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Blowout Penstemon (Penstemon haydenii) Endangered Species

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16. Abstract <p>The primary objective of the project was to create a viable population of blowout penstemon on Nebraska Department of Roads (NDOR) land that could be used to offset project impacts. University of Nebraska personnel propagated and grew seedlings in a greenhouse and transplanted them on the Bassett Northeast wetland bank site in Rock County, Nebraska that had been contoured by NDOR personnel. While the original plan called for planting 600 seedlings in 2006 and another 600 in 2007, timing made it possible to conduct a pilot study in which 600 transplants were added to the site in 2005. The pilot study provided valuable information on steepness of slope that allowed us to modify site preparation for the main experiment. Expected survival after one year, based on prior research, was 10 to 40%. Plant survival of 2006 seedlings after one year after transplanting was 81.5%. The 387 plants that flowered produced 1,027 flowering stalks, and 102 plants remained in the vegetative stage. In addition, 63 plants (10.5%) from the pilot study remained alive. Survival of the 2007 transplants will be determined in 2008. Data collected on population dynamics and flowering helped to further the scientific knowledge of the species. The plants established by this project will be important to help meet the goals outlined in the U.S. Fish and Wildlife Service's recovery plan for reclassification to threatened and eventual removal of blowout penstemon from the Endangered Species List. All of the objectives of the research were achieved.</p>			
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Project Title

Blowout Penstemon (*Penstemon haydenii*) Endangered Species

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Figure 1. Blowout penstemon (*Penstemon haydenii* S. Wats.)

Background

Prior to letting, all Nebraska Department of Roads (NDOR) road improvement projects are evaluated for presence and potential impacts to endangered or threatened species. Blowout penstemon (*Penstemon haydenii* S. Wats.) is listed as endangered in Nebraska by both state and federal agencies, and it is the only federally endangered plant species in Nebraska (Figure 1). If a NDOR project were to affect blowout penstemon, mitigation measures would be required to lessen the project's impact on the species. In the past, NDOR has been required to purchase land as mitigation for road projects when they affect other protected plant species. Addressing these issues involved in the mitigation process may cause the project to be delayed. NDOR owns the Bassett Northeast wetland bank site in Rock County, and a small parcel within this tract has been identified as suitable habitat for the introduction of blowout penstemon.

Literature Review

Description of the Nebraska Sandhills

The Sandhills region of Nebraska, the largest sand dune field in the Western hemisphere, occupies an area of about 5 million hectares (12 million acres), in north-central Nebraska (Smith, 1965; Ahlbrandt and Fryberger, 1980; Swinehart, 1990). The region stretches nearly 425 km along an east-west axis and up to 210 km in a north-south direction (Johnsgard, 1995) and contains nearly level areas and rolling hills with slopes exceeding 30% (Keech and Bentall, 1971).

The sandy soils (mixed, mesic Typic Ustipsamment) are characterized by low organic matter, low water-holding capacity, low natural fertility, and a high risk of wind erosion if soil is exposed (Elder, 1969; Keech and Bentall, 1971). Wind-blown sand has become arranged in the forms of hills and ridges whose forms and gradients of slopes vary with the age of the hill, the amount of sand, and influence of vegetative cover (Pool, 1914). Sand dune heights range up to nearly 140 meters (430 feet) above their intervening valleys and are as long as 40 kilometers (25 miles) (Swinehart, 1990; Johnsgard, 1995).

Precipitation in the Sandhills region varies from an average annual total of about 580 millimeters (23 inches) in the east to less than 430 millimeters (17 inches) in the extreme western portion, and variation from north to south is slight. Sandhills rainfall is greatest in spring and early summer, with 70% of the annual precipitation falling during the growing season. On average, surplus moisture occurs in late fall to early spring and a deficiency of moisture occurs during the summer months.

Average annual temperatures range from 9.4 °C (49 °F) in the east to about 8.9 °C (48 °F) in the west. The average winter temperature in the region is approximately 0 °C (32 °F). Prevailing winds are strong from the northwest in winter months and are less intense and more variable from the south in summer (Burzlaff, 1962; Swinehart, 1990; Wilhite and Hubbard, 1990). Wind is most important and constant climatic factor characteristic of dune regions, since sand dunes and the dune complex are commonly oriented in a definite pattern with reference to the force and direction of the wind (Keech and Bentall, 1974).

Wind erosion often results in areas of exposed sand and can be in the form of sand sheets or, more commonly, blowouts. Sand sheets are sand bodies without classified sand mounds (McKee, 1979). Low relief sand sheets comprise 7.3% of the Sandhills dune field and generally slope less than 3% (Swinehart, 1986). Blowouts were described by Pool (1914) as “round or more commonly irregularly conical depressions of varying depth and diameter, formed by the blowing of the sand and vegetation from certain areas on the upper slopes and crests of the hills and ridges.” One side of the blowout rim is typically lower than the opposite side because of the slope of the hill or ridge in which the blowout is formed (Stubbendieck et al., 1989). The prevailing northwest winds of winter and early spring can remove sand from sites disturbed by fire (presently uncommon), cattle trailing and concentration, or cultivation. As the sand erodes and is redeposited, existing vegetation in the immediate area can be destroyed by undercutting, sandblasting, or burial. This may result in a further spread of the blowout until the area is restabilized by vegetation during times with more favorable climatic conditions (Seevers et al., 1975). Improved range management practices and the control of wildfires have greatly reduced the number of blowouts. Blowouts range in size from a 10 meters² (108 feet²) to over 100 hectares (250 acres) (Keech and Bentall, 1971; Stubbendieck and Weedon, 1984). Blowouts represent a significant loss of forage production, but they provide ideal habitat for plants such as the endangered blowout penstemon (Weedon et al., 1982b; Flessner, 1988).

A major portion of the Sandhills is effectively protected from wind erosion by vegetation. Pool (1912, 1914) identified the bunchgrass association as most extensive and important climax community present in the Sandhills Prairie. The vegetation was dominated by little bluestem [*Schizachyrium scoparium* (Michx.) Nash] and sand bluestem (*Andropogon hallii* Hack.). Flessner (1988) discusses other important species in this association.

The blowout community contains plants especially tolerant of disturbance caused by wind erosion as blowout sand is excavated and wind-driven. Pool (1914) noted that blowoutgrass [*Redfieldia flexuosa* (Thurb.) Vasey] was typically the first pioneer plant in the reclamation of most of these “sandy craters,” aided by its “radially spreading network of wiry rhizomes and fine roots,” and by its “long, narrow, flexuous leaves” which enabled it to endure “longer periods of severe wind-whipping than any other similar plant of the region.” Other dominant species of the relatively young blowout community included lemon scurfpea [*Psoralidium lanceolatum* Pursh.] Rydb.] and prairie sandreed [*Calamovilfa longifolia* (Hook.) Scribn.]. Principal species in this community include sand muhly (*Muhlenbergia pungens* Thunb.), Indian ricegrass (*Stipa hymenoides* Roemer & J.A. Schultes). Sand lovegrass [*Eragrostis trichodes* (Nutt.) Wood], painted milkvetch [*Astragalus ceramicus* Sheldon var. *filifolius* (A. Gray) F.J Hermann], and blowout penstemon (Pool, 1914; Johnsgard, 1995).

Pioneering species of the blowout community cannot survive under the pressures of competing, successional species. As the establishment of the pioneer species aids the stabilization of the blowout, regular members of the bunchgrass association move into the area, through the natural process of succession. The disappearance of pioneer species leads to the eventual transformation from blowout community to the climax Sandhills Prairie. This transformation in plant composition is often so complete that the only indications of the former blowout condition are seen in the depression, which persists under the cover of the Sandhills vegetation (Pool, 1914).

History and Description of Blowout Penstemon

Blowout penstemon is an endangered plant species native to the Nebraska Sandhills (U.S. Fish and Wildlife Service, 1987). It has also been found in Wyoming. It is the rarest plant species native to the Great Plains region of the United States (Weedon et al., 1982b; Stubbendieck et al., 1997a).

Professor Ferdinand V. Hayden was the first to collect the a representative of this species while passing through Nebraska en route to Wyoming in 1857. The specimen was referred to then as sharp-leaf penstemon (*Penstemon acuminatus* Dougl. ex Lind.) and apparently was without flowers or fruit (Sutherland, 1988). In 1891, Gray Herbarium Curator Senero Watson named and described the species as *Penstemon haydeni* [sic], based on a specimen collected in Thomas County that same year by H.L. Webber (Watson, 1891). Watson had seen the Hayden collection and named the plant for its earliest collector. When Professor Francis W. Pennell, Philadelphia Academy of Sciences, could not locate the original Hayden specimen, he substituted the Webber specimen as the type collection (Pennell, 1920). Both specimens were eventually deposited at the Gray Herbarium at Harvard University. The specific epithet *haydeni* has since been modified to include an additional "i" so that it is etymologically correct (Sutherland, 1988).

Blowout penstemon is in the Scrophulariaceae, or beardtongue, family. The most recent morphological description of blowout penstemon published in the Flora of the Great Plains (Great Plains Flora Association, 1986) is as follows:

Penstemon haydenii S. Wats., Hayden's penstemon. Stout perennial herb; stems decumbent to ascending, (1.5)2-4.5 dm tall, glabrous, 1 to many from a subterranean caudex surmounting a deep taproot. Leaves entire, glabrous and somewhat glaucous, firm; basal and lower cauline leaves linear to linear-lanceolate, (2.5)5.5-11(13) cm long, 0.3-1 cm wide, acuminate to acute, sessile and clasping, upper cauline leaves linear to occasionally lanceolate, 6-11(12) cm long, 0.7-3 cm wide, acuminate with a long narrow tapering tip, sessile and clasping, the vegetative shoots with long linear leaves. Thyrses 6-16 cm long, with (4)6-10(12) verticillasters, very compact, cylindrical and not second, leafy-bracted, individual cymes with 4-6 fragrant flowers; 2-8 mm long; bracts longer than broad and very distinct from cauline leaves, the lower bracts tapering to a long narrow acuminate or caudate tip, bases cordate and broadly overlapping, concealing the peduncles and most pedicels. Calyx glabrous, lobes subequal, linear to linear-lanceolate, 8-13 mm long, 1-3 mm wide, acuminate, entire, herbaceous throughout or with scarious margins near the base; corolla 23-25 and externally, the throat 9-11 mm broad, well inflated and verrucose posteriorly, moderately ampliate, lined internally with magenta nectar guides anteriorly in mature unopened or freshly opened flowers, lobes of the upper lip arched-projecting, lobes of the lower lip projecting to spreading; staminode included, distally flattened, minutely bifurcate and slightly recurved, densely pubescent near the tip with golden-yellow hairs to 1 mm long; anther sacs 1.8-2 mm long, widely divergent, dehiscing the full length and across the connective, prominently papillose along the sutures; style glabrous. Capsule 13-16 mm long; seeds 2.5-4 mm long, discoid, light

brown to brown. (n=8) May-Jul. Endemic to dune blowouts in the Sandhills of NE; NE: Cherry, Garden, Hooker, Thomas.

Morphologically, *P. haydenii* is one of the most striking members of the sect. *Coerulei*, due to its compact cylindrical inflorescence with prominent long-acuminate bracts and its habit of forming large multistemmed clumps. The stems of *P. haydenii* root adventitiously, thus maintaining the plant in shifting sands of dune blowouts. The species is apparently unique in the *Coerulei* in that its flowers possess a distinctive fragrance.

Dr. Raymond J. Pool conducted an extensive study of the vegetation of the Sandhills and frequently mentioned blowout penstemon in his 1913 doctoral thesis. Pool listed it as a principal species in the composition of the blowout association. Pool categorized blowout penstemon as “not numerous but fairly constant” and as one of the “more common and typical species that became part of blow-outs” (Pool, 1913). Pool appears to be the first to refer to *Penstemon haydenii* S. Wats. in the literature as blowout penstemon, an indication of its restrictive habitat (Stubbendieck et al., 1997b).

Claude A. Barr made observations about the ecology of blowout penstemon (Barr, 1983). He described the species as “distinguished” and as the “most distinctive, intriguing, and beautiful of penstemon species,” as well as “delightfully fragrant.”

Sporadically collected in the first 25 years of the 20th century (Weedon et al. 1982c), blowout penstemon was consequently considered extinct by 1940, but was rediscovered in 1968 (Stubbendieck et al., 1983; Sutherland, 1988). Isolated populations have been located, but the populations occur in only a few counties.

Blowout penstemon begins spring growth in late March or early April from buds on the lower stems formed the previous year. Flowering shoots can be distinguished from vegetative shoots by the developing broad bracts of the inflorescence by early May. Plants bloom from late May through late June. Although uncommon, a few plants will occasionally bloom in August or September.

Beginning at the base of the inflorescence and proceeding upward, individual plants are typically in bloom for three to four weeks (Stubbendieck et al., 1997a). Most blowout penstemon plants bloom at two to three years of age, however, greenhouse transplants have been observed in bloom one year after planting (Flessner, 1988) and have also been observed in bloom in September of the same year they were planted (Lamphere, 1999). Not every plant blooms each year (Stubbendieck et al., 1997a). Plants may produce an abundance of basal vegetative growth through the end of the growing season.

Blowout penstemon flowers are typically cross-pollinated by many different insects, including bees, beetles, wasps, ants, and butterflies. Self-pollination does occur (Flessner and Stubbendieck, 1992).

While it varies from year to year, flowering plants have about three flowering stalks (Stubbendieck and Kottas, 2004). Each stalk has a thyrse with 4 to 14 verticillasters. Each verticillaster bears 2 to 16 capsules each containing about 16 seeds. Seed production per plant is about 3,000. Seed production counts are currently being conducted to obtain additional quantitative data.

Turning brown by late August, mature fruits split open in late August to September, and seeds fall to the ground throughout the fall and winter. While some insects, birds, and small mammals feed on the seeds, the rest are blown along the soil surface until they are covered with sand. The seeds have a protective, thick seed-coat (Stubbendieck et al., 1997a), although soil seed reserves have been found to be low (Stubbendieck et al., 1982a; Flessner, 1988). For natural seed germination to occur and for seedling roots to reach a depth where moisture is constantly available, blowout sand must remain damp for at least two weeks, conditions that do not occur every year. Seedlings are only occasionally common (Stubbendieck et al., 1997a).

No one reason has been determined for the blowout penstemon decline from being a relatively common plant in the early 1900s to an endangered plant at present. Blowout penstemon is adapted to a dynamic habitat that moves continually, but is an early successional species. These facts combine to cause plants to have a relatively short life span of about six to eight years (Stubbendieck et al., 1997b). Combined with the low natural seedling survival rates, this explains part of the problem with increases in the size of the natural population.

Loss of habitat because of suppressed wildfire events and improved range management practices, which, while beneficial to ranchers, has proved detrimental to blowout penstemon (Stubbendieck, 1982b). The Great Drought of the 1930s is the most conspicuous stressful event which occurred between the years of 1914 and 1940 (Weaver, 1954) and may have contributed to the severe reduction in plants (Stubbendieck, 1986). Blowout penstemon requires abundant soil moisture for germination, and moisture may not be adequate in some years for germination or survival. Extensive damage, of up to 75% of some populations, was caused by stem-boring larvae of a pyralid moth (Stubbendieck et al., 1997b), and other insect damage has been noted.

Most populations are physically isolated in a few sites and the probability of seeds migrating to other blowouts is small. These populations are also genetically isolated so the prospect for introduction of genetic material from one population to the next is unlikely (Stubbendieck et al., 1997a). Analysis of DNA has been used to reveal the genetic variation between blowout penstemon populations growing at different sites (Caha et al., 1996, 1998; Stubbendieck et al., 1997b). The small geographic range of existing plants is of concern since the possibility of localized droughts could severely impact entire populations.

The Nebraska Game and Parks commission listed blowout penstemon as an endangered species in 1986 under the authority of, and in compliance with, the Nongame and Endangered Species Conservation Act (Nebraska Game and Parks Commission, 1986). It was listed as endangered by the federal government in October of 1987 under the Endangered Species Act of 1973 (U.S. Fish and Wildlife Service, 1987).

U.S. Fish and Wildlife Service approved a recovery plan for blowout penstemon (Fritz et al., 1992). Studies involving life history, minimum viable population, population parameters, management criteria, propagation, seedling production, suitable planting sites, and transplanting procedures are important strategies in the recovery of the species. All known populations are monitored yearly and the search is ongoing for previously undiscovered sites (Stubbendieck and Kottas, 2005). A goal of the blowout penstemon recovery is to have a minimum of 10,000 plants total, distributed in five population centers,

so that the reclassification of the species from “endangered” to “threatened” can be made. If 15,000 total plants occur in ten population groups, the delisting process may be started (Fritz et al., 1992).

Blowout Penstemon Greenhouse Seedling Production

Since the early 1980s, studies have been conducted to identify seed preparation, germination, and propagation procedures needed for the recovery and reestablishment determined essential to the species’ survival (Stubbendieck et al., 1982a; Stubbendieck et al., 1983; Stubbendieck and Weedon, 1984; Flessner, 1988; Stubbendieck et al., 1993). Fruiting stalks are collected and air-dried. Seeds are removed and separated into heavy and light fractions in an air column (Figure 2). The heavy fraction is stored in sealed containers at 3 to 4 °C (40 °F) until it is used to establish plants in the greenhouse in November or December.

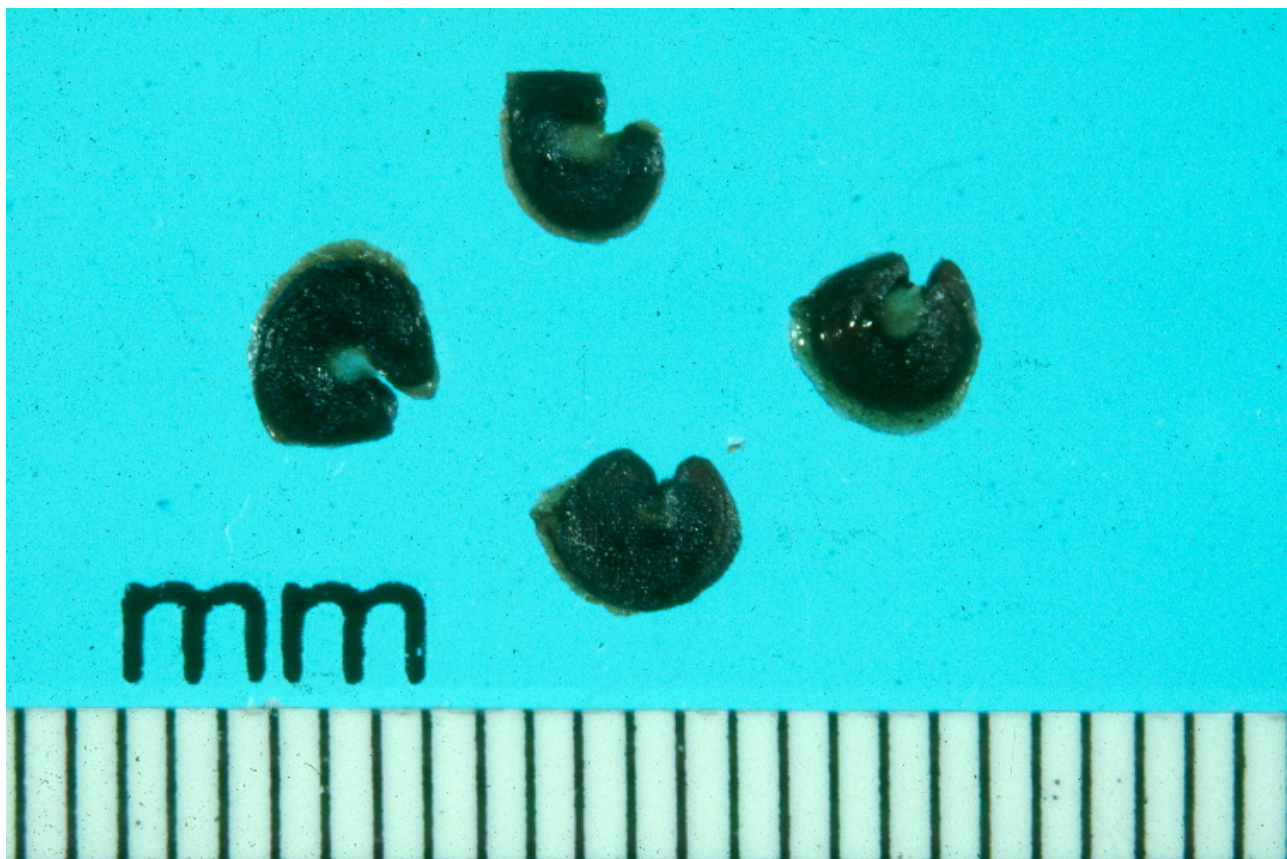


Figure 2. Blowout penstemon seeds.

The media used in greenhouse plantings is washed river sand pasteurized by steam [71 °C (160 °F) for 30 minutes]. Cone-Tainers®, or tubes, produced to grow tree seedlings, are used for blowout penstemon seedlings. Plastic filter material is placed over the holes in the bottom of the tubes, and they are filled with pasteurized sand to about 2 cm from the top. The filter material allows drainage while keeping the sand from flowing out of the tubes. A pH of 6.5 to 6.7 is attained by adding aluminum sulfate to the sand in the tubes before planting. Greenhouse temperatures are maintained between 20 °C (68 °F) and 30 °C (86 °F), and daylength is controlled at 14 to 16 hours with artificial light.

Blowout penstemon seeds have a hard seed coat which can be chemically scarified by soaking the seeds in concentrated sulfuric acid for 20 minutes. After removing the seeds from the acid bath, they are washed with flowing water for 15 minutes. The washing removes the acid and a potential chemical germination inhibitor (Stubbendieck, 1982b). This procedure improves seed germination from about 4% to nearly 90% (Flessner, 1988). Seeds are treated with the fungicide Vitamax® (carboxin) and placed between wet blotter papers in Petri dishes. The Petri dishes are placed in a germinator at 25 °C for about 24 hours before planting.

Six to eight seeds are dropped onto wetted media in each tube and covered with sand to a depth of about 6 millimeters (0.25 inches). The sand is wetted with a water mist. Each rack of 98 tubes is covered with clear plastic food wrap to prevent water loss. Seedlings begin to emerge within a week (Figure 3). The plastic wrap is removed when the seedlings grow tall enough to start to contact the wrap. Initially, lower temperatures in the greenhouse keep small seedlings from drying out and burning. For a few weeks, seedlings are watered with a fine mist so as not to dislodge the developing root system. At four to six weeks, the seedlings are thinned to one seedling per tube. Fertilizing the plants with a high phosphorus fertilizer once each week is helpful in maintaining good root growth. Clipping the seedlings at eight to ten weeks of age to leave three to four pairs of leaves may slow stem elongation and encourage root growth.



Figure 3. Blowout penstemon seedlings in the greenhouse.

Root rot can be a problem. Fungal infections of the genera *Rhizoctonia*, *Fusarium*, and *Alternaria* have been isolated from the base of diseased plants and seeds collected from the Sandhills. *Cercospora* has been found on the leaves and stems. Weekly, low dosage preventative treatments of ZeroTol® (mixture of hydrogen peroxide and peroxyacetic acid) may be used to treat these fungal diseases. ZeroTol® may also be used to reduce algal growth in the surface of the sand in the growing tubes which is exacerbated by weekly fertilization.

Blowout Penstemon Seedling Transplanting into Natural Habitat

Five- to six-month-old seedlings are transplanted into blowouts in the early spring as soon as danger of frost is past. Lowering temperatures in the greenhouse to approximate outside temperatures two weeks prior to planting can help reduce transplant shock. If seedlings are relatively large, clipping to reduce leaf area also can help to reduce transplant shock. The tubes should be watered before transplanting because damp sand will come out of the tubes more easily.

A dibble is used to create a hole in the sand that is slightly greater in diameter and as deep as the planting tube. Moist sand is most cooperative because dry sand will flow back into the hole. Seedlings are removed from the tubes by placing one hand on the top with the seedling positioned between two fingers, turning the tube upside down, and shaking the plant and soil out. If the plant and sand stick in the container, rolling the tube between your hands may help separate the sand from the sides of the container. A healthy root system will create a fine web throughout the sand and hold it together. After removal from the tube, the plant and sand are quickly turned right side up and dropped into the hole.

Research conducted each year from 1985 to 1988 was directed to transplantation and survival success in various plant communities within a blowout bowl. Seedlings were transplanted into either areas of bare soil (actively moving sand), blowoutgrass communities, annual plant communities, or Sandhills Prairie (stabilized areas where the plant community had advanced through succession to near climax condition). Transplants place in the blowoutgrass communities had the highest long-term survival rates (Stubbendieck et al., 1993).

Objectives

The objectives of this research were to 1) create a viable population of blowout penstemon plants on NDOR land that could be used to offset project impacts, 2) further the scientific knowledge of the propagation and life history of blowout penstemon for conservation purposes, and 3) increase the numbers of blowout penstemon plants to help meet the requirements of the U.S. Fish and Wildlife Service's recovery plan for reclassification to threatened, with the possibility for eventual delisting of this endangered species.

Methods

After consultation with Carol Wienhold and Art Thompson, the project was initiated to transplant 600 plants on the Bassett Northeast wetland bank site in Rock County in the spring of 2006 with an additional 600 transplants to be added in 2007. While the project was not scheduled to start until July 2005, we determined in February, 2005 that we would have an additional 600 plants that we could transplant in a pilot project on the site in May 2005. Nebraska Department of Roads personnel scraped the vegetation from a portion of the site and contoured the land to provide a transplant site (Figure 4). Six hundred greenhouse-grown seedlings (see the Literature Review for methods used to propagate seedlings) were transplanted (see the Literature Review for transplant methods) on the site in May.

Seedlings in the pilot study were monitored through 2005. A number of seedlings were lost because of water erosion. It became apparent that the slope was too great.



Figure 4. Shaping the transplant site.

In March 2006, Nebraska Department of Roads personnel shaped the 2006 and 2007 transplant sites. Based on what was learned from the pilot study, the slope was modified. Six hundred transplants were placed on the site in May, 2006, and an additional 600 plants were added in 2007 bringing the total number to 1,800 (Figure 5).



Figure 5. Transplanting seedlings on the research site.

Surviving seedlings were counted in the spring of 2006 and 2007. Data on numbers of flowering plants and flowering stalks were collected in the spring of 2006 and 2007.

Results and Discussion

In spite of an extended period without rain occurred following transplanting in the pilot study in May, about 55% of the plants remained alive in late July. Heavy rains in August and September caused severe erosion washing many plants out of the soil, and only 19.5% were viable in 2006. Seedling survival was 10.5% in 2007, two years after transplanting. Of the 63 surviving plants, 27 remained in the vegetative stage and 36 flowered producing 81 flowering stalks.

Plant survival of the 2006 transplants was 81.5% in 2007. The 489 plants were comprised of 102 in the vegetative stage and 387 in the flowering stage. The flowering plants produced 1,027 flowering stalks (Figure 6). The survival was much greater than the expected 10 to 40% achieved in previous research.



Figure 6. Blowout penstemon plants blooming on the research site.

The soil at the site was damp when the seedlings were transplanted in 2007, and additional precipitation occurred soon after transplanting. While survival of the 2007 transplants will not be determined until 2008, conditions have been favorable.

Long-term survival of the plants and propagation of new plants from seeds are difficult to predict. Wind erosion on native and other transplant sites in the Sandhills, is important in maintaining the open habitat required by blowout penstemon. Wind erosion is not occurring on the Bassett Northeast wetland bank site. Our greatest concern is that other plants will invade the habitat causing the decline of blowout penstemon.

Benefits

Cooperative research with the on-going blowout penstemon recovery project at the University of Nebraska-Lincoln has allowed NDOR to help further the body of knowledge on this endangered plant species. In addition, 552 plants have been established with an additional 600 transplants added in 2007. These plants add significantly to the total outlined in the U.S. Fish and Wildlife Service's recovery plan for reclassification to threatened and eventual delisting. The research provides NDOR with mitigation options if unavoidable impacts affect an existing blowout penstemon population. Furthermore, this research supported environmental stewardship initiatives with NDOR.

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