head of Wyoming Creek	*R. Dorn #1111* RM
Likely sub-occurrence of WY-1	5 July 1964, 31 July 1972	USDA Forest Service Region 2, Shoshone National Forest, Clarks Fork Ranger District (Park County)	1964: Head of Wyoming Creek on Beartooth Plateau 1972: headwaters of Wyoming Creek	*D.L. Pattie #s.n.*1964 RM. *R. Dorn #1742* RM
MT-2	19 Aug 1996, 1984	National Park Service, Glacier National Park (Glacier County)	St. Mary drainage	Montana Natural Heritage Program (2003). *P. Lesica #3205 and A. Debolt* 1984. Specimen #72041. MONTU. *P. Lesica #7395* 1996. MONTU.
AK-1	10 July 1956, 15 July 1956	National Park Service, Mt. McKinley National Park[2]	Northwest slope to summit of Mt. Eielson (Copper Mountain.)	*LA. Viereck #1361A and # 1214* 1956. COLO
AK-2	4 July 1956	National Park Service, Mt. McKinley National Park[2]	Slope above the Thoroughfare River	*L.A. Viereck #1096A* 1956. COLO
AK-3	18 Aug 1956	National Park Service, Mt. McKinley National Park[2]	Edge of the gravel bar of the Teklat River at the west end of the bridge	*L.A. Viereck #1793* 1956. COLO
AK-4	2 Aug 1972	National Park Service, Mt. McKinley National Park[2](?)	Mt. McKinley	Unknown collectors ALA
AK-5	11 Aug 1983	Not reported	North slope in Echooka River vicinity near Niviak Pass	*D.A. Walker #83-236* 1983 COLO
AK-6	1942, 1949	Not reported	Central and eastern interior of Alaska	*Raup (1959) cited Hultén # 542, 543* 1942 and *Hultén # 1733* 1949
AK-7	1957	Not reported	Jago Lake, northeastern Alaska	Raup (1959) cited *Cantlon and Gillis #911, #1557, #1558* 1957
AK-8	1951	Not reported	Along the Canol Road	Raup (1959) cited *Porsild #147, #148* 1951
AK-9	1956	Not reported	At Yellowknife on Great Slave Lake	Raup (1959) cited *Cody #110* 1956

[1]Herbaria abbreviations:

ALA Herbarium University of Alaska Museum, Fairbanks, Alaska, USA

COLO University of Colorado Herbarium, Boulder, Colorado, USA

MONTU Herbarium University of Montana, Missoula, Montana, USA

RM Rocky Mountain Herbarium, University of Wyoming, Laramie, Wyoming, USA

[2]Since 1980 this area was combined with Denali National Preserve to form the Denali National Park and Preserve

generally ascribed to a population, and sub-occurrences can be equated with sub-populations. Sub-populations are expected to be genetically similar and typically interact, possibly either through pollination or seed dispersal. Therefore the occurrences in the Custer and Shoshone national forests represent one population and are considered sub-occurrences of the same occurrence (**Table 1**).

Outside of Region 2, within Alaska and Canada, *Salix barrattiana* appears to be relatively uncommon range-wide, but there are several areas where it is locally abundant. In Alaska, it has been reported as rare "although it may be locally abundant above treeline on gravel terraces of some rivers in the Alaska Range" (Viereck and Little 1972). In Alaska it occurs from the head of the Chitina River in the Copper River Drainage north to the north slopes of the Alaska Range and west to the eastern end of the Alaska Peninsula (Viereck and Little 1972). It also occurs on the south slopes of the Brooks Range at Wiseman, on the north slopes from the Canning River eastward to the border, Mount McKinley National Park, and the Arctic Wildlife Refuge (Viereck and Little 1972). It could not be confirmed to occur on the slopes of the Brooks Range north of the watershed between the Arctic and Pacific oceans during a floristic survey of this area (Wiggins and Thomas 1962). The Mount McKinley region is a center of abundance (**Table 2**).

The numbers of occurrences (**Table 1** and **Table 2**) listed in Canada and Alaska are acknowledged as imprecise, and delineation of these populations typically relied on vague location and habitat descriptions. However, those data are presented to indicate its distribution and its relative abundance in certain localized areas (see **Figure 1** and locale number and management area in **Table 2**). For example, *Salix barrattiana* is relatively uncommon in the Caribou Forest region of British Columbia, Canada (Coupé personal communication 2004) but appears to have been quite frequently collected over time in particular locales from the Banff and Jasper national parks in Alberta (**Table 2**). Because there have been no systematic surveys that allow one to know where the taxon is not, the apparent localized abundance may be a function of popular collecting sites rather than reflecting its true distribution. It was first collected in the Northern Yukon Territory in 1974 (Nagy et al. 1979), and recently there have been more collections made from this area (Cody et al. 2001, Cody et al. 2002). In summary, it appears to have been collected infrequently but regularly over the last few decades in both western Canada and Alaska.

Potential habitat has not been critically defined for this species. Therefore, areas that have been reported as having potential habitat are more accurately described as areas having habitat that from casual observation appears to be suitable for the species but is not occupied by it. Given this incomplete understanding of potential habitat, it should be noted that considerable areas of potential habitat have been surveyed without finding plants. In addition, plants are not always found in areas considered to have suitable habitat even in regions near existing plants. This situation may be because certain critical microhabitat characteristics are not discernable by casual observation.

Available element occurrence information includes that collected from the Montana Natural Heritage Program, the Wyoming Natural Diversity Database, the British Columbia Conservation Data Centre, the Herbarium University of Alaska Museum (ALA), the University of Alberta Vascular Plant Herbarium (ALTA), the Caribou Forest Region Herbarium, the Rocky Mountain Herbarium (RM), the University of Colorado Herbarium (COLO), the Vascular Plant Herbarium of the Eastern Cereal and Oilseed Research Centre (DAO), Gray's Herbarium at Harvard University (GH), the Herbarium Research Section British Columbia Ministry of Forests at Williams Lake (WLK), the William and Lynda Steere Herbarium, New York Botanical Garden (NY), the University of Montana Herbarium (MONTU), and Royal British Columbia Museum (V). Records were also found in the literature (e.g., Taylor and MacBryde 1977, Nagy et al. 1979, Lesica et al. 1984, Cody et al. 2001, Cody et al. 2002). All sources are cited in **Table 1** and **Table 2**.

Population trend

There are insufficient data in the literature, associated with herbarium specimens, or at the different Heritage Programs to reasonably determine the long-term trends for *Salix barrattiana* populations. The extent to which it historically occurred in disjunct locations within the continental United States is unknown. Four collections, made approximately between 1825 and 1827, are now deposited at the New York Botanical Garden. These were collected by T. Drummond and are reported to be from the "United States of America" (New York Botanical Garden; see References section for Internet site address). This location information is a little misleading because they are more appropriately assigned to be from within the current borders of Canada. Drummond was a Scot, who

Table 2. Occurrences of *Salix barrattiana* in Canada.

Arbitrary no.	Province	Locale number	Date	Management	Location	Source[1]
1	BC	1	14 July 1977	Caribou Forest Region	East end of Two Lakes Basin, South Chilcotin Mountains	*C. Selby #204* WLK Accession #03619 (UBC V168933)
2	BC	2	24 May 1980	Caribou Forest Region	Pavilion Mountain, southwest of Clinton	*R. Coupé* WLK Accession #2744
3	BC	3	20 Aug 1974	Caribou Forest Region	Relay Basin, South Chilcotin Mountains	*J. Hilton* WLK Accession #975
4	BC	4	1980	Mount Edziza Provincial Park	Mount Edziza	*Oldriska 104 G-10; Ceska #8294* 1980 V
5	BC	5	22 June 1942	Yoho National Park	Near Takakkaw Falls	*W.C. McCalla #7052*
6	BC	6	2 Sept 1946	Yoho National Park	Yoho Valley	*W.C. McCalla #9355, 9354, 9353, 9351, 9350* ALTA
7	BC	6	26 June & 24 July 1943, 14 June 1943 (#7463)	Yoho National Park	Yoho Valley	*W.C. McCalla #7555, 7556, 7557, 7463* 1943 ALTA
8	BC	6	9 June 1943, 14 June 1943	Yoho National Park	Yoho Valley	*W.C. McCalla #7427, 7426a* ALTA
9	BC	7	1975	Unknown	Logjam Creek	*T.C. Brayshaw & C.J. Carrigan #s.n* V
10	BC	8	30 May 1960	Unknown	On Cassiar Road approximately 16 miles off the Alaska Highway	*J.A. Calder and J.M. Gillett #24833* 1960 COLO
11	AB	9	29 June 1969	Jasper National Park	Queen Elizabeth Ranges, Opal Hills	*P. Kuchar #387, 388* ALTA
12	AB	10	12 Aug 1933	Jasper National Park	No details	*E.H. Moss #2718* ALTA
13	AB	11	15 July 1901	Jasper National Park	Cavell Lake	*G.W. Argus & J. Gould #14023 & #14024* ALTA
14	AB	12	8 July 1939	Jasper National Park	Wilcox Pass	*E.H. Moss #4871* ALTA
15	AB	13	20 July 1974	Jasper National Park	1km northeast of Signal Mountain summit	*T.D. Lee and W.M. Peterson #s.n.* ALTA
16	AB	14	24 July 1941	Jasper National Park	Athabaska Glacier	*W.C. McCalla #6764* ALTA
17	AB	14	27 Aug 1938	Jasper National Park	Athabaska Glacier	*E.H. Moss #4488* ALTA
18	AB	15	17 July 1940	Jasper National Park	Banff-Jasper Highway	*W.P. Fraser #s.n.* ALTA
19	AB	16	20 Aug 1964	Jasper National Park	Columbia Icefield, about 60 miles southeast of Jasper	*H.J. Scoggan #16448, 16436* ALTA
20	AB	17	9 Aug 1968	Jasper National Park	Mt. Edith Cavell	*G.W. Argus #6920, 6921* ALTA
21	AB	17	9 Aug 1968	Jasper National Park	Mt. Edith Cavell, lateral moraine slope north of Angel Glacier valley	*G.W. Argus #6926* ALTA

Table 2 (cont.).

Arbitrary no.	Province	Locale number	Date	Management	Location	Source[1]
22	AB	18	13 Nov 1968	Jasper National Park	Sunwapta Pass, 2 miles south of pass	*G.W. Argus #6941* ALTA
23	AB	19	13 Aug 1968	Jasper National Park	Sunwapta pass, mountain slopes south of Nigel Peak	*G.W. Argus #6957, 6954* ALTA
24	AB	20	1968	Banff National Park	Near Tower Lake, Mount Eisenhower|	*P. Barclay #1750* 1968 V Gazetteer of Canada, Alberta 1988
25	AB	21	23 July 1941	Banff National Park	Bow River valley near Bow Peak	*C.L. Hitchcock and JS Martin #7766* 1941. COLO
26	AB	21	23 July 1941, 28 July 1942, 26 July 1943, 15 June 1966	Banff National Park	Bow Pass (1943: Bow Pass Summit)	*W.C. McCalla #7737, 7736* 1943 ALTA; *W.C. McCalla #7070,7070a* 1942 ALTA; *W.C. McCalla #6762* 1941ALTA; *R. Hnatiuk #s.n.* 1961 ALTA
27	AB	21	16 June & 23 July 1941	Banff National Park	Above summit of Bow Pass, Lake Louise-Jasper Highway	*W.C. McCalla #6635, 6636* ALTA
28	AB	21	21 June & 26 July 1943	Banff National Park	Below Bow Summit on the Banff-Jasper Highway	*W.C. McCalla #7517* ALTA
29	AB	21	21June & 26 July 1943	Banff National Park	Bow Lake, on Banff-Jasper Highway	*W.C. McCalla #7515, 7415* ALTA
30	AB	22	10 Sept 1942, 26 July 1943, 29 Aug 1946, 8 July 1955	Banff National Park	Lake Louise	*W.C. McCalla #7337* 1942 ALTA; *W.C. McCalla #9303* 1946 ALTA; *W.C. McCalla #7573* 1943 ALTA; *G.H. Turner #9030* 1955 ALTA
31	AB	22	28 June & 26 July 1943, 29 Aug 1946	Banff National Park	Below Lake Louise	*W.C. McCalla #7571, 7572, 7574* 1943 ALTA; *W.C. McCalla #9304* 1946 ALTA
32	AB	22	11-18 July 1945	Banff National Park	Lake Agnes, vicinity of Lake Louise.	*A.E. Porsild and A.J. Breitung #12838-9* 1945. COLO.
33	AB	23	18 June 1942, 1964, 1936	Banff National Park	Moraine Lake (1964: Moraine Lake near Lake Louise)	*W.C. McCalla #6986, #6987* 1942 ALTA; *H.J. Scoggan #16296* 1964 ALTA; *W.C. McCalla #4536* 1936 ALTA
34	AB	24	28 June 1915	Banff National Park	Mount Norquay	*F.J. Cruvis "(??)"* ALTA

Table 2 (cont.).

Arbitrary no.	Province	Locale number	Date	Management	Location	Source[1]
35	AB	25	30 June (? year 1940s)	Banff National Park	Mount Aylmer, Sulphur Mountain, Mount Rundle, Mount Edith Pass, and near mine 35 miles from Banff	*W.C. McCalla #2251* ALTA
36	AB	26	8 Aug 1956	Banff National Park	Near provincial divide above Sunshine Ski Lodge, 12 miles southwest of Banff	*F.J. Hermann #13214* ALTA
37	AB	27	21-23 Aug 1946	Banff National Park	Panther River, southwest slope of Bare Mountain	*A.E. Porsild & A.J. Breitung #16266* ALTA
38	AB	28	1-14 July 1945	Banff National Park	Vicinity of Temple Ski Lodge	*A.E. Porsild & A.J. Breitung #12607* ALTA
39	AB	29	27 July 1962	Banff National Park	Snow Creek Pass, about 40 miles north northeast of Banff	*E.H. Moss #12697, #s.n.* ALTA
40	AB	30	12 Aug 1971	Siffleur Wilderness	No details	*J.R. Gunson #s.n.* ALTA
41	AB	31	26 Aug 1971	White Goat Wilderness	No details	*J.R. Gunson #s.n.* ALTA
42	AB	32	11 Aug 1977	Kananaskis Provincial Park	Just south of Aster Lake	*N.G. Kondla #s.n.* 1972 ALTA
43	AB	33	28 July 1974	Kananaskis Ski Area	25 mi south of Trans-Canada Highway on Kananaskis-Coleman Road.	*M.G. Dumais #7214* A ALTA
44	AB	33	9 Aug 1969	Unknown	Kananaskis Forestry Road, approximately mile 95 (?), equidistant between Pyriform Mountain and Mount Head	*J.G. Packer #1969-487b* ALTA
45	AB	34	26 July 1977	Provincial Park	Burstall Valley, southwest of lakes.	*N.G. Kondla #1780* ALTA (See also Alberta Community Development 2003)
46	AB	35	7 July 1971	Unknown	Cheviot Mountain, 5 miles south of Cadomin and 5 miles from Grave Glat Road along Prospect Creek	*M.G. Dumais #5614* ALTA
47	AB	36	15 July 1976	Unknown	Prospect Mountain 10 miles southwest of Cadomin, Front Range, Rocky Mountains	*P. Mortimer #241* ALTA
48	AB	37	5 July 1975, 4 Aug 1975; 19 June 1975	Private (?) - eastern boundary of Jasper National Park	Mountain Park, town site, Mountain Park, upper site	*W.B. Russell #s.n.* ALTA; W.B. *Russell #s.n.* ALTA

Table 2 (cont.).

Arbitrary no.	Province	Locale number	Date	Management	Location	Source[1]
49	AB	37	14 June 1968	Unknown	Top of the divide southwest of Mountain Park	*M.G. Dumais #2363* ALTA
50	AB	37	7 July 1970, 22 July 1970	Unknown	Cardinal Divide, south of Mountain Park	*MG Dumais #5215, 5124* ALTA
51	AB	38	12 June 1965	Unknown	Mountain south of Whitehorse Creek	*J.G. Packer #2761a, 2761* ALTA
52	AB	39	29 May 1966	Unknown	Near Burn's Lake	*B.J. Golberg #68, 69* ALTA
53	AB	40	12 Aug 1945	Unknown	Nordegg	*R.H. Cormack #s.n.* ALTA
54	AB	41	17 June 1974	Unknown	30 miles south of Nordegg on Nordegg-Cochrane Forestry Trunk Road; 4 miles south of Otter Creek and approximately 15miles north of Ram Falls on North Ram River.	*M.G. Dumais #6833, 6836* ALTA
55	AB	42	26 July 1916	Unknown	"Simpson's Pass, ?? Range"	*D. Pelluet #s.n.* ALTA
56	AB	43	15 July 1971	Unknown	Vine Creek flows southeast into Athabasca River, between Grassy Ridge and De Smet Range	*L.R. Hettinger #253* ALTA
57	NWT	44	5 July 1939	Unknown	Mackenzie Mountains: Vicinity of Brintnell Lake, north slope of Colonel Mountain	*H.M. Raup & J.H. Soper #9422, 9371, 9370* ALTA. *H.M. Raup & J.H. Soper #9374* GH
58	YT	45	20-22 July 1999	Unknown	Ogilvie Mountains, Tombstone Range. Seela Pass	*W.J. Cody* ALA; *original field number (36369)*, ALA AC number (V0133153)
59	YT	46	1974	Unknown	Trail River, vicinity of British Mountains, north northeast of the Babbage River	*Nagy et al. #74-463* DAO (Nagy et al. 1979)
60	YT	47	8 July 1982	Unknown	Richardson Mountains	*Cody and Ginns #30896* DAO (Cody et. al 2001)
61	YT	48	12 July 1999	Unknown	Mountain above Bonnet Plume River	*V. Loewen #99-8-40* DAO (Cody et. al 2002)
62	YT	49	10 July 2000	Unknown	Upper Bonnet Plume River. Drainage Site #142 & #146	*J. Staniforth #00-133* DAO, *J. Staniforth #00-142 & 00-143* DAO (Cody et. al 2002)

Table 2 (concluded).

Arbitrary no.	Province	Locale number	Date	Management	Location	Source[1]
63	YT	49	5 July 2000	Unknown	Upper Bonnet Plume River Drainage Site #108	*J. Staniforth #00-038* DAO (Cody et. al 2002)
64	YT	49	6 July 2000	Unknown	Upper Bonnet Plume River Drainage Site #114	*J. Staniforth #00-065* DAO (Cody et. al 2002)
65	YT	50	2 July 2000	Unknown	Wind River, Camp #1	*W.B. Bennett #00-267* DAO (Cody et. al 2002)

[1]Herbaria abbreviations:

ALA	Herbarium University of Alaska Museum, Fairbanks, Alaska, USA
ALTA	Herbarium, Biological Sciences Department, University of Alberta, Edmonton, Alberta, Canada
COLO	University of Colorado Herbarium, Boulder, Colorado, USA
DAO	Vascular Plant Herbarium, Eastern Cereal and Oilseed Research Centre (ECORC), Ottawa, Ontario, Canada
GH	Harvard University, Cambridge, Massachusetts USA
WLK	Herbarium, Research Section British Columbia Ministry of Forests, Williams Lake, British Columbia, Canada
V	Royal BC Museum, Victoria, Canada

collected in the Rocky Mountains of Canada 1825 to 1828 (Geiser 1948, Birrell 2003, Glamis Inverarity Kinnettles Kirk undated). He then made a return visit to the Americas to collect in Texas in 1829, but at no time did he appear to have visited the Rocky Mountains of the United States. Long-term but sporadic collection records suggest that *S. barrattiana* exists in sustainable populations in Canada. Relatively recently, in 1999 and 2000, specimens were collected in the Bonnet Plume Drainage in the Yukon Territory; this represents an eastward extension of known range of approximately 250 km (Cody et al. 2002). These observations may not necessarily indicate that the species' actual range is expanding because historically these areas have not been well surveyed by botanists.

The two known populations in Montana appear to be stable, at least in the short term. However, there is no information on which to critically evaluate trends in abundance for these populations. No additional populations of *Salix barrattiana* have been located despite a recent floristic survey of wetlands within its range in Montana (Jones 2001). There is also little information on which to evaluate the stability of the population in Region 2. Since 1964, plants have been reported from sub-occurrences amongst three sections within the Shoshone National Forest Region 2 (**Table 1**). However, all collections may actually have been made from within one section (Dorn personal communication 2004). Someone other than the collector is likely to have assigned the sections based on the broad location information after the specimens were submitted to the herbarium for curation (Dorn personal communication 2004). In 1992, there were at least two (sub) populations that were separated by approximately 0.25 miles within one section (Dorn personal communication 2004). Since that time, only one single occurrence of approximately 100 square meters within one section appears to be currently considered in planning (Fertig and Markow 2001, USDA Forest Service 2001, Wyoming Natural Diversity Database 2003). This situation can be interpreted one of three ways. Probably the most likely is that the two sub-occurrences are still discrete and extant and just referred to as one occurrence. Alternatively, one of the sub-occurrences may be extirpated. A third alternative is that the two original discrete sub-occurrences have extended in size to become essentially one.

Habitat

Salix barrattiana grows in arctic and alpine tundra, montane, and subalpine zones (Raup 1959, Moss 1983, Hitchcock and Cronquist 2001). In Region 2, it is found between 9,800 and 10,000 ft., and northwards in Glacier National Park it grows between 6,240 and 6,800 ft. In Alaska it grows up to 4,600 ft. (Viereck and Little 1972). In Canada it grows between 3,000 and 8,500 ft. The elevation at which it occurs appears to be only loosely linked to latitude.

Salix barrattiana grows in various habitats in Canada and Alaska. It has been reported from gravel or sandy lake shores, gravel and sand bars and terraces along larger streams in mountains and foot hills, and at the forested margins of muskegs, wet meadows, prairies, and active river floodplains (Raup 1959, Viereck and Little 1972, Argus 1973). This habitat is not dissimilar to that in the central Rocky Mountains, where it grows on boggy lakeshores, stream banks, and wet sedge meadows in cold moist soil near and above timberline (**Table 3**; Lesica 1984, Fertig and Markow 2001).

This species typically appears to grow in mesic environments range-wide, but exceptions do exist. In the Caribou Forest region of British Columbia, *Salix barrattiana* has been observed on relatively dry, rocky sites as well as in wet, shrub-dominated meadows (Coupé personal communication 2004). Little information exists on the specific soil requirements of this species. In Banff National Park, *S. barrattiana* communities commonly occur on recent alluvial deposits on soils classified as Cumulic Regosols (Knapik et al. 1973). Although permanently moist, these soils tend to drain rapidly (Knapik et al. 1973). Cumulic Regosols are built up from periodic sediment deposition and vary from highly calcareous to acidic, depending upon the source materials. *Salix barrattiana* appears to have a preference, but not a requirement, for soils derived from calcareous rock types in the Caribou Forest Region and some other areas in the northwest (Hitchcock and Cronquist 2001, Coupé personal communication 2004). The geological formations with which this species is associated have not been described in detail. The geological formation on which it is found in Region 2 is an early Archean gneiss complex of metavolcanic and metasedimentary rock (Love and Christiansen 1985). Some of the granite rocks in the complex are estimated at approximately 2,600 million years old (Love and Christiansen 1985). Granitic soils often have fairly low pH. Another indication that *S. barrattiana* may tolerate relatively acidic soils is that it was found growing on coal spoils of an abandoned strip mine land in Alberta (**Table 4**). The observation that it can grow on coal spoils suggests that it has a potential use in re-vegetation efforts. See **Table 3** and **Table 4** for additional details of occupied habitat.

Salix barrattiana grows within complex vegetation community structures. It has been described as occurring within Western spruce - fir forest of the Kuchler plant associations (Kuchler 1964), the fir – spruce ecosystem and BLM physiographic Region 8

Table 3. A summary of *Salix barrattiana* habitat and comments reported for each occurrence within the United States of America (see also **Table 1**).

State - Arbitrary occurrence no.	Habitat and comments
WY-1	1964: Tundra; wet bottom of coulee; two patches, one by jeep trail. Those by jeep trail vegetative; others flowering. 1991: Boggy lake shore with *Salix planifolia*. Wet bottom of coulee, boggy lakeshore, stream banks, and wet sedge meadows
MT-1 - extends into WY-1	Saturated, open alpine glacial valley. Gneiss parent material, silty soil. Observed in 1970, 1991, 1993 (Montana Natural Heritage Program 2003)
Likely sub-occurrence of WY-1	Sparse along stream in willow bottom associated with *Salix glauca* and *S. phylicifolia*
Likely sub-occurrence of WY-1	1964: In wet sedge meadow at edge of basin near. 1972: Streambank with *S. glauca*, *S. wolfii*, and *S. planifolia*
MT-2	Near small streams on open, north-facing slopes in *Salix drummondiana*-*Carex paysonis* community; soils moist with limestone parent material. *Tofieldia pusilla* also occurs. Extends over 13 to 28.5 acres, and plants occur next to a well-used trail
AK-1	Moist tundra, fell-field, knife-edge ridge. 18-inch shrub in low-brush tundra also forming dense 2-foot high clumps in depressions in the tundra
AK-2	Steep, south-facing slope
AK-3	“Willow-tagged earlier in the summer by G. Argus.”
AK-4	No information
AK-5	Alpine meadow on silty soil
AK-6	No information
AK-7	No information
AK-8	No information
AK-9	No information

Table 4. A summary of *Salix barrattiana* habitat and comments reported for each occurrence within Canada (see also **Table 2**).

Arbitrary no.	Province	Habitat	Comments
1	BC	Shrub wetland in hummocky depressions; 1,955 m	No information
2	BC	Subalpine *Salix* shrub community; subhygric; limestone; 1,400 m	No information
3	BC	Northeast slope in alpine	No information
4	BC	No information	No information
5	BC	Low ground	Shrub 3 to 4 ft. high; leaves narrow, acute at base
6	BC	Wet ground among small spruce	No information
7	BC	Swampy ground	Style and stigma red; # 7463: anthers yellow
8	BC	Wet ground	#7426a: filaments purple, anthers red
9	BC	Open burn, valley	No information
10	BC	Occasional shrub to 4 ft. around margin of marl lake	No information
11	AB	Willow shrub community	1 to 1.5m tall; #387: oil stain on paper
12	AB	Beside stream, near glacier	No information
13	AB	Floodplain of glacial stream flowing into lake. Sedge fen near lake. Growing with *Salix barclayi*, *S. barrattiana*, *S. drummondiana*	No information
14	AB	Rocky, shady, alpine meadow	No information
15	AB	300 m below treeline: wooded with few with *Picea engelmannii*, *Tomenthypnum nitens*, and *Sphagnum warnstorfii*. Hydric. Minerotrophic	No information
16	AB	Alpine slope facing glacier	Shrub 2 to 2.5 ft. high
17	AB	Somewhat rocky slope	No information
18	AB	Beside glacial stream	No information
19	AB	Alpine slopes	No information
20	AB	Edge of *Abies lasiocarpa-Picea glauca* subalpine woods. Deep organic turf	Shrub 3 to 5 dm tall
21	AB	Lateral moraine, Salix thicket	No information
22	AB	Subalpine *Salix*, *Betula glandulosa* thicket on wet moss hummock in drainageway	Shrub 5 dm tall
23	AB	Alpine vegetation, limestone bedrock, solifluction slope	Shrub 4 dm tall
24	AB	Open alpine meadow	No information
25	AB	On floor of *Pinus contorta-Picea* woods	Shrubs 1 m tall
26	AB	1943: meadow. 1942: hollow in meadow above Bow Pass at 7,000 ft.; 1941: alpine meadow above pass at 6,900 ft	1943: shrub 1.5 to 2 ft.high. 1942: shrubs 18 inches, anthers rich red on purplish filaments--very showy; 1941: shrub 2 ft. high; 1961: oil stain on flimsy
27	AB	Alpine meadow	Shrub 2 ft. high
28	AB	Wet ground	Anthers yellow
29	AB	Swamp shore	Style and stigma reddish purple

Table 4 (cont.).

Arbitrary no.	Province	Habitat	Comments
30	AB	1942: wet flats at head of lake at 5,700 ft.; 1946: low open woods below lake; 1943: wet ground below lake	1942: shrubs 3 ft. high; 1946: style and stigma red
31	AB	1943: wet ground; 1946: low open woods	1943: anthers yellow; 1943: style and stigma pale green
32	AB	Between swampy pages	No information
33	AB	1942: low ground at edge of woods, on shore; 1964: cliffs and rocky slopes; 1936: open, wet ground near lake. 6,000 to 7,000 ft	1942: shrub 2 to 3 ft. tall
34	AB	Rocky ledges	No information
35	AB	High moist slopes	No information
36	AB	Near edge of snowbank on steep slope	No information
37	AB	No information	No information
38	AB	Alpine slopes	Erect bushes 2 to 3 ft. high
39	AB	Low moist area in the Pass	No information
40	AB	Alpine pasture, common	No information
41	AB	Moist creek bed	No information
42	AB	Above forest line, *Salix barrattiana* thicket	No information
43	AB	Eastern slopes of Kananaskis Range. Alpine meadow, under ski lift	No information
44	AB	Common in gully, moist places	No information
45	AB	Wet gravel	No information
46	AB	Alpine slope	Oil stain
47	AB	Grassy southeast-facing alpine slope with large depressions filled with *Salix barrattiana*	No information
48	AB	On coal spoils, abandoned strip mine land	No information
49	AB	Denuded slope of mountain, above timberline	No information
50	AB	Scree slope above flat towards the ridge, open rocky flat	Large leaves and catkins, oil stain
51	AB	Lower slopes of mountain, moist hollow	No information
52	AB	Alpine tundra	No information
53	AB	Alpine	No information
54	AB	Along stream - low flat on west side of road	Oil stain
55	AB	Engelmann's spruce areas	No information
56	AB	Alpine, subalpine meadows	No information
57	NWT	ALTA: Upper part of willow-birch scrub; along stream above timber, near snow	ALTA: depressed shrub. GH: var. *marcescens*; flower and fruit
58	YT	Fluvial fan with moss and peat	No information
59	YT	Moist drainage	No information
60	YT	Alpine meadow, creek beds and adjacent turfy slopes	Initially misidentified as *Salix planifolia* ssp. pulchra (Cody et al. 2001)
61	YT	No information	No information
62	YT	Wet undulating valley floor sedge meadows; shrub meadow valley bottom	No information

Table 4 (concluded).

Arbitrary no.	Province	Habitat	Comments
63	YT	Undulating upper slope, moist hummocky tundra	No information
64	YT	Valley floor, moist shrub/graminoid/moss	No information
65	YT	River bar	No information

Northern Rocky Mountains (Williams 1990). However, these broad associations do not exemplify all the variation in the habitat occupied by *S. barrattiana*. *Salix barrattiana* is often a member of shrubby tundra communities in Arctic regions of Alaska and the Yukon (Argus 1973) whereas it has only been observed in subalpine regions in the Caribou Forest region of British Columbia (Coupé personal communication 2003). In Banff National Park in Canada, it grows in a krummholz community near timberline with *Picea engelmannii* (Engelmann spruce), *Larix lyallii* (alpine larch), and *Abies lasiocarpa* (subalpine fir) (Knapik et al. 1973), on a swamp shore in a willow community, and under *Pinus contorta-Picea* (lodgepole pine-spruce) woods (**Table 3** and **Table 4**). Some of the associated species are listed in **Table 5**. This is not a comprehensive list but represents associates, reported after relatively casual observation, in the literature, and associated with herbarium specimens. On the Wyoming and Montana border, *S. barrattiana* grows with at least seven other species of *Salix* and most commonly with *S. glauca* (Montana Natural Heritage Program 2003, Wyoming Natural Diversity Database 2003). There is little information on the non-vascular plants that are part of the community to which *S. barrattiana* belongs. *Tomenthypnum nitens* and *Sphagnum warnstorfii* are species of moss that have been recorded as associates of *S. barrattiana* in Alberta. The Rocky Mountain range of both taxa extends as far south as Colorado, and so potentially both may be associated with *S. barrattiana* plants in Region 2. Although non-vascular plants and lichens are important components of the ecosystem, they are frequently overlooked during general biological surveys.

Reproductive biology and autecology

Salix barrattiana is a dioecious perennial woody shrub. The ploidy level of *S. barrattiana* is not known, but it might well be polyploid and its inheritance polyphyletic (Argus 1997). In Canada and Alaska, *S. barrattiana* is well documented as a precocious species (Raup 1959, Douglas et al. 2000). In precocious species, the flower buds appear in spring before the leaves, and the catkins are apt to mature and fall off before the leaves fully expand (Raup 1959). This is not uncommon among *Salix* species, especially those in subgenus *Caprisalix* (Newsholme 2002). It also appears to behave as a precocious species in Wyoming and Montana although the pistillate catkins have been reported to appear mostly with, rather than before, the leaves (Scott 1995). Fruits of the Glacier National Park and Canadian populations mature in July (Densmore and Zasada 1983, Lesica 1984). Apparently flowering and/or fruit maturity times may be influenced by environmental conditions. Mature catkins were also observed in August in Glacier National Park (Lesica 2002).

Where sexual reproduction occurs, *Salix barrattiana* is likely to be pollinated by insects although *Salix* species do differ in their reliance on either insect- or wind-pollination (Mosquin 1971, Argus 1974, Vroege and Stelleman 1990). The pollination syndrome of some *Salix* taxa is designated ambophilous, whereby both air currents and arthropods have an important role in pollen transfer (Vroege and Stellman 1990, Totland and Sottocornola 2001). Evidence indicates that such a dual pollination strategy is most effective in alpine environments with low and infrequent pollinator activity and high wind speeds (Totland and Sottocornola 2001). Bees (order Hymenoptera) are often pollinator species of *Salix* (Stanley and Liskins 1974, Vroege and Stellman 1990, Totland and Sottocornola 2001). The nutritional value of pollen for bees depends upon the source species, and *Salix* pollen is reported to be excellent (Stanley and Liskins 1974).

Salix barrattiana is one of the willows that disperse their seeds in summer, around July 21, in Alaska. These summer-dispersing willows produce small, microbiotic seeds that are dispersed by wind and water (Densmore and Zasada 1983, Zasada et al. undated). The seed coat is covered by long hairs, which get caught by wind currents. The seeds generally remain viable without moisture from a few days to several weeks, but they must have a moist seed-bed relatively soon after dispersal to produce vigorous seedlings. Seeds of *S. barrattiana* do not require a stratification period for germination (Baskin and Baskin 2001). They readily germinate at a range of temperatures; 93 to 100 percent germination between 5 and 25 °C (Densmore and Zasada 1983). Thompson (1992) reported that

Table 5. Some of the plant species reported to be associated with *Salix barrattiana*.

State or Province	Species
MT	*Achillea millefolium*
MT	*Agropyron caninum*
MT at WY border	*Caltha leptosepala*
MT	*Carex paysonis*
MT at WY border	*Carex scirpoidea*
MT	*Cerastium arvense*
MT at WY border	*Deschampsia caespitosa*
MT at WY border	*Phleum alpinum*
MT at WY border	*Poa alpine*
MT	*Salix drummondiana*
WY, MT	*Salix glauca*
WY	*Salix phylicifolia*
WY	*Salix planifolia*
MT at WY border	*Salix reticulata*
MT	*Salix vestita*
WY	*Salix wolfii*
MT	*Tofieldia pusilla*
MT at WY border	*Trollius laxus*
AB	*Abies lasiocarpa*
AB	*Betula glandulosa*
AB	*Picea engelmannii*
AB	*Picea glauca*
AB	*Picea* spp.
AB	*Pinus contorta*
AB	*Salix barclayi*
AB	*Salix drummondiana*
AB	*Salix* spp.
AB	*Sphagnum warnstorfii*
AB	*Tomenthypnum nitens*

seeds of *Salix* species are "normally absent" from the seed bank in alpine and arctic communities. This is because summer-dispersed willow seeds have no adaptations for delaying germination (Densmore and Zasada 1983). Summer-dispersed willow seeds contain little or no endosperm and are green at maturity with transparent seed coats (Densmore and Zasada 1983). They are able to begin photosynthesis as soon as the seeds are moistened.

Hybridization among willows is well documented (Komarov 1936, Hultén 1968, Welsh et al. 1993, Pojar and MacKinnon 1994). The potential for hybridization is only possible when sympatric species have coincident flowering times. Hybridization between species is also limited by differences in pollen morphology and some pre- and post-pollination limitations (Kim et al. 1990, Mosseler 1990). Specifically *Salix barrattiana* has been reported to hybridize with *S. barclayi*, *S. commutata*, and *S. myrtillifolia* (Moss 1983, Douglas et al. 1991). Both *S. barclayi* and *S. commutata* grow in northwestern Wyoming, Montana, and Canada, but only *S. barclayi* has been reported from the Shoshone National Forest (Dorn 1984, Dorn 2001, Fertig and Markow 2001, Newsholme 2002). There are two varieties of *S. myrtillifolia*, varieties *cordata* and *myrtillifolia*. *Salix myrtillifolia* var. *cordata* is restricted to Canada and Alaska (Douglas et al. 1991, Newsholme 2002). *Salix myrtillifolia* var. *myrtillifolia* also grows primarily in Canada and Alaska, but it is known from Colorado and a disjunct occurrence in the Clarks Fork Valley in the Shoshone National Forest in Wyoming (Fertig and

Wyoming Rare Plant Technical Council 1994, Fertig and Markow 2001).

The *Salix barrattiana* population that straddles the land managed by USFS Region 1 and Region 2 is reported to consist of a single clone of staminate plants (Fertig and Markow 2000). In this case no sexual reproduction can occur, and the population must rely on asexual vegetative reproduction. However, because of irregular flowering, it may take several years to accurately assess the sex of individual shrubs (Zasada et al. undated). Systematic observations over several years do not appear to have been made on the population in Region 2, and therefore the staminate condition of the population needs to be confirmed. Sex determination in the Salicaceae is at the genetic level, but the mechanisms are not yet well understood (Alstrom-Rapaport et al. 1998, Brunner et al. 2000, Gunter et al. 2003). Analyses of DNA markers associated with femaleness in *S. viminalis* and *S. eriocephala* suggest that gender is controlled by one or more loci (Alstrom-Rapaport et al. 1998, Gunter et al. 2003). Alstrom-Rapaport et al. (1998) proposed a two-locus epistatic genetic model of sex determination for *S. viminalis*.

Environment may also influence sex determination in the Salicaceae (Brunner et al. 2000). Skewed sex ratios amongst *Salix* populations are not uncommon although in natural populations it is most often female-biased (Zasada et al. undated). Habitat influences the relative abundance of male to female flowers in some *S. arctica* populations. Dawson (1987) reported that female *S. arctica* plants were significantly more numerous than male plants in mesic-wet, more fertile, low soil-temperature sites, whereas male plants were most prevalent in drier, less fertile sites. The basis for this "sex-bias" dynamic needs to be more fully researched. One theory is that sex-bias is related to sex-specific physiology that leads to differences in carbon balance resulting in sexual differentiation in growth and reproductive allocation (Crawford and Balfour 1983, Obeso et al. 1998). For example, among some dioecious species, males have been observed to be larger, grow faster, survive for a longer period, and exhibit a higher degree of clonal propagation than females, which in some circumstances put a higher carbon allocation into sexual reproduction and experience an increased mortality than male plants (Obeso et al. 1998, Houle 1999, Rocheleau and Houle 2001). In this case, under certain conditions the population might eventually become male-biased. The condition of the *S. barrattiana* population can only be speculated since no research has been conducted either to determine the mechanism of genetic sex expression or to examine the impact of environmental conditions on sex-bias in *S. barrattiana*.

Not withstanding the absence of sexual reproduction, populations of vegetatively propagated individuals can be very successful. Studies on the clonal shrub, *Larrea tridentata* (creosote bush), in the Mojave Desert of the southwestern United States have yielded surprising results. Observations on clonal extension of *Larrea* shrubs suggest that some individuals may be thousands of years old. The central stems die, and clonal extension leads to the formation of a ring of ramets, which advance radially less than 1 mm per year (Silvertown 1987). A ramet is the unit of clonal growth that can follow an independent existence if detached from the parent plant. Using this rate of extension, Vasek (1980) calculated that the largest clone in the study area could be 11,700 years old. In these circumstances, seed germination need only be a rare event, but when a seedling does become established, under natural conditions it can look forward to a long life.

Demography

Throughout its range *Salix barrattiana* forms extensive thickets through expansion by vegetative growth and reproduction (Hultén 1968, Moss 1983, Lesica et al. 1984). Population density is likely influenced by the availability of resources. Reproduction in the population within Region 2 is apparently restricted to clonal reproduction. The population in Glacier National Park in Montana also produces seed, but there is no information on the frequency of production, the amount, or its success in germination and seedlings establishment. Seed may not be produced annually but only when conditions are favorable. A simple life cycle model of *S. barrattiana* is diagrammed in **Figure 5**. Outside of Region 2, seed production and vegetative reproduction may have equal importance to a population's sustainability. In contrast, vegetative propagation is the most important and likely the sole method of reproduction of the population on the Shoshone and Custer national forests (see Reproductive biology and autecology section). The characteristics of *S. barrattiana*, being a perennial species that is maintained in established, relatively long-lived populations, are consistent with those of a K-selected species having a stress-tolerant life strategy (MacArthur and Wilson 1967, Grime et al. 1988).

No demographic studies have been undertaken on *Salix barrattiana*. The population biology of shrubs such as *S. barrattiana* is recognized as being difficult

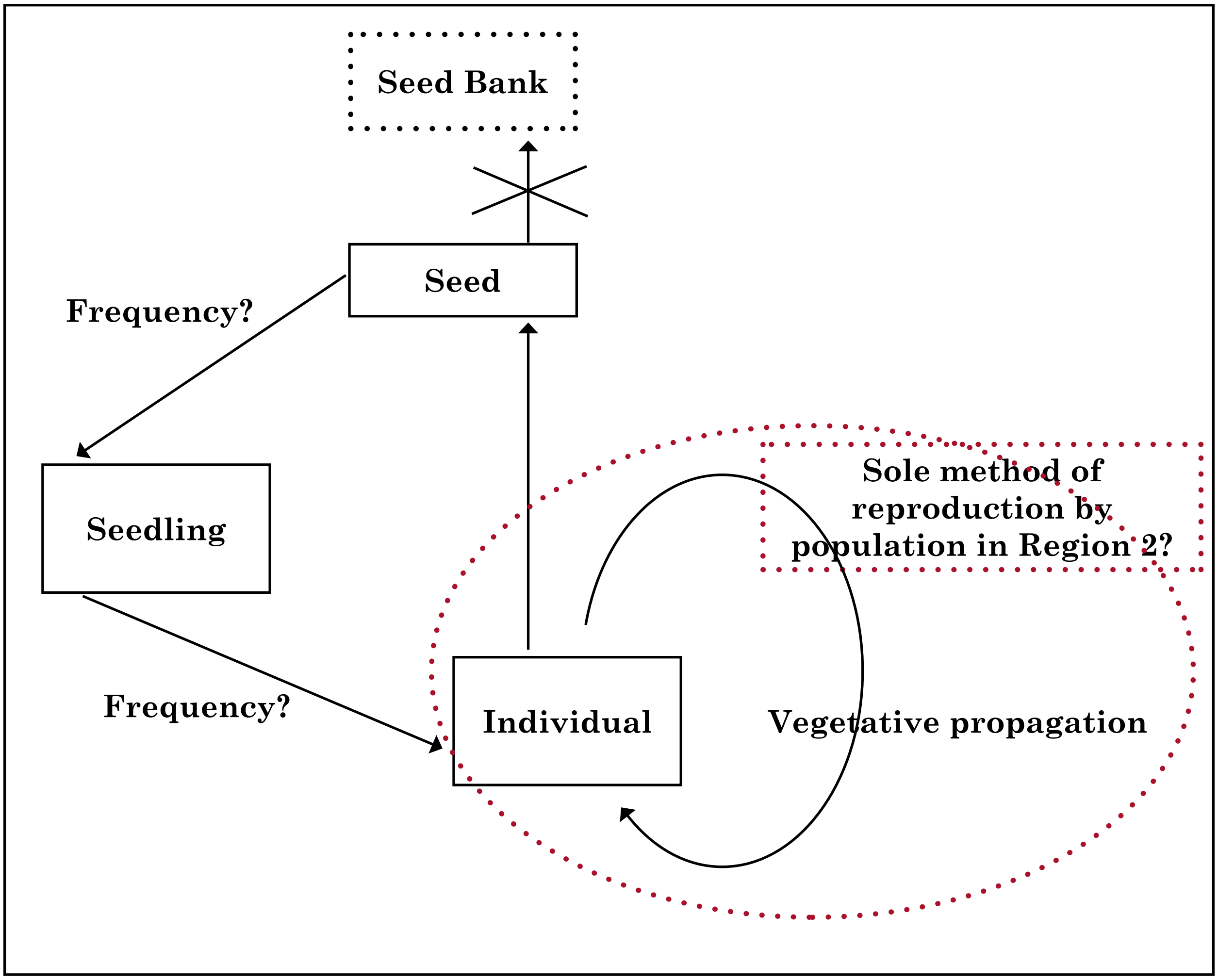

Figure 5. Life cycle diagram for *Salix barratiana*.

to study. There are at least two age structures within a population, that of the underground system and that of the aboveground shoots. There may also be a third age structure if the belowground parts do not represent the whole life of the individual. For example, when shoots independently produce roots, the age of the original individual will be difficult to estimate. The complexity of the *S. barrattiana* populations is unknown. The ages of individual shoots of *S. barrattiana* are not known. Willows are often relatively fast growing and may have life spans of a couple of decades or less. Size is unlikely to reflect the age of an individual shoot because environmental conditions, for example soil moisture gradients, can have a primary effect on plant size. Notwithstanding the complexity of the issues, detailed demographic studies and population viability analyses (PVA) have been made on a range of clonal shrub and tree taxa (e.g., Silvertown et al. 1993, Schwartz et al. 2000). Considering taxa from several families, it is clear that woody rhizomatous shrubs exhibit many different population structures and dynamics and although the condition of *Larrea tridentata* (creosote bush) is possibly an extreme, the potential longevity of isolated clonally propagating *S. barrattiana* populations cannot be underestimated. Because some level of destructive sampling is usually necessary, a critical demographic study with PVA is not appropriate for small isolated populations such as those of *S. barrattiana* in Wyoming and Montana.

Genetic exchange between populations will depend upon their distance apart and the habitat separating them. In regions linked by rivers, streams, and waterways, genotypes established in one area may be distributed downstream and across floodplains. Seeds can be transported considerable distances (Zasada et al. undated). Detached parts of willows also frequently become established to form independent individuals. Although undocumented for *Salix barrattiana*, floods can uproot whole plants of some species, which then will re-establish after dispersal (Zasada et al. undated). Spatially disjunct groups may have high levels of pollen dispersal and gene flow between them. Osborne et al. (1999) tracked individual bumblebees using harmonic radar and recorded that most bees regularly fly over 200 m (range 70-631 m) from the nest to forage even when ostensibly plentiful food was available nearby. Honeybees can regularly forage 2 km away from their hive (Ramsey et al. 1999).

There is likely to be little genetic exchange between disjunct occurrences where there are considerable distances of unsuitable habitat separating the populations. Also, several biological and geographic factors may have led to populations that are dominated by one or few genotypes. Local selection pressures can lead to increased fitness to local conditions that favor certain genotypes at the expense of others (Ellstrand and Roose 1987). For the same reasons, there may be a high degree of genetic variability between populations. Phenotypic variation that was linked to geographical location probably led to varietal distinctions being described (see Systematics and synonymy section). On the other hand, genetic isolation may not have caused substantial divergence among many *S. barrattiana* populations. Standley (1921) commented that a specimen collected in Glacier National Park was only 30 to 60 cm tall and differed from typical material in having shorter relatively broader elliptic-oval leaves (2 to 4 cm long) and catkins being only 4 cm long. Interestingly, a similar collection was also made at Rocky Mountain Park around Banff in Alberta (Standley 1921). This suggests that such variants not only do not warrant subspecies status, but are also quite widely distributed. Indeed, substantial distances may separate relatively heterogeneous populations that are composed of similar genotypes. Another consideration is that a wide variation in phenotype may not reflect a correspondingly wide diversity of genotypes. Local environmental conditions, such as soil fertility or elevation, may cause differential gene expression and can contribute to this species' variation in physical appearance.

Community ecology

Salix barrattiana is most likely to be palatable to a wide-range of native animals and livestock. The majority of *Salix* species provide a very important browse for wildlife and livestock within their range (Dayton 1931, Singer et al. 1994, Fralish and Franklin 2002). In one study, *Salix* species were second only to juniper as the most desirable winter-browse species (Harper 1977). Particularly the young leaves, stems, and buds provide valuable browse for ptarmigan and a host of other animals including mice, rabbits, porcupine, elk, moose, mule deer, bison, muskox, and reindeer (Komarov 1936, Singer et al. 1994, Kershaw et al. 1998, Tolven et al. 2001, Fralish and Franklin 2002). Browsing ungulates can reduce the numbers of seeds that willows produce (Kay and Chadde 1992). Ungulate, principally elk, browsing has had an important effect on growth form, productivity, and decreased survival rate of several *Salix* species in northern Yellowstone National Park (Singer et al. 1994, Singer and Cates 1995, Wagner et al. 1995). Specific interactions between *S. barrattiana* and native fauna have not been formally studied, but moose were observed to browse young twigs of *S. barrattiana* in Alaska (Viereck and Little 1972). Humans have long found myriad household and building uses for flexible willow branches and willow bark. Willow leaves and bark are also commonly used for medicinal purposes (Moerman 1998).

Associations between *Salix barrattiana* and non-vascular plant and lichen species have not been reported for the population in Wyoming and Montana (see Habitat section). Bryophytes, lichens, and liverworts are important components of a community and have frequently been noted as part of *Salix*-dominated communities (Boggs 2000, Cooper and Jones 2004). Little specific information is available about their association with *S. barrattiana* (see Habitat section). Although not documented specifically for *S. barrattiana*, a mutualistic association exists between many if not all arctic and alpine willow species and ectomycorrhizal fungi (Miller and Laursen 1978). The ectomycorrhizal fungi include agarics, or gilled mushrooms (Cripps and Horak 2002). *Salix* species may also be associated with arbuscular mycorrhizal fungi, and both types of mycorrhizal association have been known to occur on the same plant. The fungi facilitate the acquisition of minerals and nutrients by the plant, which in turn provides photosynthate-based nutrients to the fungi.

Interactions between *Salix barrattiana* and specific arthropods have not been reported. Unlike many other catkin-bearing taxa, *Salix* species are predominantly pollinated by bees (see Reproductive biology and autecology section). Specific pollinator species of *S. barrattiana* have not been documented. Some *Salix* species are physiologically attractive to insects and may have an advantage over other more showy flowers. The catkins of *S. arctica* and *S. barrattiana* are superficially similar, being erect and "fuzzy," and are likely to share physiological characters that are based on morphology. On calm, sunny days the female catkins of *S. arctica* can be up to 8.5 °C warmer and the male catkins up to 7 °C warmer than the surrounding air temperature (Kershaw et al. 1998). The warmer temperatures speed up pollen and seed development and also attract insects (Kershaw et al. 1998).

There are no documented responses of *Salix barrattiana* to natural disturbances that are typically encountered within its habitat. Its substantial underground system suggests that it is tolerant of solifluction (see AB occurrence 23 in **Table 4**). *Salix barrattiana* has evolved in landscapes that are subjected to periodic fire. Their root systems in the soil can survive some fires, and burned sites can also be re-colonized by wind-dispersed, off-site seed (Lyon and Stickney 1976, Williams 1990). If roots are killed, re-colonization is dependent upon an off-site seed source because there is no seed bank (see Reproductive biology and autecology section). *Salix barrattiana* may be a pioneer species under some conditions. It has been reported growing on coal spoils of an abandoned strip mine (see AB occurrence 48 in **Table 4**). The observations were made approximately 25 years after the mine, and actually also the town that supported it, had closed in 1950 (Bachusky 2004). Viereck (1966) described the vegetation succession on a gravel glacial outwash in Alaska. He noted that *S. barrattiana* came in during the Meadow Stage that was subsequent to the Pioneer Stage. In this case, the meadow was an *Elymus-Festuca-Poa* community. However, Argus (1973) suggested that, based on his experience elsewhere, seedlings would have also been present in the Pioneer Stage but that they were only difficult to see and identify. More discussion on the effects of disturbance is in the Threats section.

An envirogram is a graphic representation of the components that influence the condition of a species and reflects its chance of reproduction and survival. Envirograms have been used especially to describe the conditions of animals (Andrewartha and Birch 1984), but they may also be applied to describe the condition of plant species. Those components that directly impact *Salix barrattiana* make up the centrum, and the indirectly acting components constitute the web. Unfortunately, much of the information to make a comprehensive envirogram for *S. barrattiana* is unavailable. The envirogram in **Figure 6** is constructed to outline some of the components that appear to be resources for the species. The dashed box indicates resources that are likely but not proven.

Conservation

Threats

Some threats, such as global climate change, are common to all occurrences of *Salix barrattiana*. Other threats, such as overgrazing by livestock, are local and pertinent to only certain populations. Although general threats are outlined, only the threats related to the population in Region 2 will be considered in detail. However, threats that are not currently of concern to the population on USFS Region 2 land should still be considered as management practices and land use policies change.

Salix barrattiana appears to grow in relatively open sites, and periodic fires serve to curb canopy closure at sites below timberline. The consequence of long-term fire suppression on the abundance and distribution of this species within Region 2 lands is unknown. Historically, cool or low intensity fires may have maintained suitable habitat for *S. barrattiana*. However, the lack of seed in the seed bank and the apparent absence of nearby seed sources make the stand within Regions 1 and 2 very vulnerable to hot fires that could damage the root systems. Hot fires are high intensity fires with high temperatures that penetrate the soil deeply, thereby severely damaging and often completely destroying all vegetation.

The mesic habitat of this species is fragile and easily disturbed (Lesica 1993, Fertig and Markow 2000). Isolated populations, such as the one in Region 2, that rely on their root systems for regeneration may be particularly vulnerable to physical disturbances. Populations in centers of abundance are more likely to be re-established through off-site seed sources and detached plant parts (see Demography section). Some populations, especially those on slopes, are likely to experience disturbance from avalanches, landslides, or at least solifluction (**Table 2** and **Table 4**; Alberta Community Development 2003). However, there is no evidence to suggest that the population in Region 2 is in imminent threat from any of these disturbances. In Region 2, it grows on relatively level or undulating ground at lake- and stream-side sites.

Human-caused disturbances, such as camping, recreational vehicle use, and livestock grazing, are

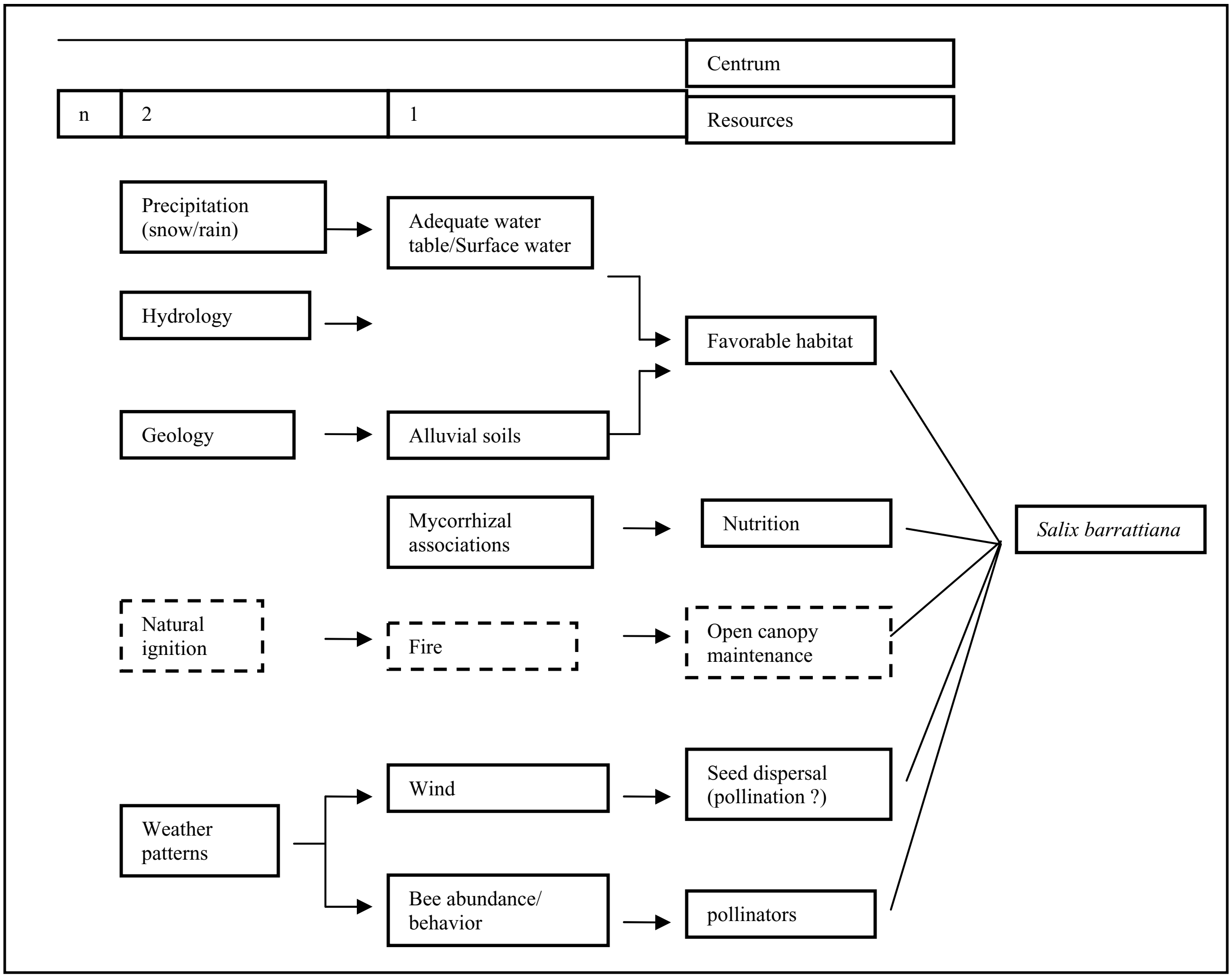

Figure 6. Envirogram outlining the resources of *Salix barrattiana*.

much more likely to be a threat to this species in Region 2. The Region 2 *Salix barrattiana* population is on the Beartooth Plateau, which is an important destination for recreational fishing (USDA Forest Service 1994b). Currently the area is managed for semi-primitive, non-motorized recreation opportunities and as rangeland (USDA Forest Service 1987). Off-road vehicle use is prohibited due to sensitive soil and watershed resources, but snowmobiling is allowed without restrictions (USDA Forest Service 1987). The demand for fishing is expected to increase in the future, and it is anticipated that some of the presently barren lakes will be stocked with fish to meet this increasing demand (USDA Forest Service 1994b). As well as for fishing, streams and lakes are popular camping sites. Recreational activities such as camping, using all terrain vehicles (ATVs), mountain bike riding, and horse riding/packing can destroy aboveground vegetation, negatively impact soil structure, and disturb roots. Snowmobiles, because they travel on frozen ground, may impact sites that would be too wet for significant recreational use in the summer. Seedlings, shrubs, and other exposed vegetation are commonly broken, and shallow roots and rhizomes can be crushed or damaged (Neumann and Merriam 1972, Ryerson et al. 1977). Snowmobiles also contribute to snow compaction, which can cause considerable damage to vegetation below the surface (Neumann and Merriam 1972). Snow compaction also causes a significant reduction in soil temperatures, which retards soil microbial activity and seed germination (Keddy et al. 1979, Aasheim 1980). There is evidence of camping, snowmobile use, and mountain bike use within the Line Creek Plateau RNA (1993). The current magnitude of these threats to the Region 2 *S. barrattiana* population is uncertain, but the popularity of the area for recreation suggests that they may increase in the future.

Direct impacts may also come from trampling and herbivory by both native and domestic ungulates (see Community ecology section). Stream and lakeside areas attract animals and are particularly vulnerable to livestock damage. Tethered horses used for recreation can impact nearby palatable browse species. The unit in which the Region 2 *Salix barrattiana* occurrence is located encompasses a grazing allotment that is managed for sheep under a year-long grazing system (USDA Forest Service 1987). The extent to which the stand has been affected by herbivory has not been studied.

Small-scale mining and timber harvesting has occurred in the Line Creek Plateau area of Region 2 in the past (Lesica 1993). The current levels are not known to pose a threat. Currently there are no manageable timber resources in the unit, and the potential for finding oil, gas, and locatable minerals is low (USDA Forest Service 1987). Oil and natural gas deposits are understood to be under the Line Creek Plateau RNA, but no drilling has occurred (Lesica 1993). If resource extraction becomes economically viable in the future, development of this land may pose a threat to the *Salix barrattiana* population. Even if the population is not impacted directly, a drier site resulting from extraction practices may have negative consequences on the stands of willow.

Many of the human-caused threats would be less of a concern if the *Salix barrattiana* occurrences were in an area managed for conservation (see Management of *Salix barrattiana* in Region 2 section). As it appears now, the occurrences within Region 2 are very near a Research Natural Area (RNA) but are not actually within its boundaries (USDA Forest Service 2000b, Armel personal communication 2004). Thus, users of the area in which the plant occurs are not legally obligated to abide by the more stringent RNA rules. This is unfortunate since one of the primary reasons for establishing the RNA was to protect rare species such as *S. barrattiana* (USDA Forest Service 2000b).

The competitive ability of *Salix barrattiana* against noxious weeds is not clearly defined. Willows are able to tolerate competition from many native species but the potential impact of aggressive alien species on *S. barrattiana* is not known. The spread of invasive plant species across lower elevations has been well documented for several decades (Sheley and Petroff 1999). More recently, several invasive weeds such as yellow toadflax (*Linaria vulgaris*), spotted knapweed (*Centaurea biebersteinii*, *C. maculosa*), and scentless chamomile (*Matricaria perforata*) have all been reported at or above the treeline on lands managed by Region 2 (Ray 2001). Small occurrences of spotted knapweed (*Centaurea maculosa*), musk thistle (*Carduus nutans*), Canada thistle (*Cirsium arvense*), timothy (*Phleum pratense*), and smooth brome (*Bromus inermis*) have been reported in the Line Creek Plateau RNA (Lesica 1993). High elevation sites can be likened to virtual islands, and this encroachment of high elevation sites may be particularly detrimental to the integrity of native communities that are likely to have evolved in isolation. In addition to using up available resources and potentially spreading far more rapidly than *S. barrattiana*, some aggressive weeds, including knapweeds, are allelopathic and additionally create an unfavorable edaphic environment for native species (Sheley and Petroff 1999, Inderjit 2005). Specifics of the weed species near the population in Region 2 are not known.

If the warming trend continues, global climate change is likely to eventually impact *Salix barrattiana*. Mountain ecosystems are likely to shift upslope, reducing habitat for many subalpine and alpine tundra species. Mountain treeline is predicted to rise by roughly 350 ft. for every degree Fahrenheit of warming (U.S. Environmental Protection Agency 1997). Over the last century precipitation has decreased by 5 to 10 percent in northwestern Wyoming and western Montana (U.S. Environmental Protection Agency 1997, U.S. Environmental Protection Agency 1998). Also over the same time period, the average temperature in Helena, Montana has increased by 1.3 °F, and over the next century, climate may change even more (U.S. Environmental Protection Agency 1997). For example, based on projections made by the Intergovernmental Panel on Climate Change and results from the United Kingdom's Hadley Centre climate model (HadCM2), by 2100 temperatures in Montana could increase by about 4 °F, with a range of 1 to 8 °F, in spring and summer and 5 °F, with a range of 2 to 10 °F, in fall and winter (U.S. Environmental Protection Agency 1997). Using the same HadCM2 model, yearly precipitation is estimated to increase slightly overall in both states, but summer precipitation may decline in Wyoming (U.S. Environmental Protection Agency 1997, U.S. Environmental Protection Agency 1998).

Predicting the impact of climate change on *Salix barrattiana* may be very complicated since both habitat and sex have been reported to influence a willow's response to temperature. In a 3-year gas exchange field study, male and female *S. arctica* individuals from dry and wet habitats were subjected to passively enhanced summer temperature using small open-top chambers (Jones et al. 1999). Elevated temperature enhanced development and growth of both male and female catkins, but the response of the leaves to elevated temperatures between habitats was more variable, particularly among male individuals (Jones et al. 1999).

Overall net assimilation was higher in the dry habitat than in the wet habitat, and higher in females than in males, although there also appeared to be some habitat-sex interactions (Jones et al. 1999). Although higher temperatures appeared beneficial to development and productivity, one deleterious consequence of the more rapid development of reproductive structures may be that they become out of synchrony with peaks in pollinator activity. This may result in a reduction of seed set and greater reliance on vegetative reproduction. The variability in response to temperature according to sex and habitat conditions indicates that results from studies on one population cannot be reliably extrapolated to another population. For example, a population of staminate individuals in Wyoming might have a significantly different response to climate change than a mixed gender population in a northern part of its range.

As well as threats associated either directly or indirectly with human activities, there are uncertainties that can only be addressed by increasing both the number and size of populations. This is particularly true for species like *Salix barrattiana* that have so few occurrences. These uncertainties, which are typically addressed in population viability analysis, include elements of environmental stochasticity, demographic stochasticity, genetic stochasticity, and natural catastrophes (Shaffer 1981; see Demography section).

Environmental stochasticity lies in random, unpredictable changes in weather patterns or in biotic members of the community (Frankel et al. 1995). Hydrological modification and variations in precipitation that reduce moisture availability are likely to directly threaten the survival of *Salix barrattiana*. Unusually high snowfall, which causes above-average scouring in the spring, is another example of an element of environmental stochasticity that may threaten *S. barrattiana* occurrences. Although many willow species are adapted to such disturbance, occurrences along rivers and streams may be vulnerable to usually high degrees of scouring (see Demography section). Variable populations of arthropods (i.e., pollinators, herbivores, granivores), rodents, and wildlife may impact populations either through decreasing reproduction, photosynthetic potential, and/or biomass (see Community ecology section).

In addition to natural variation, pesticide use can also influence pollinator abundance and may alter the composition of arthropod species (Bond 1995). Chemicals sprayed to control pests can inadvertently impact non-target arthropods, such as pollinators (Kevan 1975). For example, limited applications of Carbaryl (Sevin) insecticide are used to protect lodgepole and whitebark pine trees from mountain pine beetle infestation on the Shoshone National Forest (Metzger 2005). This insecticide has a low toxicity to mammals and birds but is highly toxic to honeybees (Cranshaw 1998). Because of pesticide use restrictions in national forests (Mezger 2005), the current level of threat from pesticide use at the Region 2 occurrence appears to be low.

Demographic stochasticity relates to the random variation in survival and fecundity of individuals within a fixed population. That is, demographic uncertainty refers to chance events independent of the environment that affect the reproductive success and survival of individuals. In very small populations, individuals have a proportionally more important influence on survival of the whole population. Few specific comments can be made on the influence of demographic stochasticity on *Salix barrattiana* because there is no information on the survival probability of individuals at any given life-stage, age, or size in any part of its range (see Demography section). *Salix barrattiana* seed germination is limited to the year it is produced, and there is no seed bank to replace a population that suffers a catastrophe. If the root system is severely disturbed, re-colonization depends upon wind-dispersed seed from off-site populations (see Reproductive biology and autecology and Demography sections). Therefore, clearly any event that causes mass extermination of mature plants (e.g., highway construction, disease) would be especially injurious to populations in isolated areas where there is no opportunity for recolonization by off-site wind-dispersed seed. For this reason, demographic stochasticities may be more formidable for the population in Region 2 if sexual reproduction does not occur. Clonal stands appear to be more vulnerable populations than those where sexual reproduction can also occur, but many clonal taxa are surprisingly successful (see Reproductive biology and autecology section).

Genetic stochasticity is associated with random changes in the genetic structure of populations, such as inbreeding and founder effects. The individuals in the Region 2 population may be genetically very similar if one genotype has dominated the clonal population (see Demography section). Even though the population is most likely very fit for the current environment, a lack of genetic diversity in the population may decrease its ability to adapt to environmental or biotic changes. Changes may arise at the local level, such as from invasive weed species or pest invasions, or at the global level as a consequence of climate change. However, there are some factors that may favor *Salix barrattiana* in this regard. Homogeneity of the population may be mitigated by heterozygosity of the individual(s) if *S. barrattiana* is polyploid (See Reproductive biology and autecology section). Polyploid individuals generally maintain higher levels of heterozygosity than their diploid progenitors and may have biochemical and ecological attributes that directly contribute to their success (Soltis and Soltis 2000).

The envirogram in **Figure 7** is constructed to outline some of the factors that directly impact *Salix barrattiana*. The paucity of studies on this species leads to stretching the significance of observations and forming opinions from inference rather than fact. Inferences must be tested and are inadequate for predicting responses to management decisions. Disturbance is included in the envirogram, but the types and levels that are actually deleterious to long-term sustainability need to be defined. Threats from disturbance can be of two types: direct impacts and subsequent effects attributable to the initial disturbance. Direct trampling by hikers, large mammals, and off-highway vehicle traffic can physically damage plants. Disturbance also contributes to soil erosion and opens areas to invasion by weed species that may eventually result in loss of habitat.

In summary, malentities and threats tend to be site-specific. The current level of threats to the population in Region 2 appears to be low, but the emphasis is on "current levels." Even if the intensity of a threat remains the same, an increase in its area of impact will have negative consequences. Although there is little on a local level that can be done to avoid the consequences of the threat of global warming, control of pressures that contribute to stress may to some extent mitigate the impacts at least in the short term.

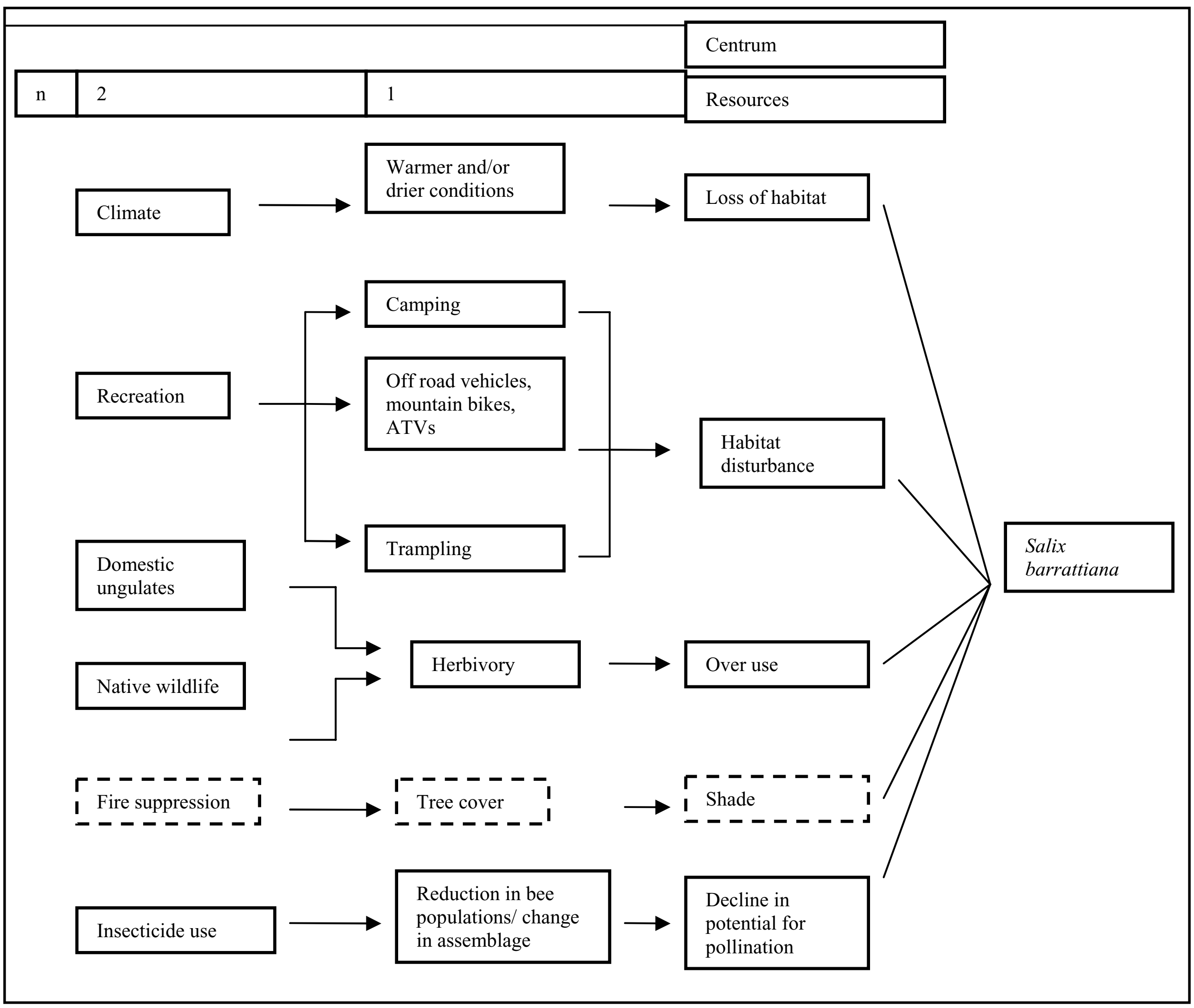

Figure 7. Envirogram outlining the malentities and threats to *Salix barrattiana*.

Management of Salix barrattiana in Region 2

Implications and potential conservation elements

The *Salix barrattiana* population on National Forest System land represents one of only two known populations in the continental United States. Existing management plans have not addressed this species, and there are no experimental data that indicate how this taxon will respond to management. Sustainability of *S. barrattiana* in Region 2 apparently relies on the underground root system, and thus management practices that increase either the frequency or intensity of natural perturbations on the soil, or provide additional stresses to the mature plants may have significant negative impacts on population viability.

The conservation value of the populations in the central Rocky Mountains may be very high, particularly if they contain genes that have been lost from the northern populations. It is most likely that the most geographically separated *Salix barrattiana* populations will have the greatest genetic divergence, and a significant loss of genetic diversity might result if populations at the edge of the range, or in obviously disjunct localities, are lost. Given the high degree of variability within *S. barrattiana* and the absence of genetic studies, there is also the possibility that the populations in Wyoming and Montana represent hybrid stands. Hybrid stands are considered to have a low conservation status (NatureServe 2005).

The Region 2 population extends onto land managed by USFS Region 1. There may be two or more sub-occurrences on Region 2 land (Dorn personal communication 2004). This concentration of individuals in one area increases the vulnerability of the species to environmental and genetic stochasticities and detrimental anthropogenic activities.

The Region 2 *Salix barrattiana* population would probably benefit from being within, rather than just outside, the boundaries of the Line Creek Plateau RNA (see Existing Regulatory Mechanisms, Management Plans, and Conservation Strategies section). Even so, the RNA documentation appears to assume that *S. barrattiana* is present within the current boundaries. The Line Creek Plateau RNA encompasses alpine tundra, a cirque basin, alpine lakes, and ponds, and it contains many unique plant species (USDA Forest Service 2000a, 2000b). The Shoshone National Forest in Region 2 and the Custer National Forest in Region 1 jointly administer this RNA. The primary objective of the Line Creek Plateau RNA is to "preserve and maintain in a natural condition the terrestrial and aquatic features of the site, along with the natural processes native to this ecosystem" (USDA Forest Service 2000b). Out of several alternative management options, Alternative 5, which was described as having potentially "no impact" on *S. barrattiana*, was selected as the preferred management direction in the RNA's Biological Evaluation (USDA Forest Service 2000b). This conclusion was reached primarily because no new ground-disturbing activities are permitted under this alternative. In addition, horse tethering/picketing and camping are prohibited within 200 ft. of surface water. This restriction reduces the potential for disturbance of areas where *S. barrattiana* populations might occur near water. RNA direction also does not encourage recreational use, and the existing levels of recreation are not anticipated to adversely impact any sensitive species (Biological Evaluation in USDA Forest Service 2000b). This RNA is, however, apparently popular for mountain biking, which will continue under current RNA management (Vandeman 2000). The current and future use of the area outside the RNA in the vicinity of the known population may change since the Shoshone National Forest is in the process of revising and updating its Land and Resource Management Plan (USDA Forest Service 2005).

Tools and practices

Detailed inventory and monitoring activities are needed for this species throughout its range and particularly on land managed by USFS Region 2. There appears to be a considerable amount of suitable habitat in the Rocky Mountains of Montana and northern Wyoming that has not been surveyed for the taxon; at least two factors suggest that *Salix barrattiana* stands might have been overlooked in the central Rocky Mountains. First, *Salix* species can be difficult to identify during most times of the year and, second, many non-targeted biological surveys actually limit identification of *Salix* stands to the genus level. *Salix arizonica* is a good example of how an ostensibly rare *Salix* taxon was found to be significantly more widespread than initially believed and was thus withdrawn from listing under the Endangered Species Act (U.S. Fish and Wildlife Service 1995). Confirmation that the *S. barrattiana* sub-occurrences found in the 1960s and 1970s are either extant or extirpated is essential to determine the status and potential stability of the current population.

Salix barrattiana was not included in the 2001 field guide for sensitive species produced for the

Shoshone National Forest (Houston et al. 2001). Sensitive species may be omitted for a variety of reasons, such as a concern for over-collection. Where possible *S. barrattiana* should be included because such handbooks are particularly useful for USFS personnel and contractors who are not necessarily botanists and need guidance in distinguishing sensitive taxa.

Bonham et al. (2001) have outlined inventory and monitoring protocols for sensitive plant species on public lands. It is very important that prior to initiating field-work the inventory and monitoring objectives are specified and methods for the statistical analyses of the data are planned. Written documentation of all facets of the effort is essential in order to assure continuity of the program during staff turnover.

Species inventory

The current field survey forms for endangered, threatened, or sensitive plant species used by the Wyoming Natural Diversity Database and the Montana Natural Heritage Program request the collection of data that are appropriate for inventory purposes (see References section for Internet addresses). The number of individuals and the area they occupy are important data for occurrence documentation. The easiest way to describe populations over a large area may be to count patches, making note of their extent, and to estimate or count the numbers of stems within patches. In dense patches where stem counts are not feasible, the area occupied and estimates of species heterogeneity are useful. In addition, even in dense patches canopies are seldom totally closed, and another measure of the density of *Salix barrattiana* cover can be estimated by defining an average gap distance (Bonham 1989). A statement like "many individuals" tends to be subjective. An estimation of the number of stems or the area occupied by a quantitative estimate of canopy cover is more serviceable when comparing data between years. Collecting information on the dates of flowering, the fraction of the population that is flowering or with fruit, and evidence of new shoots or seedlings is also valuable in assessing the vigor and fecundity of a population. Observations on habitat are also important to record. In the case of new occurrences, it is useful to collect a specimen and deposit it in a herbarium. However, it is not desirable to take specimens from small populations. The advisability of collecting a specimen needs to be considered on a site-specific as well as a species-specific basis. A close-up colored photograph and an additional photograph of the plant to show its habitat should always be taken in order to document the occurrence and status of the plants. Because of the similarities between this taxon and sympatric taxa, it is most desirable that surveys be carried out when the plant has mature leaves (Lesica 2002).

Habitat inventory

The paucity of occurrences that have been identified suggests that it is not feasible to make an inventory of areas that have the potential for colonization. Surveys need to be made to identify occupied habitat.

Population monitoring

Because *Salix barrattiana* is restricted to such a small area within Region 2, it is possible to map the patches thoroughly using GPS technology. The perimeter of patches could be walked using a GPS hand-held device, or patches could be recorded at one or several points on a point-specific co-ordinate basis. Changes to the population structure can then easily be monitored over time. No monitoring or demographic studies have been reported to date. Because some level of destructive sampling is usually necessary, a critical demographic study with PVA is not appropriate for small isolated populations such as those of *S. barrattiana* in Wyoming and Montana. However, simple methods using permanent plots and tagging individuals can determine the rate of population expansion, the longevity of shoots, and the frequency of aboveground shoot production. All of these parameters are very useful when describing a population and determining its status over subsequent time periods. As mentioned above, the density of the *S. barrattiana* cover can be estimated by defining an average gap distance in the canopy structure. A minimum gap distance below which the canopy is considered closed should be defined. This value should be determined according to the field observations on the vegetation and the questions being asked. It is important to state this value in the monitoring protocol to ensure consistency over subsequent years. Bonham (1989) suggested 2 cm, but it may be practical to assign a larger value. Some operators find using a larger gap value of 4 or 6 cm easier to estimate, and when reporting cover along a transect line, using smaller minimum gap distances can increase the time that it takes to record the data. It can be legitimately argued on both biological and ecological grounds that these considerations are inappropriate, but they are pertinent where time and financial considerations impact monitoring protocol decisions. Also monitoring protocols must be designed for multiple operators with varying levels of skill and experience.

Monitoring, in contrast to surveying for inventory, should be carried out during flowering (in the presence of catkins) so that sex allocation can be critically evaluated over several years (see Reproductive biology and autecology section). Use of permanent plots may induce errors associated with autocorrelation (Goldsmith 1991). Elzinga et al. (1998, 2001) and Goldsmith (1991) have discussed using a rectangular quadrant frame along transect lines to monitor spatially variable and clumped populations. In a *Salix* thicket that is sensitive to disturbance, a traditional quadrat-frame along a transect line or a line-intercept approach is likely to be inappropriate due to logistical reasons.

Establishing photo points and photoplots and taking appropriate photographs are helpful in describing site conditions. Photographs such as that in Dorn (1997) are particularly useful. Even though digital photographs are convenient and easy to store, many museums and researchers suggest storing additional slides or hardcopies because in 50 years time the technology to read memory sticks and CDs may no longer be available.

Habitat monitoring

Habitat monitoring in the presence of plant occurrences should be associated with population monitoring protocols. Descriptions of habitat are very useful to record during population monitoring activities in order to link environmental conditions with abundance over the long term. Soil characteristics, vegetation cover, associated species, canopy cover or lack or it, presence of arthropods, disease on all species including *Salix barrattiana*, and herbivory are all useful parameters to record on the field evaluation form (Frankel et al. 1991, Goldsmith 1991). Conditions several years prior to the onset of a decrease or increase in population size may be more important than conditions existing during the year that the change is observed. Current land use designation and evidence of land use activities are important to include with monitoring data. For example, where possible it should be noted whether populations are on an active grazing allotment and if evidence of livestock use can be observed. These two situations are not always associated. Similarly, knowing the proximity to such diverse elements as invasive plant species and campsites may be helpful in evaluating management alternatives.

Population or habitat management approaches

There have been no systematic monitoring programs for *Salix barrattiana* populations in protected areas, and therefore the benefits of protection cannot be evaluated. Similarly, there is no documentation to suggest that this taxon has been actively managed in any part of its range. Promising approaches to active management of *S. barrattiana* occurrences include controlling invasive plant species and minimizing disturbance. Elimination of invasive non-native plant species would appear to benefit *S. barrattiana* stands since non-native species are detrimental to most, if not all, native communities (Sheley and Petroff 1999).

Other approaches to increasing the number of occurrences may include restoring suitable habitat and establishing new occurrences of *Salix barrattiana*. Assurance that suitable habitat can be restored is limited by the fact that all of the critical factors that constitute potential habitat are not known. Restoration of many wetland and riparian areas involves re-establishing stands of *Salix*. Introduction of other *Salix* species into habitat occupied by *S. barrattiana* is not advisable since there is the potential for hybridization. For the same reason, one might consider reducing or eliminating other native *Salix* taxa in occupied habitat. However, if the community of mixed taxa appears to be natural, rather than the consequence of anthropogenic habitat modification, removal of native species is also likely to be inadvisable since the consequences are unknown and may affect the integrity of the functional community. Establishing new occurrences of *S. barrattianna* in unoccupied habitat may be a viable option, but introducing or translocating *S. barratiana* from other areas, thereby possibly representing other genotypes, into occupied habitat should be avoided. Local selection pressures can lead to increased fitness to local conditions that favor certain genotypes at the expense of others (Ellstrand and Roose 1987). Intentional translocation of populations from one part of a taxon's range to another can result in genetic homogenization of the gene pool, which is likely detrimental to the long term sustainability of a taxon (Olden et al. 2004). It is important to fully understand components of the genetic system and the ecology of a species before being confident of the outcome of transplanting or re-establishing populations (Young and Murray 2000).

Information Needs

- ❖ The discrepancies between the USFS Line Creek Plateau RNA boundary designation and the documented locations of *Salix barrattiana* need to be resolved in order to evaluate potential management decisions on the only known *S. barrattiana* population within Region 2.

- The current status of all known occurrences within Montana and Wyoming needs to be determined. The current status and extent of the sub-occurrences in the Shoshone National Forest of Region 2 need to be confirmed.

- The observation that the population in Region 2 is composed solely of staminate clones needs to be confirmed. Flowering is not necessarily annual, and sex allocation within a population is difficult to determine unless observations are made annually over several years.

- Additional targeted inventory is desirable. At the present time, *Salix barrattiana* is very rare in the continental United States. Additional land, especially on the Shoshone National Forest, the Custer National Forest, and in Glacier National Park, needs to be surveyed in order to confirm that there are actually only two populations in the central region of the Rocky Mountains. Many non-targeted biological surveys limit identification of *Salix* shrubs to the genus level, and there is the potential that *S. barrattiana* stands have been overlooked in the central Rocky Mountains.

- Population monitoring is needed to determine the sustainability of populations. Recording critical baseline data and then monitoring the sites are essential to understanding the implications of existing and new management practices. The spatial dynamics within populations are also unknown. The rate and mode of colonization and microhabitat preferences influence how populations can recover after significant disturbance. Given that flowering is not necessarily annual and sex allocation within a population is difficult to determine, it is prudent to detail specifically flowering behavior within a monitoring plan.

- The impact of human activities on the Region 2 population of *Salix barrattiana* needs to be determined in order to promote proactive steps towards threat mitigation.

- A comparison of the genetic composition of the populations in Montana and Wyoming to those in Canada and Alaska would clarify the conservation value of the populations in the continental United States. The possibility that the populations in Wyoming and Montana represent hybrid stands with lower conservation status or that they contain genes lost to northern populations possibly conferring higher conservation value needs to be explored.

- Knowing the genetic variability within *Salix barrattiana* would also permit evaluating the potential genetic losses associated with loss of individual populations. It would also indicate the appropriateness of re-establishing populations that are lost due to anthropogenic actions.

DEFINITIONS

Allelopathy – "the release into the environment by an organism of a chemical substance that acts as a germination or growth inhibitor to another organism" (Allaby 1992).

Allopolyploid – a polyploid formed from the union of genetically distinct chromosome sets (Allaby 1992).

Archean – rocks from the Archeozoic time that refers to the earlier part of Precambrian time (Bates and Jackson 1984).

Autocorrelation – the phenomenon whereby a change in one year will exert some influence on what happens in a successive year. For example, in a single quadrant on a transect line there are 10 individuals in year one. In year two, the number of individuals declined by eight to two individuals. In the third year, the number cannot decline by more than two individuals and is thus not completely independent of the change that occurred between years one and two. See Goldsmith (1991) for further discussion.

Binomial, trinomial – binomial is derived from the binary nomenclature system in which the name of a species consists of a generic name (genus) and a specific epithet (species); trinomial refers to infraspecific taxa, that is, varieties or subspecies. The authorship of the botanical names that have been proposed for *Salix barrattiana* Hooker are:

> *S. barrattiana* var. *angustifolia* Andersson *in* Salices Boreali-Americanae. A Synopsis of North American Willows. 1858
> *S. barrattiana* var. *latifolia* Andersson *in* Salices Boreali-Americanae. A Synopsis of North American Willows. 1858
> *S. barrattiana* var. *marcescens* Raup *in* Sargentia 6:157 1947
> *S. barrattiana* Rowlee *in* Bulletin of the Torrey Botanical Club. 34:157 1907
>
> See Systematics and synonymy section for additional information.

Catkin – a spike or spike-like, usually pendulous (but in the case of *Salix barrattiana* erect), inflorescence of unisexual flowers (Harrington and Durrell 1986).

Clone – "a group of genetically identical cells or individuals, derived from a common ancestor by asexual mitotic division" (Allaby 1992).

Gneiss – "a foliated rock formed by regional metamorphism" (Bates and Jackson 1984).

Granite – used broadly to describe "any holocrystalline quartz-bearing plutonic rock" (Bates and Jackson 1984).

Heterozygosity – "the presence of different alleles (forms of a given gene) at a particular gene locus" (Allaby 1992).

Introgression – the incorporation of genes from one species into the gene pool of another (Allaby 1992).

K-selected species – this terminology has been used to describe both plants and animals. K-selected organisms live in stable, persistent habitats, and their populations are typically very stable. An emphasis is on delayed reproduction and adult competitiveness.

Lanate – from the Latin word meaning "woolly."

Lichen – a type of composite organism that consists of a fungus and an alga or cyanobacterium living in a symbiotic association (Allaby 1992).

Mesic – having a moderate or well-balanced supply of water. Applied to describe an environment that is neither extremely wet (hydric) nor extremely dry (xeric) (Allaby 1992).

Metavolcanic – volcanic rocks that show evidence of having been subjected to metamorphism (Bates and Jackson 1984).

Metasedimentary – a sediment, or sedimentary rock, that shows evidence of having been subjected to metamorphism (Bates and Jackson 1984).

Polyphyletic – a taxon that has descended via different ancestral lineages (Allaby 1992).

Polyploid – “the condition in which an individual possesses one or more sets of homologous chromosomes in excess of the normal two sets found in diploid organisms” (Allaby 1992).

Ranks – NatureServe and the Heritage Programs Ranking system.

Critically Imperiled, G1, S1 “Critically imperiled globally [G] or in the state or province [S] “because of extreme rarity or because of some factor(s) making it especially vulnerable to extinction. Typically 5 or fewer occurrences or very few remaining individuals (<1,000) or acres (<2,000) or linear miles (<10).”

Apparently Secure, G4, S4 “Uncommon but not rare (as a G4 it may be rare in parts of its range, particularly on the periphery), “and usually widespread. Apparently not vulnerable in most of its range, but possibly cause for long-term concern. Typically more than 100 occurrences and more than 10,000 individuals.”

Secure, G5, S5 “Common, widespread, and abundant. Not vulnerable in most of its range. Typically with considerably more than 100 occurrences and more than 10,000 individuals.”

For further information see NatureServe Internet site: http://www.natureserve.org.

Section – in North America, the species in the genus *Salix* are divided into sub-genera, which in turn are divided into sections and sometimes further into sub-sections (Newsholme 2002).

Sericeous – from the Latin word meaning silky with long, straight close-pressed glossy hairs (Stearn 1998).

Solifluction – “the slow downslope movement of waterlogged soils …... Solifluction is generally more rapid than soil creep” (Bates and Jackson 1984).

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