ARIZONA GAME AND FISH DEPARTMENT
HERITAGE DATA MANAGEMENT SYSTEM

Plant Abstract **Element Code:** PDSAL020E0
Data Sensitivity: No

CLASSIFICATION, NOMENCLATURE, DESCRIPTION, RANGE

NAME: *Salix bebbiana*
COMMON NAME: Gray, Bebb's or Long-beaked Willow
SYNONYMS: *Salix rostrata*, *Salix starkeana* subsp. *bebbiana*
FAMILY: Salicaceae

AUTHOR, PLACE OF PUBLICATION: Sargent, Charles Sprague. Garden and Forest 8(404): 462. 1895. Annotation as "Bebbiana."

TYPE LOCALITY: New York, NY House

TYPE SPECIMEN: NYBG 284026 (Isotype). J. Richardson (#s.n.). July 20, 1827.

TAXONOMIC UNIQUENESS: The Arizona Flora (Kearney and Peebles 1951) lists 16 species of *Salix* that occur within the State.

DESCRIPTION: **Stems**: branches divaricate, sometimes ± brittle at base, yellow-brown to dark red-brown, not or weakly glaucous, pilose to glabrescent, peeled wood often with very dense striae, to 25 mm; branchlets yellow-green or red-brown, moderately to very densely villous to glabrescent. **Leaves**: stipules rudimentary or absent on early ones, apex acute, acuminate, or convex; petiole convex to flat adaxially, 2-5.5-13 mm, pubescent adaxially; largest medial blade narrowly oblong, narrowly elliptic, elliptic, oblanceolate, or obovate, 20-44-87 × 10-16-45 mm, base cuneate, convex, or rounded, margins flat, entire, crenate, or irregularly serrate, glands submarginal, apex acute, acuminate, or convex, abaxial surface glaucous, moderately densely pubescent or long-silky to glabrescent, hairs white or gray, wavy, adaxial finely impressed-reticulate, dull or slightly glossy, moderately densely pubescent, sparsely short-silky, or glabrescent, hairs white or gray; proximal blade margins entire, gland-dotted; juvenile blade yellowish green or reddish, pilose or sparsely to moderately densely tomentose or long-silky abaxially, hairs white. **Catkins**: staminate flowering just before leaves emerge, pistillate flowering as leaves emerge; staminate stout to globose, 10-42 × 7-16 mm, flowering branchlet 0.5-11 mm; pistillate loosely flowered, stout, slender, or subglobose, 16.5-85 × 9-32 mm, flowering branchlet 1-26 mm; floral bract tawny, 1.2-3.2 mm, apex rounded, abaxially hairy to glabrescent, hairs straight or wavy. **Staminate flowers**: adaxial nectary oblong or ovate, 0.3-0.8 mm; filaments distinct or connate less than 1/2 their lengths, glabrous or hairy on proximal 1/2; anthers yellow or purple turning yellow, ellipsoid or shortly cylindrical, 0.5-0.8 mm. **Pistillate flowers**: adaxial nectary oblong or square, 0.3-0.8 mm; ovary obclavate, beak slightly bulged below styles (long-beaked); ovules

6-16 per ovary; styles 0.1-0.4 mm; stigmas slenderly to broadly cylindrical. **Capsules** 5-9 mm. (Flora of North America 2015),

AIDS TO IDENTIFICATION: Bebb willow is a large native shrub ten feet tall or a small bushy tree fifteen to twenty-five feet. The leaves are elliptical to oblanceolate; one to three inches long, and are hairy when young, smooth and strongly veined when old. The fruit is a capsule, six to eight millimeters long, long beaked, and sparsely hairy. The bark is thin, reddish, olive-green, or gray tinged with red and slightly divided by shallow fissures. The roots are shallow and dense (EOL 2015).

The following key from Kearney and Peebles 1951 can be used to identify *S. bebbiana*:

- Petioles more than 3mm long or if shorter, then the larger leaves more than 7 mm wide, or closely serrate or serrulate.
- Margins of the leaves entire or obscurely serrulate.
- Leaves acutish to attenuate at base, white or whitish beneath.
- Capsules silky pubescent.
- Leaves not broadly obovate.
- Leaves not more than 4 times as long as wide, elliptic, oval, oblong-lanceolate, or narrowly obovate, rounded to acute at apex, the upper surface consistently pubescent…… *S. bebbiana*

ILLUSTRATIONS:
Photos: http://swbiodiversity.org/seinet/taxa/index.php?taxon=Salix%20bebbiana.
Photos, Line Drawings, Herbarium Mounts: http://eol.org/pages/584378/media.

TOTAL RANGE: Eurasia, throughout Canada and Alaska, and in the continental U.S. from Maine to Maryland in the NE U.S. and across the northern U.S. States from Pennsylvania, Ohio, Indiana, Illinois, Iowa, Nebraska, Wyoming, Idaho and Oregon, and the SW States Colorado and New Mexico to California.

RANGE WITHIN ARIZONA: North Rim of the Grand Canyon (Coconino Co.), Mogollon Rim from Flagstaff to McNary, Mount Baldy and Alpine (Coconino, Navajo, Apache, Gila, Graham and Greenlee Counties), and the Lukachukai Mountains (Apache County). These populations represent the southern-most extension of the species range (EOL 2015).

SPECIES BIOLOGY AND POPULATION TRENDS

GROWTH FORM: Usually a shrub in Arizona, to 15 feet (4.5m) tall.

PHENOLOGY: Flowering early April to late June (range-wide). Seed dispersal occurs from late June and early July at Fern Mt. in northern Arizona (G. Waring). Willow seeds have no dormancy and germinate within twelve to twenty-four hours after falling on moist ground (Dirr & Heuser 1987).

BIOLOGY: The ideal habitat for colonization by Bebb's willow is probably no different than that for most riparian species: ample water, and less than ample plant competition and limited herbivory. This was borne out by germination experiments at Fern Mountain, Arizona, which showed all three of these factors-open habitat, water and herbivory-to be highly important to seedling success (Waring 1991). Disturbances such as major flooding or fire serve to open up colonizable habitat for Bebb's willow, reducing competition for resources such as sunlight, space, water and nutrients. And Bebb's willow does establish readily in disturbed sites (e.g. roadway margins), although it also becomes established in sites that are open but not recently disturbed (Waring 1991). Such sites include dense knee-high CAREX and grass stands fed by seeps. The ability to establish in shaded areas seems unlikely. As with other willows, this species seems dependent on sun and considerable water for establishment. While Bebb's willow appears tolerant of drier conditions as a mature plant, there is no doubt that seedling recruitment requires ample water. This means that it can persist in habitats that become somewhat drier, but recruitment will cease to occur, such as at Fern Mountain.

While established plants are remarkably tolerant of herbivory, herbivory is probably contributing strongly to the low recruitment that characterizes this species in most populations. There is little information available on the terrestrial animal fauna, aside from large vertebrates, associated with Bebb's willow. Willows are known to support many animals. Through casual observation, numerous pollinating bees, flower-mining fly and lepidopteran larvae, and leaf galls were found on the Bebb's willows at Fern Mountain, Arizona. In general, established plants are remarkably free of herbivore attack except by large species such as elk and cattle (EOL 2015).

Atchley (1989) reported that plants in soil with higher silt and clay content tended to grow more than plants in soils with higher sand content. This may relate to the greater water-holding capacity of clays compared to sand.

While adult Bebb's willow can persist in seemingly dry sites, such as Fern Mountain, AZ (Waring 1991), there is no doubt that establishment of Bebb's willow seedlings is strongly dependent on ample water. This is borne out by recent experiments by Atchley (1989), Maschinski (1991), and Waring (1991), and observations of seedling distributions in western populations (Waring 1991). In a recent study, Waring (1991) determined that seeds placed in plots near established plants would not germinate without supplemented water.

SUCCESSIONAL STATUS: Bebb's willow seedlings colonize habitats that are newly disturbed, and habitats that have been previously colonized by species such as grasses, *Carex* and shrubs (Waring 1991). These patterns suggest that it may play an intermediate successional role in some plant communities.

In the western U.S., Bebb's willow recruitment was found to be occurring in several types of habitats: at seeps where the ground was wet, sunny, open and colonized by *Carex*; at open areas along streams; in wide floodplain sites and in wet disturbed sites, such as along

roadways (Waring 1991). These patterns suggest that disturbed sites, such as road margins, are readily colonized, and less disturbed sites, such as *Carex* stands, are also colonized. This latter may be possible as long as water and sunlight are adequate. Juvenile plants, as well as seedlings, were most commonly found at the seep sites. Current year seedlings only were found growing in cobble and sand bars along streams, suggesting that these sites are unstable due to increased seasonal water flows, or low level flooding. Saplings were found at a stream site in the White Mountains of AZ, at the stream edge and up to 30 m away, on the edge of the floodplain.

In an experiment conducted at the Fern Mountain site, it was determined that seedling germination and survivorship were greatest in plots that had been cleared of additional vegetation (Waring 1991). Intermediate levels of germination occurred in plots with intermediate levels of vegetation. From this it appears that disturbance is likely to enhance recruitment in Bebb's willow.

HERBIVORY: There is considerable evidence that herbivore pressure on established Bebb's willow can be intense.

More work is needed on the impact of herbivory on seedling establishment. However, an experiment at Fern Mountain, AZ, showed that herbivory had significant effects on Bebb's willow seedling survivorship (Waring 1991). Densities of seedlings were significantly higher in plots that were covered with cages that excluded vertebrate and invertebrate herbivores. High densities of grasshoppers, ants and snails were seen at this Fern Mountain site, as well as numerous elk tracks, indicating that many herbivores were present.

Heavy mortality of *Salix lasiolepis* seedlings due to grasshopper herbivory is known to occur in northern Arizona (Sacchi 1987). Herbivory by grasshoppers accounted for over 70% seedling mortality in some experimental plots and no mortality in others. Seedling mortality due to herbivory was variable between years and tended to be greater following dry winters. In another experiment, over 20% of seedlings in plots were grazed by grasshoppers, but only 1-2% died as a result. This study suggests that levels of seedling mortality from invertebrate herbivores can be high although extremely variable.

A survey survey of western Bebb's willow populations showed that seedling densities appeared to be lowest at sites that were heavily-grazed by cattle (Waring 1991). It has been suggested that intense grazing in Utah may limit Bebb's willow community growth because seedlings are unable to establish (Padgett et al. 1989).

Bebb willow is greatly favored by fire in most habitats. It will sprout rapidly from basal stems following disturbance. It has small, extremely light seeds capable of dispersing over long distances (EOL 2015).

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Fire, as a form of disturbance and nutrient recycling, can provide direct benefits to this species. It will create sites for recruitment and promote the persistence of older individuals, by altering successional processes (EOL 2015).

This species readily hybridizes with several other species of willow.

HABITAT: Riparian and upland conifer forests, wet lowland thickets, stream margins, lakeshores, dry south facing slopes, cienegas, seeps, and disturbed areas (Flora of North America 2015). In Arizona, in coniferous forests chiefly along streams (Kearney and Peebles 1951).

ELEVATION: Rangewide: 0 – 10825 feet (0-3300m), Flora of North America 2015. In Arizona, 8000-11000 feet (2440-3355m), Kearney and Peebles 1951.

EXPOSURE: Shade intolerant and grows best in full sunlight (EOL 2015)

SUBSTRATE: *Salix bebbiana* colonizes a variety of soils, including cobble, gravel, sand, loam, and clay and combinations of these . These soils are probably relatively nutritious, as willows tend to have high nutrient requirements (EOL 2015).

It is usually found on moist sandy or gravelly soils, but is adapted to a wide variety of soil textures. It will tolerate moderately alkaline soils' but does poorly in extremely acidic or alkaline conditions. The general pH range for willows is 5.5 to 7.5. Bebb willow can survive short periods of standing water, but growth rates decline sharply if water persists above the root collar. This willow is not drought tolerant. (EOL 2015).

PLANT COMMUNITY: In New Mexico and Arizona, *Salix bebbiana* occurs with alder (*Alnus tenuifolia*) and conifers, although it comprises up to 90% of the total tree density at some sites including Fern Mt., AZ, and Fenton Lake, NM (Szaro 1989). Willows are often replaced by alder and spruce at higher elevations and successionally in undisturbed habitats (EOL 2015).

POPULATION HISTORY AND TRENDS: Unknown for Arizona. While there are nearly 100 known collections (not including duplicates), the fact that the species is usually restricted to higher elevation riparian settings in Arizona and recruitment is questionable has earned *S. bebbiana* a listing as a Sensitive Species by the Forest Service and imperiled by NatureServe.

SPECIES PROTECTION AND CONSERVATION

ENDANGERED SPECIES ACT STATUS: None.
STATE STATUS: None.

OTHER STATUS: Forest Service Sensitive (USDA, FS Region 3 2013).
[Forest Service Sensitive (USDA FS Region 3 2007)]

MANAGEMENT FACTORS: Overall, many Bebb's willow populations in the west are dominated by old, over-mature plants with little evidence of recent recruitment. Three factors have been implicated experimentally in the reduced recruitment for this species (Waring 1991). They include (i) insufficient water availability, (ii) absence of disturbance, like fire, to open up space for seedling germination and establishment, and (iii) herbivory by cattle and large ungulates. Management to address these factors include hydrological restoration of the site, prescribed burns or mowing to open up germination space for seedlings, and removal of cattle or reduction in ungulate populations to permit seedling establishment.

Some of the specific threats that have been recognized for the species include:

WATER: A decline in water availability will limit recruitment in Bebb's willow populations. This may result from diversion of stream channels and channel downcutting (both resulting in water-table drawdown) and domestic use (diversion) of spring output (Avery 1991). The community at Fern Mountain, AZ, appears to have experienced a decline in water availability, possibly due to all of these factors (Avery 1991), and the structure of the Bebb's willow population was strongly skewed towards old individuals. This apparent decline in water availability probably relates to increased use of available water by an expanding nearby community and also to drought-like conditions in the area, especially during the last five years. The rarity of intermediate sized plants at this site suggests, however, that water has probably been limiting for an even longer period of time. Soils that were once wet enough to allow establishment of the existing population of adult plants are now too dry to support further seedling establishment.

However, a recent survey of soil moisture levels at over 20 Bebb's willow sites, suggests that water may not currently be a limiting factor at many sites (Waring 1991). The Fern Mountain site seems somewhat exceptional in this regard.

PATHOGENS: There are several pathogens associated with Bebb's willow. The most common foliage pathogen is the rust *Melampsora epitea* (Hepting 1971). This species attacks most other *Salix* species in the southwest (Yohem et al. 1985). It is conspicuous in the fall as bright yellow-orange powdery masses of urediospores on leaves. Its basidiospores are produced on fallen willow leaves in the spring. These attack conifers, which produce aeciospores that infest live willow leaves in the summer. Telia are produced on willow leaves in the fall. Infection can spread between willows and it appears that this pathogen can persist on willows without alternate coniferous hosts present (Sinclair et al. 1987). Coniferous hosts include *Pinus, Abies* and *Tsuga* (Hepting 1971).

Other pathogens known to be associated with Bebb's willow include *Phellinus punctatus*. This fungus is associated with canker rot in living hosts and apparently kills tissue in the stem of living plants (Walla 1984).

GRAZING: According to a recent geographical survey of Bebb's willow sites in the western U.S., ungrazed or lightly grazed sites had significant variation in the number of juvenile or sapling plants. However, this variation did not appear to be related to the intensity of grazing at the sites. In contrast, all heavily grazed sites had no saplings or juveniles (Waring 1991). These results suggest that heavy cattle grazing may prohibit regeneration but, at lower stocking rates, other factors may be responsible for reduced recruitment. Cattle can have the same juvenilizing effect on Bebb's willows that wild Alaskan herbivores do, as plants as old as 15 years and reaching only 0.25 m in height were found in a survey. Negative impacts of cattle grazing on recruitment in riparian ecosystems have been found elsewhere (Glinski 1977). Insect herbivores such as grasshoppers have been shown to devour large numbers of *Salix lasiolepis* seedlings (Sacchi 1987), indicating that small herbivores also pose a threat to seedling establishment in some willow species.

Restoration Potential:

The recovery potential for damaged or disturbed sites, including Fern Mountain, AZ, seems high. The factors that appear to be limiting recruitment appear to be few, straightforward and reconcilable. In essence, the amount of colonizable habitat in some Bebb's willow populations needs to be increased and grazing pressure needs to be reduced, at least long enough to enable seedlings and juveniles to outgrow susceptibility to grazing damage. Creation of colonizable habitat will require opening up land that has high soil moisture content and considerable sunlight. Fire may be one option for this. An alternative would be to divert enough water from an existing drainage to create new stream or seep habitat. Ultimately, creation of habitat colonizable by seedlings will be essential, as vegetative propagation of stems has been unsuccessful.

The situation at Fern Mountain is different from most sites in the West because there is currently no water in the existing drainage to divert. Hydrological studies should determine the basis for this situation and possibly some solution. Studies examining the potential for establishing seedlings in the small amount of moist soil available at Fern Mountain will determine if some level of recruitment is possible without supplementing water levels from another source. It may be that this site was colonized long ago during much wetter conditions and the existing lack of recruitment is an unavoidable consequence of drier times.

If new or augmented water supplies are needed, this may be accomplished by reduced groundwater pumping, eliminating development and use of spring water for domestic/agricultural purposes, construction of retention structures to reverse channel erosion problems and to slow down the removal of water from the site, and restore the natural drainage pattern by filling in ditches and diversions and reconstructing roads and trails.

PROTECTIVE MEASURES TAKEN: USDA Forest Service, both Coconino and Apache-Sitgreaves NF, identified the continuous existence of this species within these forests as "perilous" in 2007 and 2013. The species is listed as "Sensitive."

SUGGESTED PROJECTS:

In the mid-1980's, numerous studies were conducted on *S. bebbiana* at Fern Mountain in northern Arizona. Cattle were removed in 1984 from the Bebb's willow site and the perimeter was fenced, but only a small increase in recruitment was observed because most of the site was too dry to sustain germination and establishment (Waring 1991, Maschinski 1991). The Nature Conservancy worked with the U.S. Forest Service and academic scientists to restore the natural hydrology to the site (which had been greatly modified) in an attempt to increase water availability for the willows. Other research and monitoring programs included studies on seedling establishment and over-wintering survivorship, a geographic survey of Bebb's willow populations western states to determine population structure and site conditions (Museum of Northern Arizona), soil moisture monitoring, Bebb's willow germination response to several levels of light and soil moisture (The Arboretum at Flagstaff), Bebb's willow germination and short-term survival in a multifactorial field experiment examining water, plant competition (alleviation of it by manual clearing and fire) and herbivory (Museum of Northern Arizona), responses of adult Bebb's willow to fire at Fern Mountain (Coconino NF), the fire history of the Fern Mountain area (The Nature Conservancy), an assessment of xylem water potential status of Bebb's willow on a seasonal basis at Fern Mountain Ranch as a measure of seasonal patterns of water availability, (The Nature Conservancy), and the historic and current status of hydrological conditions at Fern Mountain Ranch (Dept. of Forestry, Northern Arizona University).

LAND MANAGEMENT/OWNERSHIP: Major land owners having significant populations of *S. bebbiana* include the USDA Forest Service (Kaibab, Coconino and Apache-Sitgreaves National Forests), USDI Bureau of Indian Affairs (White Mountain Apache and Navajo Nation), and the USDI National Park Service (Grand Canyon NP and Canyon de Chelly NM).

SOURCES OF FURTHER INFORMATION

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MAJOR KNOWLEDGEABLE INDIVIDUALS:

Gwendolyn Waring, PhD, Museum of Northern Arizona, Flagstaff.

ADDITIONAL INFORMATION: The wood of Bebb willow is medium hard, fine grained, lightweight, and brittle. Bebb willow is the most important producer of "diamond willow". This term applies to several species with diamond-shaped patterns on their trunks. When the stems are carved they result in a pattern of diamond-shaped cavities with a sharp contrast between the white sapwood and the reddish brown heartwood. Bebb willow is carved into canes, lamp posts, furniture, and candle holders. It was also formerly used for baseball bats, charcoal, and gunpowder. Native Americans used the flexible willow stems for baskets, arrow shafts, scoops, and fish traps. Willows provided medicine for many ailments such as cuts, indigestion, worms, and stomach complaints (EOL 2015).

Revised: 2015-11-13 (BDT)