Yellowstone Sand Verbena (Abronia ammophila): A Yellowstone Lake Endemic

Jennifer J. Whipple

Abstract

Yellowstone sand verbena, *Abronia ammophila* Greene, is restricted to stabilized sand sites that principally lie just above the maximum splash zone along the shoreline of Yellowstone Lake. A 1998 survey of the entire population found little more than 8,000 plants, most of which were seedlings. A summation of current knowledge regarding the life history of the species is presented, though many aspects still require further elucidation. Historical collections suggest that this species was more widely distributed around the lake in the early years after the park's establishment. The high level of human activity on the beaches, especially along the northern shoreline of the lake, may have resulted in the extirpation of the sand verbena from significant portions of its original range. The long-term survival of Yellowstone sand verbena is in doubt if the remaining sites are adversely affected. Strategies will be presented to help insure the continued survival of this unique endemic.

Introduction

Yellowstone National Park is known for the spectacular abundance of geysers and other geothermal phenomena and also as one of the premier places to see wildlife in the temperate zone. An overlooked and underappreciated component of the ecosystem on the Yellowstone Plateau is an endemic wildflower, Yellowstone sand verbena, *Abronia ammophila* Greene (Figure 1). According to park records, prior to this study the sand verbena was known to occur only along the northern shoreline of Yellowstone Lake. Yellowstone sand verbena is restricted to stabilized sandy sites that lie primarily just above the maximum splash zone along the shoreline of the lake.

Frank Tweedy in 1885 was the first Euroamerican to collect the sand verbena, at the mouth of Pelican Creek along the north shoreline of Yellowstone Lake. This specimen was originally identified as *Abronia villosa* (Tweedy 1886), a common purple-flowered species of the American southwest. Subsequently, Per Axel Rydberg looked at Tweedy's specimen and decided that the material from Yellowstone was sufficiently different to justify recognition as a unique species (Rydberg 1900) and named it *Abronia arenaria*. Archibald Menzies, though, had previously used this name for one of the maritime sand verbenas that occurs in sand dunes along the west coast of North America. E.L. Greene resolved the resulting problem by proposing the name *Abronia ammophila* (Greene 1900) for the Yellowstone species.

Figure 1. Abronia ammophila *in bloom.*

Treatments of the Yellowstone flora in the first half of the twentieth century continued to recognize the sand verbena as *A. ammophila* (Coulter and Nelson 1909; Conard 1928; McDougall and Baggley 1936, 1956). More recently, Yellowstone sand verbena was included within the widespread western species *A. fragrans* Nutt. ex Hook. by C. Leo Hitchcock and Arthur Cronquist in Vascular Plants of the Pacific Northwest (Hitchcock et al. 1964), which Despain then followed (Despain 1975). The monograph on *Abronia* by Galloway (Galloway 1975) reevaluated the Yellowstone material and resurrected *A. ammophila* as a unique species. Galloway included within his interpretation of *A. ammophila* material from Yellowstone National Park and also from sandy hills near Big Piney, Sublette County, Wyoming. Subsequent investigations have revealed that the specimens reported from Sublette County are now believed to be *A. mellifera* (Marriott 1993; Fertig et al. 1995; L.A. Galloway, personal communication). *A. ammophila* is now recognized to be a highly restricted endemic of Yellowstone National Park.

Even though Yellowstone sand verbena was described as an annual in the only recent monograph of the genus (Galloway 1975), the plants are clearly perennial, with a substantial taproot that can be more than 0.5 m in length in large individuals. The taproot is often vertically oriented and not highly branched. The prostrate plants are spread on the sand, rarely rising more than a couple of inches from the surface. Sticky glands are present everywhere on the plants except on

parts of the corolla, causing the plants to be covered in sand. The white flowers are in head-like arrangements of up to 20 separate flowers subtended by membranous bracts. During the bright sun of mid-day the flowers usually close, reopening again in the evening. Examination of the plants during the early 1990s revealed that flowering begins by the middle of June, and the plants continue blooming well into September until a killing frost occurs. The flowers may be sensitive to light levels, opening when light levels decrease, such as under heavy thunderclouds and in the evening, but the controlling mechanisms appear to be more complex since observations are confusing. Possible different hypotheses include responses to temperature or temperature change, wind speed, time of day, cloud cover, or a complex interaction of several factors.

Apparently the plants are pollinated by insects. Moths have been observed visiting flowers, but whether pollination is occurring is unknown. Observations of the plants revealed that fruits were first observed on 15 July in 1998. However, unlike many of its associated native species, *Abronia* continues to flower vigorously long after setting fruit. Seed set is sporadic, with many flowers not developing mature seeds. The flowers of several *Abronia* species do not appear to self-pollinate (Tillett 1967; L.A. Galloway, personal communication). Perhaps the extended blooming season for Yellowstone sand verbena is in part due to the very erratic presence of pollinators.

Seed dispersal may be facilitated by the sticky surface of the anthocarps. Some fruits accumulate in depressions in the sand where the wind has deposited them. The widely dispersed locations occupied by the sand verbena suggest that there is some effective method of seed dispersal, perhaps on the feet of gulls or waterfowl. Seed longevity in the seed bank is unknown.

One of the continual difficulties in determining the distribution of an unusual plant such as *A. ammophila* is the dilemma inherent in trying to determine the original distribution of the species. The most valuable records are old herbarium sheets that can be examined and found to be the species in question. Yellowstone National Park was the scene of a phenomenal amount of collecting during the last part of the nineteenth century as botanists flocked to see the new national park and the wonders that were being preserved. As a result, herbariums literally all over the world have material from Yellowstone National Park. The advent of the Worldwide Web and the efforts to make specimen data available in computer databases will eventually make it possible to search for *A. ammophila* specimens at many institutions. Meanwhile, locating specimens is difficult due to the time and expense involved with searching widespread collections.

The historical distribution of *A. ammophila* is uncertain, but clearly the species was more widely distributed in the past along the shoreline of Yellowstone Lake. Apparently, plants were present in the vicinity of the Fishing Bridge Museum in the 1920s. H.S. Conard made a collection of Yellowstone sand verbena on 23 June 1926 from “near Fishing Bridge Camp; Lake.” The Fishing Bridge campground was located at that time in the vicinity of what is now the current parking area near the Fishing Bridge Museum (Haynes 1928; Figure 2). Conard also mentions the habitat as being sandy dune. There are sandy dune

deposits stretching from near the outlet of the Yellowstone River to the mouth of Pelican Creek. Aven Nelson collected extensively in 1899 throughout Yellowstone National Park, including near the Lake Hotel on Yellowstone Lake. On 23 August, he collected Yellowstone sand verbena from "[o]n the sandy banks, near lake Hotel" (Nelson 1899). The closest extensive sand banks to the Lake Hotel would be the shoreline in the vicinity of the current Fishing Bridge development. Leo A. Galloway visited the west side of the mouth of Pelican Creek on 28 August 1968. In his field notes, he states that he was a quarter of a mile west of the mouth of Pelican Creek, where there were numerous small plants in the vicinity (L.A. Galloway, personal communication).

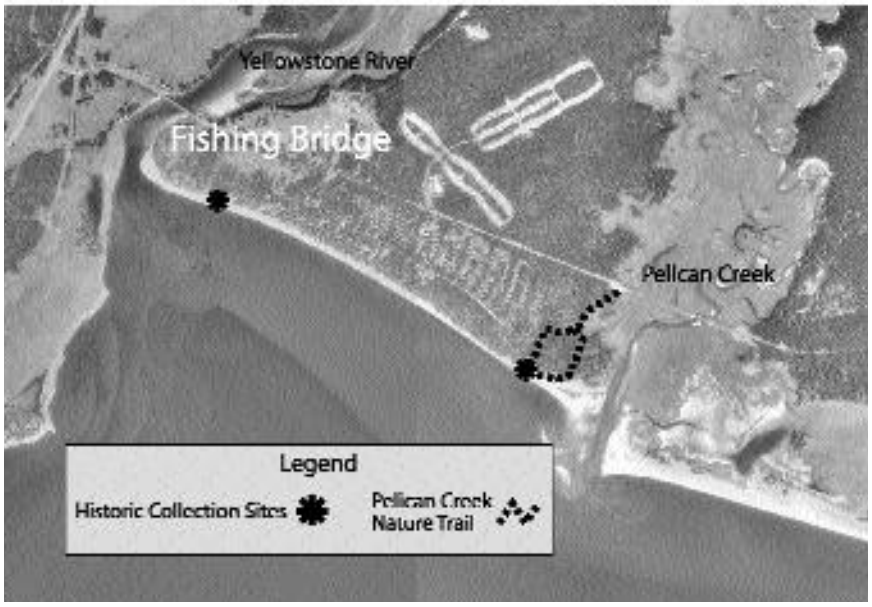

Figure 2. Map of known historical locations of Yellowstone sand verbena along the north shore of Yellowstone Lake.

Surveys during the early 1990s along the north shoreline of Yellowstone Lake revealed that there are no plants present from the mouth of Pelican Creek west to the outlet of the Yellowstone River. This area appears to represent good habitat for Yellowstone sand verbena, as documented by the historic collections of Nelson and Conard. Further east, Mary Bay may also at one time have supported a population of *A. ammophila*. No herbarium collections are known from this stretch of beach, but the habitat appears to be very similar to the occupied area from Storm Point to the east side of the mouth of Pelican Creek. Currently, the east entrance road is directly on top of the area that would be occupied by the sand verbena if it were present in the area. The construction of the road in the 1930s may have extirpated plants.

The Wyoming Natural Diversity Database maintains a list of plant species of

special concern for the state (Fertig and Beauvais 1999). *A. ammophila* is listed as a state endemic with a high conservation priority. The global and state ranks of the plant are G1/S1. This rank means that Yellowstone sand verbena is "critically imperiled," either because of "extreme rarity," which is defined as being known "from 5 or fewer extant occurrences or very few remaining individuals," or because "some factor of [the] species' life history makes it vulnerable to extinction" (Fertig and Beauvais 1999).

Yellowstone sand verbena was classified as a category 2 candidate for listing under the Endangered Species Act in the 30 September 1993 notice of review (U.S. Fish and Wildlife Service 1993). Category 2 includes those taxa for which information now in the possession of the U.S. Fish and Wildlife Service indicates that proposing to list as endangered or threatened is possibly appropriate, but for which sufficient data on biological vulnerability and threat are not currently available to support such a listing (U.S. Fish and Wildlife Service 1993). This category was eliminated by the U.S. Fish and Wildlife Service in 1996.

Yellowstone sand verbena does not have any official status under the Endangered Species Act at this time. Nonetheless, this endemic restricted to the shoreline of Yellowstone Lake certainly qualifies as a rare species that must be carefully managed. The limited distribution and relatively small number of plants increases the danger that the species could undergo a significant decline that could lead to its global imperilment, and necessitate its listing as either endangered or threatened under the Endangered Species Act.

With increasing evidence suggesting that at least part of the habitat had been adversely impacted, and the realization that *A. ammophila* was a highly restricted endemic within Yellowstone National Park, it became apparent that more information about the current status and distribution of the species was needed. A study was therefore initiated in 1998 to (1) survey all of the likely habitat along the shorelines of the major lakes within Yellowstone National Park for additional populations, (2) establish a permanent grid system at all known locations, and (3) count all individuals present.

Methods

Survey. Yellowstone Lake, as the site of the only known population, was the primary focus for the shoreline survey. All of the lake's 144 miles of shoreline, including Stevenson, Dot, Frank, and Peale islands, the two Molly Islands, and the unnamed island in the southwest corner of the South Arm, were systematically searched by foot, power boat, and canoe for *A. ammophila*. All locations where sand occurs were carefully investigated for the presence of sand verbena. The shorelines of Heart, Delusion, Duck, Riddle, Lewis, and Shoshone lakes were also searched by foot, canoe, or both. In total, 200 miles of shoreline were surveyed. Additional backcountry areas have been investigated opportunistically at scattered locations around Yellowstone Park.

The Shoshone Lake shoreline was surveyed by foot and canoe in July 1995. Yellowstone Lake and its islands, and Lewis, Delusion, Duck, and Riddle lakes were searched from mid-June to mid-September 1998. Several promising areas

of habitat on Yellowstone Lake were rechecked later in that summer, in case plants were late in emerging from the sand. The Heart Lake survey was conducted in August 1999. *Abronia*-occupied sites and areas of potential habitat were marked on U.S. Geological Survey 7.5-minute topographic quad maps. These sites were then mapped, using a Trimble Pro-XR global positioning system (GPS) unit that had meter to submeter accuracy with differential correction, and entered into the Yellowstone National Park Geographic Information System (GIS) database.

Census. Fieldwork for the census data was conducted during July and August 1998. A baseline of permanent points was established at all the sand verbena sites, with additional reference points placed outside of the baseline to aid in relocating the baseline if any points are lost through time (Whipple 1999). A list of all permanent reference points placed at the occupied sites, each point's UTM (Universal Transverse Mercator coordinate) as determined by GPS, bearings ahead (to the next point on the baseline), bearings to landmarks, and physical location description were documented. All permanent reference points were mapped using a Trimble Pro-XR GPS unit.

A grid of 1-m^2 cells was used to census the areas occupied by *Abronia.* A meter-tape was stretched between baseline points and a series of 1-m-wide rows perpendicular to the baseline was created with another meter-tape and string attached to survey stakes. A 1-m^2 quadrat was placed in a row and moved down a meter at a time, counting *Abronia* plants within each 1-m^2 plot. Each plot was denoted by its position in meters along the baseline and the number of meters north or south of the baseline. The position north or south of the baseline was denoted by letters. Areas between major groups of *Abronia* were subdivided into rows perpendicular to the baseline and several meters wide. The sections were searched and any isolated plants found were given a plot designation, using their distance along and from the baseline. The tape and string row boundaries were leapfrogged over each other so there were no gaps in coverage. Sites with only a few Yellowstone sand verbena plants were censused in a similar manner, though the orientation of the baseline could differ.

All rows and plots containing *Abronia* were photographed using 35-mm cameras with both color slide (Kodachrome 64) and black-and-white film. Horizontal format was used for individual plot photos and vertical format for rows. All photos were taken facing south, except that long rows were photographed from both the north and south ends. Photographs were taken from a position 1 to 2 m beyond the near edge of the subject plot or row, which was centered in the frame.

Yellowstone sand verbena plants were censused with four size/demography classes that were selected and defined on the basis of field observations. The classes are: recruit (<5 cm diameter, basal leaves only, no stem branching, no flowering); medium (<5 cm diameter, branching present, flowering or not); large (>5 cm but <30 cm diameter); and very large (>30 cm diameter).

Some of the larger plants have a mat-like morphology. Examination of *A. ammophila* exposed in a wave-cut slope found that stem branches can spread at least a decimeter in different directions from the top of the root, which may be

buried several decimeters deep in the sand. Since excavating most or all of a plant was not appropriate, determination of an individual was not always possible because impacts to the plants needed to be kept to a minimum. When determination of an individual was problematic, the most likely number of plants in a mat or clump was recorded followed by the maximum possible number, e.g., a plant that appeared to be one but could have been as many as three was recorded as 1(3). Final tallies therefore include a "most probable" total and a "maximum possible" total.

Plants were tallied in the plot in which they were rooted. Few plants fell directly on plot boundaries, but those that did were counted in the plot closest to the beginning (point 0) of the baseline. Dead plants were also tallied. A few *Abronia* were nearly dead and desiccated with a tiny amount of green tissue remaining; these were tallied as "dying."

Results

Survey. The field survey found three previously unknown *A. ammophila* sites on the shoreline of Yellowstone Lake: at Rock Point; at the unmarked fishing access near Pumice Point; and one isolated plant on the east shore of the South Arm of Yellowstone Lake (Figure 3). No *Abronia* was found on any of the islands in Yellowstone Lake or at any of the other large lakes. The four known Yellowstone sand verbena sites are all located on loose, unconsolidated sand with minimal fines, gravel, and organic matter. Three of the four sites are on beach sand, just outside the maximum wave zone. The exception is the Pumice Point site, which is located on black sand that is significantly above the current lake level. This sand may have weathered in situ from rhyolite, but probably represents a residual sand accumulation from a former lake level. Several of the occupied areas, notably Rock Point, Storm Point, and a small group on the north shore, occur in horseshoe-shaped, sandy depressions that are slightly bowl-like in cross-section.

A. ammophila is found as high as approximately 10 m elevation above the high-water line and as far inland as roughly 60 m, although it mostly occurs within 40 m of the shoreline. The species generally occurs above the high-water mark, but in the north shore site some plants were found on and below a sand slope cut by the unusually high water level of Yellowstone Lake of 1997. No plants were found in any location that appears to be regularly inundated.

Yellowstone sand verbena favors open, sunny sites with widely spaced vegetation. Common associates include *Phacelia hastata* Dougl. ex Lehm., *Rumex venosus* Pursh, *Polemonium pulcherrimum* Hook., and *Lupinus argenteus* Pursh. Other species that often occur in the vicinity include *Haplopappus macronema* Gray var. *linearis* (Rydb.) Dorn, *Aster integrifolius* Nutt., *Chaenactis douglasii* (Hook.) H. & A., and *Polygonum douglasii* Greene.

Census. In all, 8,326 *Abronia* plants (a maximum of 9,680, if some mats are greater than one plant) were found among all the sites. In addition, 41 dying and 68 dead plants were also counted. A total of 7,978 live plants (9,316 maximum) were found at the north shore site; 325 live plants (339 maximum) at the Rock

Figure 3. Map of Yellowstone Lake showing the location of all current Yellowstone sand verbena sites.

Point site; 22 plants (24 maximum) at the Pumice Point site; and one plant along the shore of the South Arm (Table 1).

The north shore population was 18% recruit size, 27% medium, 45% large, and 10% very large. Percentages are based on the "most probable" totals. The recruitment class made up a disproportionate share of most of the small, isolated subpopulations within the north shore population: 33% of the 166 plants near 400 m on the baseline, and 79% of the 82 plants near 575 m. Some of the seedlings seen were tiny, with only one or two leaves and less than 1 mm diameter. It is possible that the field personnel overlooked some seedlings and that the recruit class may have constituted a larger proportion of the north shore population than indicated.

Rock Point had the same percentage of plants in the recruit category, 18%, but the other size classes differed from the north shore site, with 49% of plants in the medium class, 29% in the large, and 3% in the very large. Many of the medium-

Table 1. Yellowstone sand verbena population count for all sites with the number of individuals followed by the maximum possible number if a large mat is composed of more than one individual. The four size classes are: recruit (<5 cm diameter, basal leaves only, no stem branching, no flowering); medium (<5 cm diameter, branching present, flowering or not); large (>5 cm but <30 cm diameter); and very large (>30 cm diameter).

	Recruit	Medium	Large	Very Large	Total
North Shore	1,448	2,183	3,573	774	7,978
		(2,287)	(4,329)	(1,252)	(9,316)
Rock Point	59	161	96	9	325
		(168)	(103)	(9)	(339)
Pumice Point	3	4	14	1	22
			(16)	(1)	(24)
South Arm	0	0	1	0	1
			(1)		(1)
Total	1,510	2,348	3,684	784	8,326
		(2,459)	(4,449)	(1,262)	(9,680)

sized Rock Point plants appeared later in the summer in an area that had been devoid of *Abronia* when first visited in June. The small number of plants at Pumice Point yielded 14% in the recruitment class, 18% in the medium, 64% in the large, and 5% in the very large. The lone plant along the shore of the South Arm was in the large size class.

In 1998, the total population of Yellowstone sand verbena was composed of 18% recruitment size, 28% medium, 44% large, and 9% very large. Percentages are based on the "most probable" totals. Fifteen percent of the north shore plants, mostly large and very large but also a few mediums, were recorded as possibly more than one plant. If "maximum possible" totals are used, the percentages in the large and very large size classes increase slightly and those in the recruit and medium classes decrease slightly. No assumption of age of the individuals can be made at this time, except for the recruitment class, which apparently were all first-year seedlings.

The north shore site had less than 1% dead or dying plants. No dead or dying plants were found at Pumice Point or the South Arm. Notably, the Rock Point site had 12% dead and 31% dying *Abronia,* apparently due at least in part to a herd of elk trampling the area.

Discussion

A casual survey of the north shore population in 1994 yielded a population estimate of approximately 1,000 individuals. At that time there were relatively few plants that were small, with most forming obvious mats, though no attempt was made to count different size classes. No young seedlings were observed. In contrast, by 1997 it was obvious that there were many more plants along the north shore, with young plants forming a conspicuous component. Apparently,

the conditions during the intervening time had been highly conducive for new plant establishment. The size classes of the plants censused in 1998 reflect the large recruitment event that had recently occurred. Most of the plants present in the early 1990s were apparently in the largest size class, which in 1998 numbered approximately 784 individuals, with a maximum of 1,252 individuals (Table 1). Since the census in 1998, the summers have been relatively dry, with drought conditions occurring during 2000 and 2001. The total number of extant sand verbena individuals can be presumed to have dropped significantly, and many of the plants in the recruit and medium size classes have probably died from water stress. Possibly, the number of plants present on the lakeshore at this time could more closely resemble the number present in the early 1990s than in the complete count of the population in 1998.

The restriction of the sand verbena at all sites to a zone of relatively open vegetation suggests that this species may not be capable of competing adequately in areas that are more highly vegetated. This tendency is obvious when one examines the distribution of plants around the lakeshore. Typically, the plants occur in a relatively constrained zone between the area influenced by wave action and the densely vegetated region inland. Some natural disturbance may be necessary to prevent the establishment of dense vegetation that would then preclude sand verbena.

The record high lake levels of 1996 and 1997 (Farnes 2000) eroded the southern edge of the stabilized sand along the north shore, washing out part of the occupied habitat. Perhaps dynamic changes in lake levels, such as occurred with these high levels and the correspondingly low levels observed in 2001, may be important to the persistence of the sand verbena since the increase in erosion and fluctuation in water level reopens or creates new habitat. Since the lake level has varied tremendously during the last several thousand years (Meyer and Locke 1986; Cannon, Pierce, and Crothers 1995), Yellowstone sand verbena must be capable of moving with the changing lake levels to be able to persist along the lakeshore. Global warming may cause a change in the climate of the Greater Yellowstone area, thereby affecting the lake levels in the future, so the plant's ability to respond to change will continue to be important.

Another component that affects *A. ammophila* is the presence of thermal activity in the immediate vicinity of some of the plants along the north shore. The largest subpopulation on the north shore is adjacent to a small thermal barren. The center of the thermal area is unvegetated, but a sandy mound to the northwest hosts the most dense concentration of Yellowstone sand verbena known to exist, as well as some of the largest individuals. Many of the plants in this area are on ground with a slight thermal influence. Most of the associated species drop out as the ground temperature becomes hotter, leading to an area where the sand verbenas dominate the vegetation. The possibility exists that the warmth associated with thermal sites along the lakeshore has enabled sand verbena to persist during periods when the climate was perhaps not as conducive for the survival of this species, or that the thermal habitat provided sites where sand verbena was at a competitive advantage over other species that thrive on cooler sand.

Elucidating questions about the evolution and current population biology of *A. ammophila* requires further investigation of many facets of the plants. The relationship of Yellowstone sand verbena to other sand verbenas is unknown. DNA analysis is needed to ascertain relationships among the sand verbenas of the northern Rockies. This information might clarify whether the sand verbena is a recent immigrant into the park, and thus closely related to other taxa or perhaps not actually distinct, or whether the sand verbena has been evolving in Yellowstone for an extended period of time.

Yellowstone sand verbena appears to have a relatively poor seed set (L.A. Galloway, personal communication). Investigation into who are the pollinators and what other constraints are affecting the pollination ecology of this species is needed. Corollary questions involving population dynamics that warrant further investigation include what conditions are advantageous to recruitment, the longevity of plants, and the presence and effects of herbivory.

In order to maintain a healthy population of Yellowstone sand verbena, the park must protect all known sites. The South Arm site and the Rock Point site are easily accessible only by boat and due to low levels of boating use on Yellowstone Lake do not need any special management attention at this time. There is the possibility that the single individual present at the South Arm site represents the lone survivor of a more extensive group of individuals that was washed out during the high lake levels of 1996 and 1997. The relatively dry summer weather in the succeeding years may be preventing new seedling establishment. An alternative hypothesis is that one individual grew from a single dispersed seed and is persisting, but due to a lack of pollinators there has been no viable seed production so the population is not increasing.

The Rock Point site, which prior to 1998 was unknown to the National Park Service, was perhaps first located by Loran C. Anderson, who visited Sand Point on 30 June 1958 and collected *Abronia ammophila* (Allyson Davis, collection manager, Intermountain Herbarium, personal communication). The information on specimen #1241 (UTC #95348) reads: “Frequent in moist sand of Sand point, southeast neck of the West Thumb of Yellowstone Lake, Yellowstone National Park.” There was no Yellowstone sand verbena at Sand Point in 1998, but it is possible that the collector was actually at Rock Point and only had available a park brochure or other map that didn’t include both names. An alternative hypothesis is that the sand verbena formerly did occur on Sand Point, since the area appears able to support the taxon but was flooded and eroded out during 1996 and 1997. Under the later scenario, Yellowstone sand verbena would be expected to eventually recolonize Sand Point if lake levels remain low.

The Pumice Point fishing access should continue to be left unmarked by signs in order to keep the visitation and use of the picnic tables at current levels. This subpopulation is currently declining, with only one plant visible in 2001, in contrast to 22 in 1998. The sand at this site is elevated above the shoreline, with rocky substrate preventing the roots of the plants from intercepting the water table associated with the lake level. The decline appears to be natural, caused by the drought conditions during the summers of 2000 and 2001. This site may be

ephemeral and an artifact of the wet years in the mid-1990s.

Currently, there is a low level of visitor use within the area occupied by the north shore population. It may become necessary to place signs at the east end of this site adjacent to Storm Point asking people to stay on the Storm Point trail. At this time there is no need to close the area as long as visitor use within the area stays low, though this action should be considered if use and corresponding plant loss increase on the east end of the occupied habitat on the north shore.

The lakeshore from the outlet of the Yellowstone River to the mouth of Pelican Creek was formerly occupied by *A. ammophila*. Due to the high levels of visitor use in the area near the Fishing Bridge development, it is not practical to attempt reintroduction in that area. As late as 1968, sand verbena was still present a quarter of a mile west of Pelican Creek in the vicinity of the Pelican Creek Nature Trail (L.A. Galloway, personal communication). The presence of this nature trail has probably contributed significantly to, if not caused, the extirpation of sand verbena from this portion of the shoreline. Since the closure of the Fishing Bridge Campground in 1989, there has presumably been a decrease in visitor use on the eastern portion of the beach away from the Fishing Bridge Visitor Center. If the Pelican Creek Nature Trail was removed, it is very likely that Yellowstone sand verbena might be able to re-establish near Pelican Creek. Without removal of the trail, the disturbance of the sand is expected to continue at a level that would preclude the possibility of natural reestablishment or successful reintroduction of sand verbena. Currently, the Pelican Creek Nature Trail is in need of some repair. Consideration should be given to removing or relocating the trail to another area that is less sensitive environmentally, rather than repairing it. Of the areas that were historically occupied by Yellowstone sand verbena, this is the only place where recolonization or reintroduction is likely to succeed, especially if the beach is closed to public access.

Yellowstone sand verbena has been extirpated from a significant portion of its original range along the shoreline of the lake due largely to human influences. The north shore site is the key to the survival of this Yellowstone endemic, as it is the location of 96% of the species' entire population. The presence of three additional sites is interesting, but doesn't change the reality that the continued survival of *A. ammophila* is coupled to the survival of the plants on the north shore.

Acknowledgments

First and foremost, the intrepid field crew of Pat Correy and Cheryl Decker did a marvelous job of the arduous task of counting all of the plants, and surveying the shorelines for additional sites, with occasional help from Freya Ross. Kevin Schneider and Shannon Savage utilized their expertise to produce the figures for the manuscript. In addition, I would like to thank Mary Hektner, Sue Consolo Murphy, and Roy Renkin for providing much constructive advice on the manuscript and encouraging me to persevere.

References

Cannon, K.P., K.L. Pierce, and G.M. Crothers. 1995. Caldera unrest, lake levels, and

archeology: the view from Yellowstone Lake. *Park Science* 15:3, 28–31.
Conard, H.S. 1928. Flora of Yellowstone National Park (tabulation). Unpublished report. (On file at Yellowstone National Park, Wyoming.)
Coulter, J.M., and A. Nelson. 1909. *New Manual of Botany of the Central Rocky Mountains (Vascular Plants).* New York: American Book Company.
Despain, D.G. 1975. *Field Key to the Flora of Yellowstone National Park.* Yellowstone National Park, Wyo.: Yellowstone Library and Museum Association.
Farnes, P.E. 2000. Effects of the 1988 Yellowstone fires on the 1997 Yellowstone River peak flow. Unpublished report. (On file at Yellowstone National Park, Wyoming.)
Fertig, W., and G. Beauvais. 1999. *Wyoming Plant and Animal Species of Special Concern.* Laramie, Wyo.: Wyoming Natural Diversity Database.
Fertig, W., C. Refsdal, and J. Whipple. 1995. *Wyoming Rare Plant Field Guide.* Cheyenne, Wyo.: Wyoming Rare Plant Technical Committee.
Galloway, L.A. 1975. Systematics of the North American desert species of *Abronia* and Tripterocalyx (Nyctaginaceae). *Brittonia* 27:4, 328–347.
Greene, E.L. 1900. Corrections in Nomenclature-III. *Pittonia* 4, 224–226.
Haynes, J.E. 1928. *Haynes New Guide and Motorist's Complete Road Log of Yellowstone National Park.* 39th ed. Yellowstone National Park, Wyo.: Haynes Picture Shops.
Hitchcock, D.L., A. Cronquist, M. Ownbey, and J.W. Thompson. 1964. *Vascular Plants of the Pacific Northwest. Part 2: Salicaceae to Saxifragaceae.* Seattle: University of Washington Press.
Marriot, H.J. 1993. Status report for *Abronia ammophila* (Tweedy's sand verbena), Sublette County, Wyoming. Unpublished report prepared for the Bureau of Land Management Rock Springs District by the Wyoming Public Lands Program of The Nature Conservancy.
McDougall, W.B., and H.A. Baggley. 1936. *Plants of Yellowstone National Park.* Washington, D.C.: U.S. Government Printing Office.
———. 1956. *The Plants of Yellowstone National Park.* 2nd ed. Yellowstone National Park, Wyoming: Yellowstone Library and Museum Association.
Meyer, G.A., and W.W. Locke. 1986. Origin and deformation of Holocene shoreline terraces, Yellowstone Lake, Wyoming. *Geology* 14, 699–702.
Nelson, A. 1899. Collection book, year 1899, nos. 6203–6943. Unpublished collection notes. (On file at Rocky Mountain Herbarium. Laramie, Wyoming.)
Rydberg, P.A. 1900. Catalogue of the flora of Montana and the Yellowstone National Park. *Memoirs of the New York Botanical Garden* 1.
Tillett, S.S. 1967. The maritime species of *Abronia* (Nyctaginaceae). *Brittonia* 19, 299–327.
Tweedy, F. 1886. *Flora of the Yellowstone National Park.* Washington, D.C.: Published by the author.
U.S. Fish and Wildlife Service. 1993. Plant taxa for listing as endangered or threatened species; notice of review. *Federal Register* 50 CFR Part 17 58(188), 51144-51190 (30 September).
Whipple, J. 1999. Survey and Assessment of Yellowstone (WY) sand verbena (*Abronia ammophila*) project #97-073-031 final report to National Fish and Wildlife Foundation. Unpublished report. (On file at Yellowstone National Park, Wyoming.)

Jennifer J. Whipple, National Park Service, P.O. Box 168, Yellowstone National Park, Wyoming 82190; Jennifer_Whipple@nps.gov

✧✧✧✧✧