Large-Fruited Sand-Verbena
Abronia macrocarpa Galloway

5-Year Review:
Summary and Evaluation

Photograph by Dr. Paula Williamson

U.S. Fish and Wildlife Service
Austin Ecological Services Field Office
Austin, Texas

5-YEAR REVIEW
Large-Fruited Sand-Verbena / *Abronia macrocarpa* Galloway

1.0 GENERAL INFORMATION

1.1 Reviewers

Lead Regional Office: Southwest Regional Office, Region 2
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1.2 Methodology used to complete the review:

The public notice for this review was published in the *Federal Register* on April 23, 2007 (72 FR 20134). This review considers both new and previously existing information from Federal and State agencies, non-governmental organizations, academia, and the general public. Information used in the preparation of the review includes the Texas Parks and Wildlife Department (TPWD) Natural Diversity Database (NDD), final reports of Section 6-funded projects, monitoring reports, scientific publications, unpublished documents, personal communications from botanists familiar with the species, and Internet web sites. The 5-year review was prepared by personnel of Austin Ecological Services Field Office of the U.S. Fish and Wildlife Service (USFWS) without peer review.

1.3 Background:

Large-fruited sand-verbena was federally-listed as endangered without critical habitat on September 28, 1988 (53 FR 37975). The State of Texas listed the species as endangered on December 30, 1988.

The species' common name has been spelled with and without hyphenation. We have chosen to use hyphens, particularly to help clarify the unfortunate confusion between "sand-verbenas", which are members of the genus *Abronia* and family Nyctaginaceae, and "verbenas", which are members of the genus *Verbena* and family Verbenaceae. Sand-verbenas and verbenas are not closely related.

The first use of technical terms and words with arcane meanings in the lexicons of science and government are underlined, and are defined in the glossary on pages 37-40.

1.3.1 FR Notice citation announcing initiation of this review:

72 Federal Register 20134, April 23, 2007.

1.3.2 Listing history:

Original Listing
FR notice: 53 Federal Register 37975.
Date listed: September 28, 1988.
Entity listed: *Abronia macrocarpa* (large-fruited sand-verbena).
Classification: Endangered without Critical Habitat.

1.3.3 Associated rulemakings: None.

1.3.4. Review History:

No previous 5-year review has been conducted for this species. Other review documents include:

Status Report: Turner 1983.

Revised Status Report: Kennedy et al. 1990.

1.3.5 Species' Recovery Priority Number at start of 5-year review: 2.

The species' current Recovery Priority Number is 2, meaning that it is a full species with a high degree of threat and a high recovery potential.

1.3.6 Recovery Plan or Outline

Name of plan or outline: Large-fruited Sand-verbena (*Abronia macrocarpa*) Recovery Plan.
Date issued: September 30, 1992
Dates of previous revisions, if applicable: Not applicable.

2.0 REVIEW ANALYSIS

2.1 Application of the 1996 Distinct Population Segment (DPS) policy:

The Distinct Population Segment policy applies only to vertebrate animals.

2.2 Recovery Criteria

2.2.1 Does the species have a final, approved recovery plan? Yes.

2.2.1.1 Does the recovery plan contain objective, measurable criteria? Yes.

2.2.2 Adequacy of recovery criteria

2.2.2.1 Do the recovery criteria reflect the best available and most up-to date information on the biology of the species and its habitat? No.

The Recovery Plan was published in 1992, prior to the discovery of six of the nine populations now known. Additionally, four scientific investigations, completed between 1996 and 2008, have greatly increased our knowledge of the ecology and management of *Abronia macrocarpa*.

2.2.3 List the recovery criteria as they appear in the recovery plan, and discuss how each criterion has or has not been met, citing information:

Downlisting criterion: For downlisting from endangered to threatened status at least 20 healthy, stable populations with a minimum of 600 plants in each should be located or established. A healthy population would be considered to be one with a habitat area of at least 25 acres, demographically stable, and genetically viable. These populations should be distributed throughout the natural, potential geographic range of the species, as determined by recovery research activities.

Delisting criterion: *Abronia macrocarpa* could be considered for delisting when the 20 populations described above have maintained needed population structure and viability for at least 10 years. In addition, long-term agreements and management plans should be in place that will ensure their continued protection.

Williamson (2008 and pers. comm. 2010) and others have now documented nine wild populations of *A. macrocarpa* on private lands in Leon, Robertson, and Freestone counties, Texas, ranging from about 750 to 30,000 individuals each and from 1.1 to 12 hectares (ha) (2.7 to about 30 acres [ac]) in area (see Population Summary in Table 4 and map in Figure 2). Additionally, nine experimental reintroductions have so far established three small populations, and have led to improved reintroduction techniques (Goodson 2007; Williamson 2008). While all 9 wild populations surpass the minimum number criterion of 600 individuals, only 1 meets the minimum size criterion of 25 ac. The private landowners of the wild and experimental populations have cooperated with conservation efforts, but have not been willing to sign voluntary conservation agreements (Williamson 2002, 2008). Although the recovery criteria have not been fully achieved, this review documents significant progress over the last 18 years. New information indicates that the recovery criteria should be revised, and that full recovery is possible (see Section 2.4.).

The recovery plan includes the following outline of recovery actions. The actions that have been implemented are indicated with an asterisk (*) in the list and in italics (*recovery action xxx*) in the text of this review.

1. Protect *A. macrocarpa* populations from existing and future threats and develop management plans.
    11. Contact private landowners offering assistance and advice and enlist interested landowners in a cooperative program.
        111. Establish protected sites.
        112.* Work cooperatively with landowners to establish short-term management practices adequate to protect the species.
        113.* Develop and implement a long-term management plan for each site.
    12. Enforce applicable Federal and State laws and regulations.
    13.* Monitor populations for general condition, reproductive success, and to elucidate any needed revisions to the management plans.
    14.* Assess and revise management plans regularly to address species needs.
2. Maintain a reserve germ bank/cultivated population with a responsible agency/institution.
    21.* Include maximum genetic diversity.
    22. Establish a monitoring and management plan.
    23. Coordinate cultivation program with restoration research efforts, giving support, and incorporating results.
3. Initiate studies to gather information necessary for protective management and restoration.
    31.* Determine exact habitat requirements.
        311.* Geologic, edaphic (soil conditions), and microclimate profiles.
            3111.* Geology.
            3112.* Soils.
            3113. Microclimate.
        312.* Community structure.
        313.* Community dynamics/ecology.
            3131. Necessary natural phenomena.
            3132.* Seral stage.
            3133.* Response to disturbance, agricultural practices, and other land uses.
            3134.* Beneficial, neutral, and negative interactions with other species.
    32.* Study population biology.
        321.* Determine present conditions and determine stability requirements for populations.
            3211.* Assess present demographic conditions, evaluate needs to achieve stability, and develop recommendations for any needed augmentation.
            3212.* Assess present genetic viability, evaluate requirements for stability, and develop recommendations for augmentation.

322.* Characterize phenology and assess most vulnerable stages of the life cycle.
323.* Determine reproductive biology.
3231.* Determine types of reproduction and contribution to the population.
3232.* Investigate pollination biology.
3233.* Investigate seed production and dispersal.
3234.* Seedling recruitment.
33.* Study cultivation requirements.
331.* Seed biology.
332.* Germination requirements.
333.* Seedling biology.
334.* Investigate other propagation techniques.
4.* Search/inventory potential habitat.
41.* Search for existing populations.
42.* Search/inventory for potential restoration sites.
5.* Assess restoration feasibility.
51.* Examine reintroduction techniques available.
52.* Establish a pilot program.
53.* Assess feasibility of reintroduction program.
6.* Develop and implement a reintroduction plan, if feasible.
7.* Develop public concern and support for the preservation and study of *A. macrocarpa.*
8. Develop a post-recovery monitoring plan.

Recovery team:

Abronia macrocarpa does not have a recovery team.

Section 7 consultations:

Three formal section 7 consultations (21450-1996-F-0291, 21450-1997-F-0098, and 21450-1998-F-0762) have evaluated potential impacts to *A. macrocarpa*. In each case, the species was not found in the project area, and the biological opinions state that these projects would have no effect on the species.

Section 6 funded grants:

"The Cooperative Endangered Species Conservation Fund (section 6 of the ESA) provides grants to States and Territories to participate in a wide array of voluntary conservation projects for candidate, proposed, and listed species. The program provides funding to States and Territories for species and habitat conservation actions on non-Federal lands" (U.S. Fish and Wildlife Service 2009). The TPWD and the USFWS have supported three section 6 grants in Texas that address *A. macrocarpa* conservation and recovery, summarized in Table 1 (below).

Table 1. Section 6 grants involving large-fruited sand-verbena.

Job/Project/ Grant no.	Final Report Date	Principal investigator (citation)	Amount	Project title
Project 44, Grant E-3-1	Nov 30, 1996	Dr. Paula S. Williamson (Williamson 1996)	$52,100	Large-fruited sand-verbena monitoring and management study. September 1992 – August 1996.
Project WER41, Grant E-11	Nov 1, 2002	Dr. Paula S. Williamson (Williamson 2002)	$51,838	Large-fruited sand-verbena landowner technical assistance.
Grant E-58	Mar 27, 2008	Dr. Paula S. Williamson (Williamson 2008)	$86,454	Protection on Private Lands and Research for Recovery of Large-fruited Sand-verbena.

The objectives of Grant E-3-1 were: (1) protect the known populations from existing and future threats; (2) establish and maintain a genetically diverse germ bank and captive population; and (3) gather biological information necessary for protective management and restoration. Grant E-11 was a three-year project to assess *A. macrocarpa* population sizes and to protect existing populations from present and future threats through technical assistance to private landowners. Grant E-58 addressed three major recovery actions listed in the recovery plan: protect existing populations, search for new populations, and develop plans for reintroduction into suitable habitat. The information gathered and results of these section 6-funded projects are discussed in Section 2.3.

Additionally, section 6 grant no. E-1 (Project WER71) contributed to the creation of Rare Plants of Texas (Poole et al. 2007), an invaluable compilation of data on 232 rare, threatened, and endangered plants of Texas, including *A. macrocarpa*.

Contracts and Cooperative Agreements:

USFWS has supported two cooperative agreements that involved *A. macrocarpa*, listed in Table 2, below.

Table 2. Contracts and cooperative agreements involving large-fruited sand-verbena.

Agreement No.	Final Report Date	Principal Investigator (citation).	Project Title / Performance Period
14-16-0002-86-931	Sep 8, 1989	Helen Ballew (Ballew 1989).	Landowner contact report on endangered plant sites.
14-16-0002-91-284 as amended	Jun 29, 1998.	Dr. Paula S. Williamson (Williamson 1998).	Response to disturbance by large-fruited sand-verbena (*Abronia macrocarpa*). FY93-FY96.

Agreement number 14-16-0002-91-284 supported a three-year investigation of the response of *A. macrocarpa* to habitat disturbance caused by the development of a petroleum well in August 1992. This study included a comparison of disturbed and undisturbed habitat, and a list of associated species. The results of this project are discussed in Section 2.3. Additionally, in 1998 the National Fish and Wildlife Foundation (NFWF) awarded grant number 98-084-006 to USFWS to determine specific threats to populations of *A. macrocarpa*, provide technical assistance to landowners, and establish and implement management plans. However, our records indicate NFWF received no invoices related to this grant; we assume this project was never done, although the reasons are no longer evident.

2.3 Updated Information and Current Species Status

2.3.1 Biology and Habitat

2.3.1.1 New information on the species' biology and life history:

Abronia macrocarpa is an edaphic endemic found in Leon, Robertson, and Freestone counties, in the post oak savanna region of eastern Texas. The 9 documented wild populations occur no more than 80 kilometers (km) (50 miles [mi]) apart, where acidic, relatively infertile sandy soils of the Arenosa, Silstead-Padina, Pickton, and Wolfpen series lie 79 to 127 centimeters (cm) (31 to 50 inches [in]) deep over sandy clay loam (Kennedy, et al. 1990; Williamson 1996, 2002). These soils derive from the Eocene geological formations known as the Carrizo Sand, Sparta Sand, and Queen City Sand (U.S.D.A. 1989; Stoeser, et al. 2005). Corlies (1991) determined that the soil composition of 2 sites in Leon and Freestone counties ranged from 90.4 percent to 92.8 percent sand, 4.2 percent to 6.2 percent clay, and 3.0 percent to 3.4 percent silt. (*Recovery actions 3111, 3112*).

Williamson (1998) observed that *A. macrocarpa* seeds in the field have the highest germination rates in the fall and winter, while no seeds germinated from May to September. Laboratory studies revealed that the highest seed germination rates require scarification followed by warm and then cold stratification (Goodson 2007; Williamson 2008). Initial seedling growth is allocated primarily to development of the taproot rather than leaves and flowers (Williamson 1996). The seedling mortality rate ranged from 73 percent to 93 percent after 3 years (Williamson 1998). *Abronia macrocarpa* plants usually form rosettes from October through February, then begin flowering with the peak of anthesis and fruit set in April and May, followed by senescence of the above-ground portion from mid-May or June until October (Williamson 1996). However, the species occasionally flowers in the fall (Kennedy et al., 1990; Corlies 1991; U.S. Fish and Wildlife Service 1992). During the summer months, the plants perenniate as taproots found at depths of 1 to 12 cm (0.4 to 4.7 in) (Williamson 1996). Williamson (1998) found that 53 percent of 1 cohort of seedlings was flowering at

2 years of age, and 78 percent of another cohort flowered at 3 years of age. (*Recovery actions 3234, 331, 332, 333, 322*).

The inflorescence is a capitulum of 25 to 35 flowers (Figure 1) that open centripetally over 7 to 8 days (Corlies 1991). The flowers open from 3:00 or 4:00 pm until 9:00 or 10:00 am, and have a strong sweet aroma resembling honeysuckle that increases until early evening (Williamson et al. 1994); these are typical characteristics of moth-pollinated flowers. Williamson et al. (1994) observed, captured, and identified several species of crepuscular and nocturnal moths visiting *A. macrocarpa* flowers, including the Sphynx moths (family Sphingoidea) *Dolba hyloeus* (black alder or pawpaw sphynx), *Deidamia inscripta* (lettered sphynx), and *Erinnyis obscura* (obscure sphynx), in addition to the noctuid moth (family Noctuidae) *Hypsoroph monilis* (large necklace moth). The probosci of these moths were dusted with *A. macrocarpa* pollen, hence they are likely pollinators. The larval food sources for these moth species include *Ilex decidua* (Yaupon), *Vitis* spp. (grape), and *Asclepias* spp. (milkweed), which are all found at known *A. macrocarpa* sites. Among the diurnal floral visitors, some incidental pollination may be due to bees (genus *Bombus* and *Apis*) (Williamson et al. 1994). (*Recovery action 3232*).

Corlies (1991) reported pollen viability of 91.6 percent (standard deviation 6.9 percent) for greenhouse-grown *A. macrocarpa*. Williamson (2002) found that pollen viability of 7 wild populations ranged from 84 percent to 98 percent. Using a stain, Corlies determined that stigmas were probably most receptive to pollen on the first day, and progressively less on the second and third days, while the anthers dehisced on the second day. Floral morphology does not prevent self-pollination, yet the species is obligately xenogamous, requiring sexual fertilization between different, unrelated individuals (Corlies 1991, Williamson et al. 1994). Williamson and Bazeer (1997) found that pollen from self- and cross-pollinated flowers adhered to stigmas and germinated, forming pollen tubes in both cases. However, the growth of self-pollinated tubes was soon arrested at the stigma surface by the formation of callose deposits and did not penetrate the stigma. The out-crossed pollen tubes grew through the style and reached the ovule in 48 to 72 hours. Therefore, self-incompatibility in *A. macrocarpa* is due to a pre-fertilization barrier, and is likely to be sporophytic. (*Recovery actions 3232*, *3231*).

The characteristic fruit of the genus *Abronia* and other members of the tribe Mirabileae of the Nyctaginaceae is an achene, born within an anthocarp (Galloway 1975; see Figure 1c). Interestingly, the unpollinated flowers of *Abronia* inflorescences, including those of *A. macrocarpa*, will develop anthocarps if even one or two flowers of the same inflorescence are pollinated, but the anthocarps of the unpollinated flowers do not develop achenes (Galloway 1975, Corlies 1991, Williamson et al. 1994). The peduncles of successfully-pollinated inflorescences turn pink and bend downward 180°, while the peduncles of unpollinated inflorescences turn brown and bend only 90°; the anthocarps mature in about 3 weeks (Corlies 1991). The proportion of field-collected anthocarps that contained mature achenes in three different studies was 28 percent (Corlies 1991), 66 percent (Williamson et al. 1994), and 43 to 81 percent (Williamson 2002). Seed viability of field-collected achenes was 26 to 28 percent (Corlies 1991), 95 percent (Williamson et al. 1994), and 65 to 95 percent (Williamson 2002). (*Recovery action 3233*).

Although *A. macrocarpa* anthocarps are wind-dispersed, the majority fall within 30 cm (11.8 in) of the parent plant; this may explain in part the species' "clumped-contagious" spatial distribution in occupied habitats (Williamson 1998). "Clumped-contagious" distribution means that the presence of one individual indicates a high probability that there are others nearby. (*Recovery action 3233*).

Figure 1. Photographic images of large-fruited sand-verbena.

1. Seedling.
2. Flowering.
3. Left: Individual flower.
   Middle: Anthocarp.
   Right: Achene.
4. Habitat.

2.3.1.2 Abundance, population trends (e.g. increasing, decreasing, stable), demographic features (e.g., age structure, sex ratio, family size, birth rate, age at mortality, mortality rate, etc.), or demographic trends:

When the recovery plan (U.S. Fish and Wildlife Service 1992) was published, only three populations of *A. macrocarpa* were known from privately-owned land in Leon, Robertson, and Freestone counties. The Revised Status Report (Kennedy et al., 1990) indicates that no additional populations were found during surveys of 68 sites in 25 Texas counties (Anderson, Angelina, Atascosa, Bexar, Burleson, Caldwell, Colorado, Franklin, Freestone, Guadalupe, Hardin, Henderson, Leon, Medina, Nacagdoches, Newton, Robertson, Rusk, San Augustine, Shelby, Smith, Tyler, Upshur, Van Zandt, and Wood). Sixteen species of *Abronia* have been documented in Mexico, but not *A. macrocarpa* (Comisión Nacional para el Conocimiento y Uso de la Biodiversidad 2010).

Two section 6-funded projects (Williamson 1996, 2008) included surveys for new populations in Leon, Robertson, Freestone, and Caldwell counties, Texas. Jim Yantis (TPWD) and others have also conducted surveys for the species. Nine populations have now been documented in Leon, Robertson, and Freestone counties (Williamson 2008; Williamson, pers. comm. 2010). These nine include one each in Leon and Robertson counties that were both combined from two previously-recognized populations, based on genetic analyses and field surveys (Williamson 2002). All known populations are on privately-owned lands that were surveyed with landowner permissions. In addition, three small experimental populations have been successfully established on private land. The total known population has increased from about 35,250 in 1996 to 94,509 in 2008. This increase is due both to the discovery of new populations, and to growth of the known populations resulting from land use changes that are more favorable to conservation of the species (Williamson 1996, 2008) (see Section 2.3.1.6). (*Recovery action 41*).

The TPWD manages the State's NDD, which compiles data on tracked plant and animal species that is submitted by a vast consortium of Federal, State, academic, and non-governmental organizations (NGOs), private researchers, and consultants. The NDD tracks 232 rare, threatened, and endangered plant species in Texas, including all 33 federally-listed plant species (23 endangered, 6 threatened, 3 candidate, and 1 endangered plant species proposed for de-listing). The geographic, population, and other relevant data for each species are tracked as element occurrences. "An Element Occurrence (EO) is an area of land and/or water in which a species or natural community is, or was, present" (NatureServe 2002). Element Occurrences may consist of one or many "sites" as reported by surveyors. In the geographic information system (GIS) component of the NDD, EOs are displayed as points and polygons buffered by their estimated geographic precision. For this reason, historic reports that do not contain precise geographic coordinates are shown as relatively large polygons, while more recent survey data collected with global positioning system (GPS) instruments are represented by smaller polygons. Therefore, it must be understood that the tracked species occur within, but not necessarily throughout, the polygons displayed in the GIS. The NDD is an essential tool for the long-term conservation and management of species at risk. The USFWS makes frequent use of the NDD in listing actions, for planning and tracking recovery of listed species, for section 7 consultations, and for Habitat Conservation Plans.

Nevertheless, the most recent NDD update on *A. macrocarpa*, provided to us on May 4, 2010, does not include population data more recent than 1996 (Texas Natural Diversity Database 2010). Table 4 summarizes the known populations reported in the NDD as well as by Corlies (1991), Williamson (1996, 1998, 2002, 2008, and pers. com. 2010), Williamson and Werth (1999), Meredith (2006), Goodson (2007), and University of Texas (2010). Figure 2 shows the global range of these populations. (*Recovery action 41*).

Meredith (2006) and Williamson (2008) found much greater variation in population structure between seven populations than within those populations (summarized in Table 3). Their data indicate that recruitment does occur in all of these populations. *Abronia macrocarpa* is able to re-colonize sites following severe habitat disturbance (see discussion in Section 2.3.1.6). (*Recovery action 3211*).

Table 3. Percentage of large-fruited sand-verbena plants in three structure classes. Reprinted from Williamson 2008.

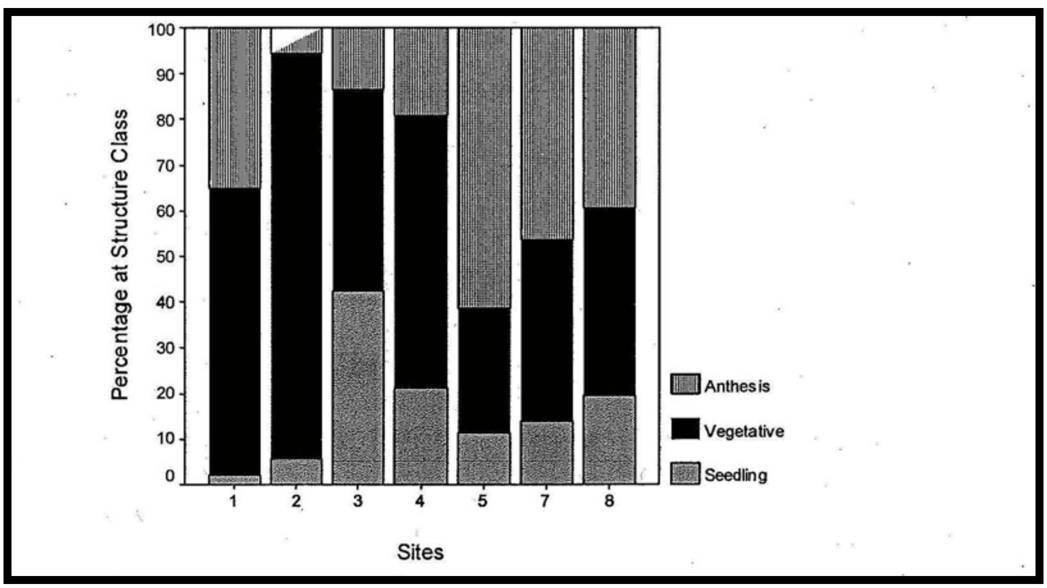

Table 4. Documented populations of large-fruited sand-verbena.

Population[1]	EO_Num[2]	EO_ID[2]	County	Topo Quad	Pop (2002)[1]	Pop (2008)[1]	Area (ha)[1]	Soil[1]	Geology
WP1	3	4873	Freestone	Lanely	28,000	28,000	8.4	Pickton loamy fine sand	Queen City Sands
WP2	n/a	n/a	Leon	Round Prairie	6,200	6,200	2.2	Arenosa	Carrizo Sands
WP3	4	1899	Leon	Round Prairie	12,000	12,000	36.3	Arenosa	Carrizo Sands
WP4	1	5727	Leon	Hilltop Lakes	8,000	8,000	3.4	Arenosa	Sparta Sands
WP5	5	7701	Robertson	Franklin	4,000	5,000	1.2	Arenosa	Sparta Sands
WP6	2	3599	Robertson	Camp Creek Lake	2,000	750	4.3	Arenosa	Sparta Sands
WP7	6 & 7	6256 & 2817	Robertson	Edge & Camp Creek Lake	4,500	4,500	4.5	Arenosa	Sparta Sands
WP8	n/a	n/a	Freestone	Turlington	1,000	30,000	12.1	Pickton/Wolfton	Carrizo Sands
WP9	n/a	n/a	Leon	Robbins	Unk	Unk	Unk	Unk	Queen City Sands
EP2	n/a	n/a	Leon	Margie	n/a	29	0.0006		Sparta Sands
EP4	n/a	n/a	Freestone	Turlington	n/a	13	0.0006		Carrizo Sands
EP7	n/a	n/a	Leon	Keechi	n/a	17	0.0006		Queen City Sands
Wild Populations:					65,700	94,450	72		
Experimental Populations:					0	59	0.0018		
All Populations:					65,700	94,509	72		

1. Adapted from Williamson 2002, 2008.
2. TPWD NDD 2010.

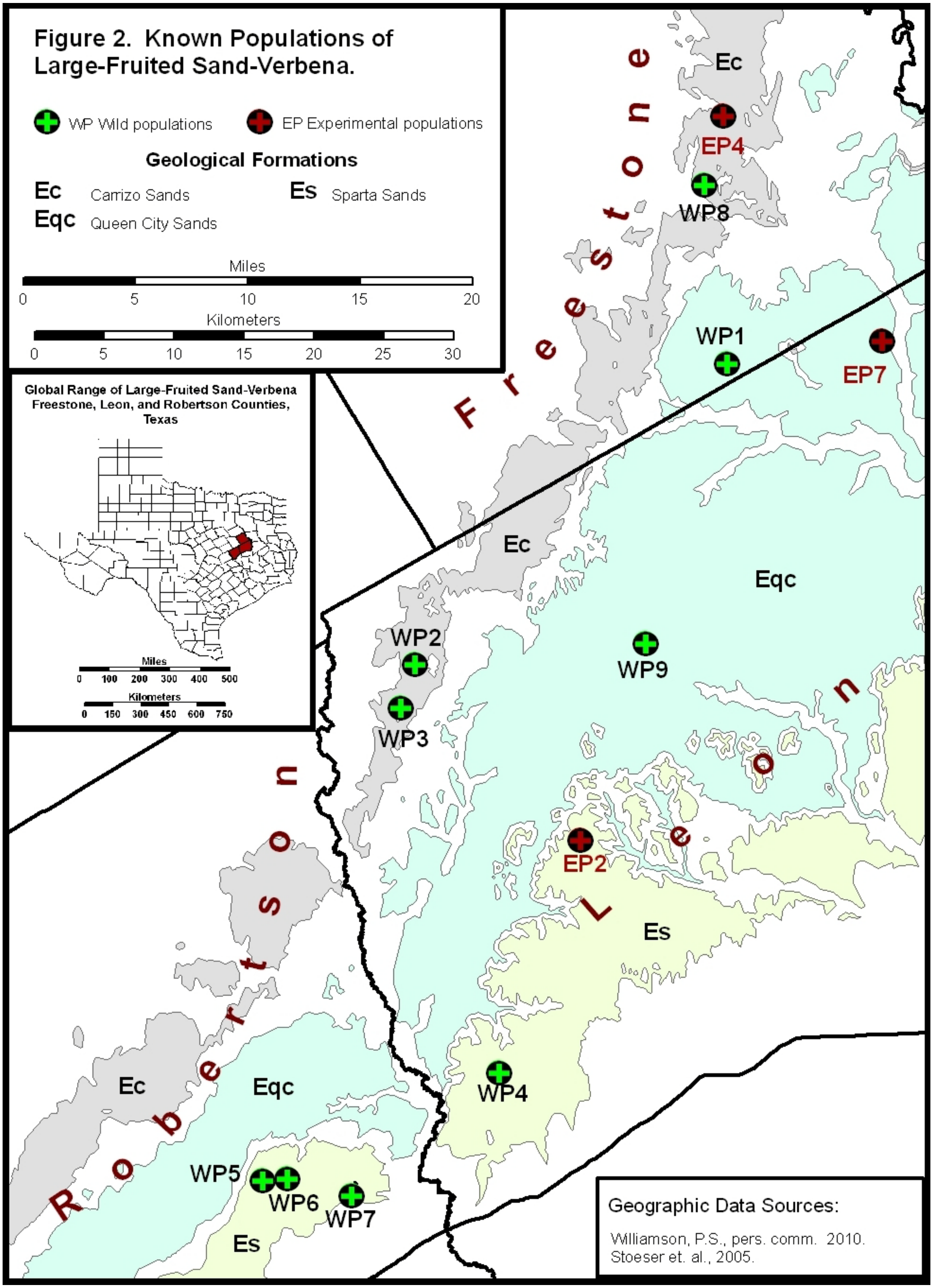

Figure 2. Known Populations of Large-Fruited Sand-Verbena.

As depicted by the population area in Table 4, the average area for a population is 6.6 ha (16.3 ac), with only 2 populations of the 11 with area data (WP3 and WP8) exceeding the recovery criterion of 10 ha (25 ac). The other 9 populations remain present in areas smaller than 10 ha (25 ac), suggesting that populations can persist with areas less than 10 ha (25 ac), but the timeframe of population survival is not known. Of the 11 populations with the number of individuals counted in 2008 (Table 4), most of these exceeded the recovery criterion of 600 individuals, with a mean number of individuals in these populations of 8,592. All but 3 populations (EP2, EP4, and EP7) are above 600 individuals and 6 of these populations occupy areas less than 10 ha (25 ac), indicating that areas between 1.2 and 8.4 ha (3 and 20.8 ac) can support from 750 to 28,000 individual *A. macrocarpa* plants. Based on her research and the trend in these data, Dr. Williamson believes that the recovery criterion of 10 ha (25 ac) per population is unrealistic, since almost none of the known wild populations is that large in area. She also believes that the minimum viable population criterion of 600 individuals is too small, and should be increased.

To improve accuracy for estimates of individual *A. macrocarpa* plants per population, models of plant traits can be used. Mathematical models for predicting minimum viable population size require quantitative data on reproductive biology, genetics, and ecology that are often unknown, and perhaps unknowable, for many rare plant species. Pavlik (1996) provides a practical guideline (adapted in Table 5, below) for estimating minimum viable plant populations when it is not possible or realistic to use the mathematical models. Considering that *A. macrocarpa* scores at the high end of at least 6 of these 9 factors, we estimate that the minimum viable population would be about 1,500 or greater.

Table 5. Minimum viable population estimates (based on Pavlik 1996) applied to *Abronia macrocarpa*.

Factor	**As few as 50 individuals**	**Up to 2,500 individuals**	***Abronia macrocarpa***
Longevity	Perennial	Annual	Perennial
Breeding system	Self-fertilizing	Outcrossing	Outcrossing
Growth form	Woody	Herbaceous	Herbaceous
Fecundity	High	Low	Relatively Low
Ramet production	Common	Rare or none	None
Survivorship	High	Low	Relatively Low
Seed duration	Long	Short	Unknown
Environmental variation	Low	High	Moderate
Successional status	Climax	Seral or Ruderal	Apparently ruderal

2.3.1.3 Genetics, genetic variation, or trends in genetic variation (e.g., loss of genetic variation, genetic drift, inbreeding, etc.):

Williamson and Werth (1999) used allozyme electrophoresis to study genetic variation and migration history among and within 7 of the 10 known populations of *A. macrocarpa* (now considered to be 9 populations). Despite the extremely small geographic range of the species (see Figure 2), they found that *A. macrocarpa* had a higher index of genetic diversity than the average of wide-ranging plant species; this is unusual for such a narrow endemic species. Genetic diversity was not evenly distributed, nor correlated to population size. The two largest populations had the lowest level of genetic diversity, which may be explained by their relative isolation. The relatively high genetic diversity of *A. macrocarpa* supports a hypothesis of relictual rather than founder origin (due to long-distance dispersal); *A. macrocarpa* has not passed through a genetic bottleneck. Duplicate gene expression and gene silencing suggests a polyploid ancestry of ancient origin. The preponderance of loci in Hardy-Weinberg equilibrium indicates that outcrossing is the prevalent mode of breeding (self-fertilization or inbreeding would lead to increased homozygosity in the populations). However, heterozygote deficiency at some but not all loci suggests that the "*A. macrocarpa* populations may be genetically structured, i.e., composed of subpopulations within which mating is approximately random but between which mating may be infrequent." These authors concluded that there appears to be little gene flow between *A. macrocarpa* populations despite their proximity within a narrow geographic range. The limited range of the hawk moth and noctuid moth pollinators, the limited seed dispersal range, and the disjunct distribution of the deep sand habitat, all explain the lack of gene flow between populations. The effective size of known populations ranges from 500 to 8000, and the total effective population size for the species is from 15,000 to 25,000 (Williamson and Werth 1999). (*Recovery action 3212*).

McGlaughlin et al. (2002) investigated another rare *Abronia* subspecies, *A. umbellata* ssp. *breviflora* (pink sand-verbena), an endemic of the coastal sands of Oregon and California. They compared 65 polymorphic loci from 4 reintroduced populations and from the Port Orford source population. The reintroduced populations ranged from 18 to 4,111 individuals. They predicted that 90 percent of the source population's genetic variation can be sustained in reintroduced populations having from 600 to 1,250 individuals. This conclusion may be a useful guide in planning reintroduction of *A. macrocarpa*, as well.

2.3.1.4 Taxonomic classification or changes in nomenclature:

Abronia macrocarpa continues to be recognized as a valid species, and is distinguished from other members of this genus by the large (8 to 15 millimeter (mm) long by 5 to 12 mm wide) (0.3 to 0.6 inches [in] long by 0.2 to 0.5 in wide), thin-walled papery anthocarps (Galloway 1972; Integrated Taxonomic Information System 2010; Natural Resources Conservation Service 2010; Tropicos 2010).

Galloway (1975) investigated the taxonomy of the Abroniinae, a subtribe within the tribe Mirabileae (as described in Heimerl 1934) of the family Nyctaginaceae. The Abroniinae are distributed primarily in arid regions of western North America, and most species are psammophiles. Galloway distinguished the genus *Abronia* from the closely-related *Tripterocalyx* on the basis of "differences in anthocarp structure, flower maturation, receptacle structure, the connective area between the upper and lower perianth, and, apparently, embryology."

Douglas and Manos (2007) conducted a phylogenetic analysis of 51 species of Nyctaginaceae, including all 25 North American genera, using 3 chloroplast loci (ndhF, rps16, rpl16, and nrITS). They found strong support for a clade that includes mostly North American xerophytic genera. This "NAX" clade diversified in the deserts of the southwestern United States and northwestern Mexico. The genera *Abronia* and *Tripterocalyx* form the tribe Abronieae (Bittrich and Kühn 1993) within the "NAX" clade.

Williams and Werth (1999) note that *A. macrocarpa*, the easternmost species of the genus, is separated from the ranges of its closest relatives by 300 km (186 mi); *A. fragrans* occurs in northwest Texas, and *A. ameliae* is found in the south Texas sand plain. These authors speculate that *A. amelia* and *A. macrocarpa* both may descend from *A. fragrans*.

2.3.1.5 Spatial distribution, trends in spatial distribution (e.g. increasingly fragmented, increased numbers of corridors, etc.), or historic range (e.g. corrections to the historical range, change in distribution of the species within its historic range, etc.):

Although the number of known populations has increased from 3 to 9 since the recovery plan was completed, the known range is still restricted to an 80 km (50 mile) span of deep sandy soils of the Carrizo Sands, Sparta Sands, and Queen City Sands geological formations in Leon, Robertson, and Freestone counties, Texas.

2.3.1.6 Habitat or ecosystem conditions (e.g., amount, distribution, and suitability of the habitat or ecosystem):

Meredith (2006) and Williamson (2008) described the habitats of eight wild populations of *A. macrocarpa*. They found no correlations between soil chemical parameters (summarized in Table 6, below) and the relative density of *A. macrocarpa* (soil analyses were performed by the Texas Cooperative Extension Soil, Water, and Forage Testing Laboratory). Table 9 lists the associated plant species of seven wild populations. The density of *A. macrocarpa* at these sites ranged from 0.75 to 12.45 plants per square meter (m^2) (0.07 to 1.16 plants per square foot [ft^2]). The community structure of these sites was determined from the relative densities of each associated species or group of species (summarized in Table 7), calculated as:

$$\text{Relative Density, species A} = \frac{\text{Number of plants of species A x 100}}{\text{Total number of plants, all species}}$$

Community coefficient analysis indicated strong similarities in vegetation composition among these 7 sites, which had more than 50 percent of species in common. *Tradescantia occidentalis* (spiderwort), *Hymenopappus artemisiifolius* (old plainsman), *Senecio ampullaceus* (Texas groundsel), *Croton argyranthemus* (silver croton), *Rhododon ciliatus* (pink sand mint), and *Plantago aristata* (bracted plantain) occurred at all seven sites. Principal Component Analysis indicated relatively strong correlations between site components and *R. ciliatus,* several *Plantago* species, *C. argyranthemus*, and *Opuntia compressa* (eastern prickly pear). Table 8 summarizes the percent cover of vegetation, leaf litter, and bare ground at eight sites. Those sites with the highest densities of *A. macrocarpa* all had more than 50 percent cover of bare ground.

Therefore, the characteristics common to all known *A. macrocarpa* populations can be used to predict the occurrence of additional populations and to define high-potential sites for reintroduction. These characteristics include deep sandy soils of the Carrizo, Sparta, and Queen City Sands geological formations, soil pH ranging from 4.8 to 6.6, soil nitrate ranging from 2 to 11 parts per million (ppm), the presence of the indicator species *Rhododon ciliatus*, *Plantago* species, *Croton argyranthemus*, and *Opuntia compressa*, and at least 50 percent cover of bare ground. (*Recovery actions 3112, 312, 3134*).

Table 6. Soil parameters of eight wild populations of large-fruited sand-verbena (Meredith 2006; Williamson 2008).

Parameter	**Detected range**	**Interpretation**
pH	4.8 - 6.6	Acid to slightly acid
Nitrate	2 - 11 ppm	Low to very low
Phosphorus	13 - 29 ppm	Low to high
Potassium	24 - 39 ppm	Low
Calcium	87 - 398 ppm	Moderate to high
Magnesium	11 - 26 ppm	Low to moderate
Sulfur	8 - 10 ppm	Moderate to high
Sodium	163 - 197 ppm	Moderate
Iron	5.79 - 33.2 ppm	Very high
Zinc	0.18 - 3.78 ppm	Moderate to very high
Manganese	1.16 - 12.19 ppm	Very high
Copper	0.05 - 0.38 ppm	Moderate to very high

Table 7. Relative densities of plant species associated with seven large-fruited sand-verbena populations (Meredith 2006; Williamson 2008).

Species or Species Group	**Relative Density Range (no. per m^2)**	**Representative species in group**
Small annuals	47.5 - 92.3	*Gaillardia pulchella*, *Cerastium glomeratum*, *Spermolepis echinata*
Grasses	9.7 - 20.7	*Bromus unioloides*, *Vulpia octoflora*, *Schizachyrium scoparium*
Rhododon ciliatus	0.02 - 25.7	
Plantago spp.	3.2 - 15.7	
Tradescantia occidentalis	0.9 - 7.5	
Abronia macrocarpa	0.38 - 4.9	

Table 8. Percent cover of vegetation, leaf litter, and bare ground of eight large-fruited sand-verbena populations (Meredith 2006; Williamson 2008).

Cover Category	**Percent Cover Range**
Vegetation	25 - 67%
Leaf litter	9 - 29%
Bare ground	16 - 40%

Table 9. Plant species[1] associated with large-fruited sand-verbena (adapted from Williamson 1996, 2008).

Family	**Genus**	**Species**	**Life Form[2]**	**Undisturbed[3]**	**Disturbed[3]**	**Common[4]**
Agavaceae	*Yucca*	*arkansana*	P			+
Amaranthaceae	*Froelichia*	*drummondii*	A	+	+	
Apiaceae	*Spermolepis*	*echinata*	A	+	+	+
Apocynaceae	*Apocynum*	*cannabinum*	P	+		+
Aquifoliaceae	*Ilex*	*vomitoria*	P	+	+	+
Asclepiadaceae	*Asclepias*	*amplexicaulis*	P	+		
Asclepiadaceae	*Asclepias*	*tuberosa*	P	+		
Asclepiadaceae	*Matelea*	*cynanchoides*	P	+		
Asteraceae	*Ambrosia*	*artemisiifolia*	A	+	+	
Asteraceae	*Ambrosia*	*psilostachya*	P	+	+	
Asteraceae	*Aphanostephus*	*ramosissimus*	A	+		+
Asteraceae	*Chrysopsis*	*pilosa*	A	+		
Asteraceae	*Coreopsis*	*tinctoria*	A	+		+
Asteraceae	*Gaillardia*	*amblyodon*	A			+
Asteraceae	*Gaillardia*	*pulchella*	A	+	+	+
Asteraceae	*Helenium*	*amarum*	A	+	+	+
Asteraceae	*Heterotheca*	*latifolia*	A		+	
Asteraceae	*Heterotheca*	*pilosa*	A		+	
Asteraceae	*Heterotheca*	*subaxillaris*	A	+		+
Asteraceae	*Hymenopappus*	*artemisiifolius*	B	+		+
Asteraceae	*Palafoxia*	*hookeriana*	A	+	+	
Asteraceae	*Rudbeckia*	*hirta*	A	+		+
Asteraceae	*Senecio*	*ampullaceus*	A	+		+
Betulaceae	*Betula*	*nigra*	P	+		
Brassicaceae	*Lepidium*	*virginicum*	ABP	+	+	+
Cactaceae	*Opuntia*	*compressa*	P	+	+	+
Capparaceae	*Polanisia*	*erosa*	A	+	+	+
Caryophyllaceae	*Arenaria*	*serpyllifolia*	A	+		
Caryophyllaceae	*Cerastium*	*glomeratum*	A	+		+

Caryophyllaceae	*Paronychia*	*drummondii*	A	+		
Caryophyllaceae	*Stellaria*	*media*		+		
Chenopodiaceae	*Chenopodium*	*ambrosioides*	A	+	+	
Commelinaceae	*Tradescantia*	*occidentalis*	P	+	+	+
Convolvulaceae	*Cuscuta*	*sp.*	A	+	+	
Convolvulaceae	*Stylisma*	*pickeringii*	P	+	+	+
Cornaceae	*Cornus*	*florida*	P	+		
Cupressaceae	*Juniperus*	*virginiana*	P	+		+
Cyperaceae	*Carex*	*sp.*	nd	+		
Cyperaceae	*Cyperus*	*sp.*	nd	+	+	
Ebenaceae	*Diospyros*	*virginiana*	P	+	+	
Ericaceae	*Vaccinium*	*arboreum*	P	+	+	
Euphorbiaceae	*Chamaesyce*	*cordifolia*	A	+	+	
Euphorbiaceae	*Cnidoscolus*	*texanus*	P	+		
Euphorbiaceae	*Croton*	*argyranthemus*	P	+	+	+
Euphorbiaceae	*Croton*	*capitatus*	A	+	+	
Euphorbiaceae	*Croton*	*lindheimerianus*	A	+		
Euphorbiaceae	*Croton*	*michauxii*	A	+	+	
Euphorbiaceae	*Stillingia*	*sylvatica*	P	+		
Fabaceae	*Astragalus*	*nuttallianus*	A	+		
Fabaceae	*Baptisia*	*nuttalliana*	P	+		
Fabaceae	*Chamaecrista*	*fasciculata*	A	+	+	+
Fabaceae	*Medicago*	*lupulina*	A	+	+	
Fabaceae	*Medicago*	*polymorpha*	A	+	+	
Fabaceae	*Mimosa*	*pudica*	AP			+
Fabaceae	*Sesbania*	*vesicaria*	A	+		
Fabaceae	*Vicia*	*ludoviciana*	A	+		+
Fagaceae	*Quercus*	*incana*	p	+		+
Fagaceae	*Quercus*	*stellata*	P	+		+
Fumariaceae	*Corydalis*	*curvisiliqua*	A	+		
Geraniaceae	*Geranium*	*texanum*	A	+	+	
Hydrophyllaceae	*Phacelia*	*glabra*	A			+
Juglandaceae	*Carya*	*texana*	P	+		
Lamiaceae	*Monarda*	*citriodora*	A	+		+
Lamiaceae	*Rhododon*	*ciliatus*	A	+	+	+
Liliaceae	*Allium*	*drummondii*	P	+		+
Liliaceae	*Nothoscordum*	*bivalve*	P	+		+
Nyctaginaceae	*Abronia*	*macrocarpa*	P	+	+	
Onagraceae	*Oenothera*	*laciniata*	P	+	+	+

Papaveraceae	*Argemone*	*albiflora*	A	+		+
Phytolaccaceae	*Phytolacca*	*americana*	P	+		
Plantaginaceae	*Plantago*	*aristata*	A	+	+	+
Plantaginaceae	*Plantago*	*hookeriana*	A	+	+	
Plantaginaceae	*Plantago*	*major*	P			+
Plantaginaceae	*Plantago*	*patagonica*	A	+	+	
Plantaginaceae	*Plantago*	*virginica*	AP			+
Poaceae	*Bromus*	*catharticus*	A	+		+
Poaceae	*Cenchrus*	*spinifex*	P	+	+	
Poaceae	*Dactyloctenium*	*aegyptium*	A	+		
Poaceae	*Dichanthelium*	*oligosanthes*	P	+	+	+
Poaceae	*Schizachyrium*	*scoparium*	P			+
Poaceae	*Stipa*	*sp.*	P	+		
Poaceae	*Vulpia*	*octoflora*	A	+		+
Polemoniaceae	*Ipomopsis*	*rubra*	B	+		
Polemoniaceae	*Phlox*	*drummondii*	A	+		+
Polygonaceae	*Eriogonum*	*multiflorum*	A	+	+	
Polygonaceae	*Eriogonum*	*sp.*	P	+	+	
Polygonaceae	*Rumex*	*hastatulus*	P	+		
Primulaceae	*Anagallis*	*arvensis*	A	+	+	+
Rosaceae	*Rubus*	*trivialis*	P	+	+	+
Rubiaceae	*Diodia*	*teres*	A	+	+	
Scrophulariaceae	*Linaria*	*texana*	A	+	+	+
Scrophulariaceae	*Penstemon*	*murrayanus*	P	+		+
Smilacaceae	*Smilax*	*bona-nox*	P	+	+	+
Verbenaceae	*Callicarpa*	*americana*	P	+		
Verbenaceae	*Glandularia*	*bipinnatifida*	A	+	+	
Vitaceae	*Vitis*	*mustangensis*	P	+	+	+
Total		96		87	45	47
No. Annuals		49		45	27	23
No. Perennials		39		36	16	20
No. Biennials		2		2	0	1

1. Taxonomy updated to conform to the PLANTS database (Natural Resources Conservation Service 2009).
2. A = annual; B = biennial; P = perennial; nd = not determined.
3. Adapted from Williamson 1996.
4. Adapted from Williamson 2008.

Abronia macrocarpa occurs on deep, unstable, permeable sands of the Arenosa, Silstead-Padina, Pickton, and Wolfpen soil series. These soils are used primarily for rangeland, hay land, and woodland, and are not well suited for urban development (U.S. Department of Agriculture 1989). Table 10 (below) compares the projected human populations of Leon, Robertson, and Freestone counties and the state of Texas in 2010 and 2035, based on growth scenario 0.5 (Texas State Data Center 2006). The average population density in these 3 counties of 7.4 inhabitants per square kilometer (km^2) (19.2 inhabitants per square mile [mi^2]) and their average projected growth rate of 16 percent over this 25-year period are both well below the average densities and growth rates for the entire state. Consequently, we expect relatively little habitat loss due to urban development and land use changes over the next 25 years.

Table 10. Projected human population growth in Freestone, Leon, and Robertson counties, Texas (Texas State Data Center 2006).

COUNTY	**Area-Mi²**	**Area-Km²**	**Population 2010[a]**	**People per km²**	**Population 2035[a]**	**People per km²**	**Population Increase 2010 - 2035[a]**
Freestone	877.4	2,272.5	19,094	8.4	21,365	9.4	1.12
Leon	1,072.0	2,776.6	16,813	6.1	18,892	6.8	1.12
Robertson	854.6	2,213.3	17,637	8.0	21,629	9.8	1.23
3-County Total	2,804.0	7,262.4	53,544	7.4	61,886	8.5	1.16
Texas Total	261,797.1	678,054.6	24,336,724.0	35.9	33,811,846	49.9	1.39

a. Projected according to scenario 0.5.

Throughout the species' range, some habitat has been lost or degraded through the conversion of native grassland to "improved pasture" planted with introduced grasses, such as *Cynodon dactylon* (bermudagrass) and *Eragrostis curvula* (weeping lovegrass) (Williamson 2002).

In August, 1992, a petroleum well was excavated at the species' type locality, known as Hilltop Lakes Resort, in Leon County. In 1993, Couch (1996) and Williamson (1998) initiated a long-term study of the unaided recovery of this site, where an estimated 2,500 *A. macrocarpa* plants and 0.94 ha (2.3 ac) of habitat were destroyed. Williamson compared populations and importance values (the sum of relative cover, relative density, and relative frequency) for all plant species in both the disturbed site and adjacent undisturbed habitat. By spring 1998 there were 418 *A. macrocarpa* plants (85 seedlings, 254 mature vegetative, and 79 flowering individuals) in the disturbed area. *Abronia macrocarpa* importance values were 2.2 and 6.5 in disturbed and undisturbed areas, respectively. While annual plants had higher importance values in disturbed (121) versus undisturbed (40.3) areas, perennials had higher importance values in undisturbed (117.9) versus disturbed (44.7) areas. The mean percent bare ground was greater in the undisturbed area, and leaf cover was greater in the disturbed area; this was probably due to the greater cover of annual plants in the disturbed area. Williamson concluded that "…the disturbed area is being successfully recolonized by *A. macrocarpa* and returning to viable state." However, "…a period of time longer than six years is necessary for the population to establish to normal levels following a disturbance." By 2005, 522 *A. macrocarpa* individuals had recolonized the disturbed area (Meredith 2006). However, there were still many differences between the disturbed and undisturbed areas, summarized in Table 11 (below). Most of the *A. macrocarpa* plants were close to the edges of the disturbed area, while the interior 60 percent of this area had no *A. macrocarpa* plants. This pattern may be explained by the limited seed dispersal range of *A. macrocarpa*, and by competition from dense vegetative cover in the disturbed area, 46 percent of which consisted of a single, introduced, invasive species, *Chenopodium ambrosioides* (epasote). (*Recovery actions 3133, 3132, 3134, 3234*).

Table 11. Differences between disturbed and undisturbed areas of large-fruited sand-verbena habitat, 13 years after disturbance (adapted from Meredith 2006).

Observation	**Disturbed**	**Undisturbed**	**Significance**[a]
Density ABRMAC/m^2	0.2	5.2	+
ABRMAC: Percent Seedlings	0%	21%	+
ABRMAC: Percent Vegetative	30%	59%	+
ABRMAC: Percent Flowering	70%	20%	+
Cover: Percent Vegetated	58.4%	16.3%	+
Cover: Percent Litter	29.6%	17.0%	-
Cover: Percent Bare	12.0%	66.8%	+

a. Statistically different quantities within a row are indicated by "+".

Section 6 grant E-11supported a three-year project (2000 to 2002) to inventory and map seven wild *A. macrocarpa* populations with GPS and to protect those populations through technical assistance to landowners (Williamson 2002; see Table 4).

Grant E-58 supported continued surveys, mapping, and landowner technical assistance at eight wild *A. macrocarpa* populations from 2005 to 2007, and also initiated a series of pilot reintroductions (Williamson 2008). Voucher specimens were collected from each population and deposited at the Texas State University - San Marcos herbarium. Monitoring and landowner interviews revealed a range of uses of these privately-owned sites, including oat and clover cultivation, cattle grazing, and hunting leases. Land uses that the investigators determined to be compatible with *A. macrocarpa* conservation include brush control, prescribed burning, native grassland restoration, and well-managed cattle grazing. Annual wildlife food plots, herbicide application, small-scale clearing for fence or road construction, off-road vehicle (ORV) use, mowing, and feral hog trapping may also be compatible if these activities avoid the active growth period for *A. macrocarpa* (October – May); oil and gas exploration, if conducted outside of occupied habitat), may also be compatible.

Based on observations, Williamson (2008) determined that incompatible land uses include clearing of native vegetation, planting non-native pasture grasses, perennial wildlife food plots, over-stocking of grazing animals, herbicide application from October to April, mowing from February to April, ORV use within populations from October to April, oil and gas exploration conducted within occupied habitat, and broad-scale insecticide use (which could kill the pollinating moths). If grazed, it is preferable to remove cattle from February through April. Dense cover of *A. macrocarpa* occurred at some sites after they were disk-harrowed, but subsided after several years; this suggests that the species may depend on disturbance. (*Recovery actions 41, 112, 3133, 113, 13, 14, 51, 52, 53*).

2.3.1.7 Conservation measures:

Public outreach and education:

The criterion for downlisting is the discovery and/or establishment of 20 genetically viable, demographically stable populations of at least 600 individuals on 10.1 ha (25 acres) of habitat each; the species may be delisted if the downlisting criterion is maintained for at least 10 years. Since all known wild *A. macrocarpa* populations occur on private land, recovery of the species will depend on successful public outreach and landowner cooperation. Williamson (1996, 2002, 2008) promoted *A. macrocarpa* conservation through public presentations, the local news media, and scientific conferences, and provided specific land management recommendations to eight private landowners of *A. macrocarpa* sites. The landowners have adopted many recommendations, such as delaying mowing or herbicide application until after *A. macrocarpa* plants have dispersed seed and become dormant. The landowners have also been presented with TPWD voluntary conservation agreements. “Despite being very cooperative, to date, no landowner has been willing to sign such an agreement.” (Williamson 2008). A landowner in Leon County wrote articles in a local newspaper promoting the conservation of *A. macrocarpa*, which led to requests for surveys from additional landowners and the discovery of a new population near the town of Jewett. Although surveys of 10 other properties in Leon and Freestone counties in 2006 and 2007 detected no *A. macrocarpa* populations, 7 of these sites had appropriate physical and biological characteristics and landowner support for reintroduction. (*Recovery actions 7, 113, 41, 42*).

Seed germination and propagation:

Recovery of the species is likely to require successful propagation and reintroduction and/or augmentation of existing populations. Propagation and reintroduction is also an important safeguard to enable the recovery of populations following catastrophic loss. Williamson (2002, 2008) collected seeds from seven wild populations, using CPC guidelines for rare plants (Center for Plant Conservation 1991). These seeds are stored in <u>seed banks</u> at Lady Bird Johnson Wildflower Center, Mercer Arboretum and Botanic Gardens, and the National Seed Storage Laboratory in Ft. Collins, CO (Oxley, pers. comm. 2002;

Tiller, pers. comm. 2002). Considering the relatively ample genetic diversity of this species, and that populations in closer proximity were genetically more similar than they were to populations of other regions (Williamson and Werth 1999), Williamson (2008) recommends that reintroduction projects should use seeds collected from a nearest neighbor population to avoid disrupting locally coadapted gene complexes. (*Recovery actions 21, 3212*).

Galloway (1975) germinated seeds of *Abronia* species, including *A. macrocarpa*, by removing the achenes from anthocarps, soaking them for 10 minutes in 20 percent household bleach, washing the achenes 8 to 10 hours in running water, and cold-stratifying the seeds for 10 days at 8° Celsius (C) (46° F) prior to planting. Young (1990) determined that seeds germinate best when planted beneath the soil rather than at the soil surface. Wieland (1995) reported that the bleach treatment appears to have little effect on germination. Drennan (2008) found that 100 micro-moles per liter ($\mu mol\ l^{-1}$) of ethylene, generated either by exposure to ethephon or to ripe apples, enhanced the germination of *A. fragrans*, *A. maritima*, *A. umbellata*, and *A. villosa*. (*Recovery actions 332, 334*).

Williamson (2002, 2008) and Goodson (2007) investigated seed germination and conducted experimental reintroduction (pilot reintroductions) in the field. The experimental germination techniques included warm stratification, cold stratification, 0.2 percent potassium nitrate, gibberellic acid, and mechanical scarification, as well as combined treatments, conducted on both achenes and whole anthocarps. The highest germination (68.6 percent) resulted from scarification followed by warm and then cold stratification of achenes. They also compared germination of seeds planted directly in soil in the spring and fall at three experimental reintroduction sites; in all cases, germination was evaluated the following spring. Germination of fall-planted seeds was 0, 0.83, and 0.83 percent; spring-planted seed germination was 16.3, 16.7, and 4.2 percent, and was significantly greater in the first two sites. The results of field and laboratory germination trials make sense, considering that *A. macrocarpa* seeds disperse naturally in the spring. Based on these results, about 3,600 seeds are required to establish a reintroduction site with 600 survivors. Since removing this amount of seeds from a wild population would likely exceed the CPC seed collection guidelines, reintroduction sites may have to be established over multiple years. The number of seeds required to establish a viable reintroduced population might be reduced by using nursery-grown seedlings; however, this would require an investment of infrastructure, material, and labor to produce, transport, and transplant the seedlings. Three small experimental reintroductions have now been successfully established (Williamson, pers. comm. 2010; see Table 4). (*Recovery actions 332, 334, 51, 52, 53*).

Based on their investigations, Williamson (2008) and Goodson (2007) summarized their recommendations for planning reintroduction as follows. Reintroductions sites should have Arenosa fine sandy soil, Pinkton loamy fine sandy soil, or Silstead-Padina soil. Soil pH should be between 4.8 and 6.6, and soil nitrate should be from 2 to 11 ppm. The cover of bare ground should be from 25 to 67 percent, and preferably greater than 50 percent. Inoculating reintroduction sites with mycorrhizal soil from an existing population could also introduce pathogens; therefore, it is preferable to select sites with plant compositions similar to known populations. *Rhododon ciliatus, Plantago* species, and *Croton argyranthemus* are good indicators of suitable habitat, and the appropriate moth pollinators must also be present. Seed should originate from the closest wild population that has the highest coefficient of community index to the reintroduction site. Reintroductions accomplished over multiple years will have a varying age-class structure. Reintroduction sites should also be monitored for multiple years. (*Recovery action 6*).

2.3.2 Five-Factor Analysis (threats, conservation measures, and regulatory mechanisms).

The Revised Status Report (Kennedy et al., 1990) and the Recovery Plan (U.S. Fish and Wildlife Service 1992) list the following as potential threats to conservation and recovery of *A. macrocarpa*:

- Clearing of vegetation for petroleum exploration and residential development (Listing Factors A and D).
- The conversion of native grassland to improved pastures of introduced grasses (Listing Factors A and E)
- Conversion of open grassland to woodland (Listing Factor A).
- Fire suppression (Listing Factor A).
- Off highway vehicle (OHV) use (Listing Factor A).
- Wildflower collecting (Listing Factor B).
- Livestock grazing (Listing Factors A and C).
- Deer browsing (Listing Factors A and C).

Other threats that have been documented more recently include mowing, herbicide application, and the establishment of wildlife food plots.

2.3.2.1 Present or threatened destruction, modification or curtailment of its habitat or range - Listing Factor A:

Residential, industrial, mineral development:

As discussed in Section 2.3.1.6, the human population density and projected growth rates are relatively low within the known range of the species, and the deep sandy soils that characterize its habitat are poorly suited for construction and row-crop farming. Therefore, we anticipate relatively little loss of habitat from urban and agricultural development, although habitat could be lost through other forms of development, such as surface mining; petroleum exploration; highway, power line, and pipeline construction; etc. All known populations occur on private land, where state and federal regulations provide only minor protection to endangered plants. Landowners have been interested and cooperative in conserving this plant, but we do not know if land and mineral development will occur in *A. macrocarpa* habitat in the future. Given the restricted substrate preferred by this narrow endemic, development and construction in areas occupied by or adjacent to *A. macrocarpa* would threaten the species.

Habitat conversion:

The conversion of native grasslands to "improved pastures" of introduced grasses is an ongoing threat to *A. macrocarpa*. Highly competitive introduced grasses (specifically bermudagrass and weeping lovegrass) are clearly incompatible with *A. macrocarpa* conservation; nevertheless, these species were not noted within any of the existing wild populations (see Table 9). However, we do not know what proportion of potential *A. macrocarpa* habitat has been converted to improved pasture, nor the current rate at which this practice continues. Introduced grasses should be considered a real threat of unknown extent that is likely to continue into the future.

Fire suppression:

Similarly, the suppression of wildfire and poor rangeland management could certainly lead to increased cover of woody vegetation, as has happened elsewhere in Texas (Bogusch 1952; Texas Agricultural Extension Service 1980; Archer, et al. 1988; Scifres and Hamilton 1993; Frost 1998). Competition from increased woody cover could reduce *A. macrocarpa* habitat quality; however, the effects of fire frequency and grazing patterns on *A. macrocarpa* ecology have not been investigated, making the degree of threat to the plant difficult to assess.

Livestock grazing and deer browsing:

Well-managed livestock grazing appears to be compatible with *A. macrocarpa* conservation, particularly if grazing animals are not present during the flowering period (Williamson 2002). However, grazing management trends within occupied *A. macrocarpa* habitat, and its potential effects on the species reproduction and survival, have not been documented.

Other land uses – OHV use, mowing, clearing, herbicides, wildlife food plots:

Some land uses, including OHV use, mowing, small-scale clearing, herbicide application, and annual wildlife food plots, can directly harm or destroy *A. macrocarpa* individuals, or reduce their reproductive potential. These threats may be avoided or minimized by conducting these activities during the seasons when *A. macrocarpa* plants are not actively growing or flowering; many landowners have voluntarily adopted these recommendations to protect *A. macrocarpa* populations on their land (Williamson 2002).

2.3.2.2 Overutilization for commercial, recreational, scientific, or educational purposes – Listing Factor B:

We are unaware of any documented use or over-use of *A. macrocarpa* for any human purpose, including flower arrangements. If a market for the species were to arise, illicit collection would be thwarted by the lack of public access to the known privately-owned populations.

2.3.2.3 Disease or predation – Listing Factor C:

Williamson (1996) observed very little herbivory of *A. macrocarpa* plants in wild populations by domesticated grazing animals, deer, insects, or other herbivores. This may be due to the amount of sand that adheres to the leaf surfaces (see Figure 1), which have sticky glandular trichomes. We have no documentation of significant impacts to *A. macrocarpa* from either native or introduced pathogens or insects.

2.3.2.4 Inadequacy of existing regulatory mechanisms – Listing Factor D:

The Endangered Species Act (ESA) does provide some legal protection for federally-listed plants on land under federal jurisdiction. Federally-listed plants occurring on private lands have very limited protection under the ESA, unless also protected by State laws; the State of Texas also provides very little protection to listed plant species on private lands. All known *A. macrocarpa* populations occur on privately-owned land. Approximately 95 percent of Texas land area is privately owned. It is reasonable to assume that the vast majority, if not all existing *A. macrocarpa* habitat, including sites that have not been documented, occurs on private land. Therefore, the species' populations and habitats are not subject to Federal or State protection unless there is a Federal nexus, such as provisions of the Clean Water Act or a federally-funded project.

Chapter 88 of the Texas Parks and Wildlife Code lists plant species as state-threatened or endangered once they are federally-listed as threatened or endangered. *Abronia macrocarpa* was listed as endangered by the State of Texas on December 30, 1988. The State prohibits taking and/or possessing for commercial sale of all or any part of an endangered, threatened, or protected plant from public land. The TPWD requires permits for the commercial use of listed plants collected from private land. Scientific permits are required for collection of endangered plants or plant parts from public lands for scientific or educational purposes. In addition to State endangered species regulations, other State laws may apply. State law prohibits the destruction or removal of any plant species from State lands without a TPWD permit.

2.3.2.5 Other natural or manmade factors affecting its continued existence – Listing Factor E:

Climate change:

According to the Intergovernmental Panel on Climate Change (IPCC) (2007) "Warming of the climate system is unequivocal, as is now evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice, and rising global average sea level." It is very likely that average Northern Hemisphere temperatures were higher during the second half of the 20th century than during any other 50-year period in the last 500 years; it is also likely that average temperatures during this period were the highest in at least the last 1,300 years (IPCC 2007). It is very likely that over the last 50 years, cold days, cold nights, and frosts have become less frequent over most land areas, and hot days and hot nights have become more frequent (IPCC 2007). It is likely that heat waves have become more frequent over most land areas, and also that the frequency of heavy precipitation events has increased over most areas (IPCC 2007).

The IPCC (2007) predicts that changes in the global climate system during the 21st century are very likely to be larger than those observed during the 20th century. For the next two decades a warming of about 0.2°C (0.4°F) per decade is projected (IPCC 2007). Afterwards, temperature projections increasingly depend on specific emission scenarios (IPCC 2007). The range of emission scenarios suggest that by the end of the 21st century, average global temperatures may increase from 0.6°C to 4.0°C (1.1°F to 7.2°F) with the greatest warming expected over land (IPCC 2007). Localized projections suggest that the southwestern U.S. may experience the greatest temperature increase of any area in the lower 48 States (IPCC 2007). The IPCC says it is very likely that hot extremes, heat waves, and heavy precipitation will increase in frequency (IPCC 2007). There is also high confidence that many semi-arid areas like the western United States will suffer a decrease in water resources due to climate change (IPCC 2007). Milly et al. (2005) project a 10 to30 percent decrease in precipitation in mid-latitude western North America by the year 2050 based on an ensemble of 12 climate models.

We do not know whether the climate changes that have already occurred have affected *A. macrocarpa* populations or distribution, nor can we predict how the species might be affected by the type and degree of climate changes forecast by the range of models. The species is endemic to deep sandy soils in 3 east Texas counties, and the known wild populations are not more than 80 km (50 miles) apart. Rising temperatures might enable the species to survive further north than at present, but might also reduce the southern limit of the range. Similarly, changes in the frequency and amount of precipitation could favor a shift in geographic range or habitat type. However, the discontiguous nature of the populations and potential habitat, the limited seed dispersal range, and the existence of new, anthropogenic barriers to migration could impede the spontaneous movement of the range. Changes in temperature and rainfall amounts and patterns could alter the species' competitive advantage in the unique micro-habitats it now inhabits. Regardless of how these changes may affect the autecology of *A. macrocarpa*, the altered synecology may be far more significant. For example, higher winter temperatures could increase competition from bermudagass or other introduced grasses. Conversely, higher temperatures and altered rainfall patterns might also stimulate bermudagrass parasites and pathogens, thereby reducing its competition. At present, we cannot predict how the infinitely complex aggregation of climate change effects will affect the synecology of the species and its habitat. Therefore, we will continue to monitor the species and its habitat, and will adapt our recovery and management strategies when necessary to address the changing conditions.

2.4 Synthesis.

Large-fruited sand-verbena is an attractive, perennial forb of the family Nyctaginaceae (and is not a *Verbena* as the name might suggest). Nine populations have now been documented that range from 750 to 30,000 individuals and total almost 95,000 individuals. With respect to genetic diversity, these populations have effective sizes of 500 to 8,000 individuals. Three section 6-funded projects and a research cooperative agreement have contributed significantly to our knowledge of the species' reproduction and ecology. It reproduces by sexually-produced seeds, and is an obligate out-crosser that depends on several moth species for pollination. Seed dispersal range in the wild is extremely limited (usually less than 1.0 m [3.28 ft]). The known populations possess a relatively high amount of genetic diversity, considering their isolation and extreme endemism. However, the populations are genetically distinct, and there is little or no gene flow between them. The structure of known populations indicates that recruitment occurs regularly at all sites, and one population is slowly recolonizing a severely-disturbed portion of formerly-occupied habitat.

This endemic of deep, unstable sands in Leon, Robertson, and Freestone counties, Texas, has been found exclusively on privately-owned land. Considering that surveys have only been conducted with landowner permission, and that only a small fraction of the potential habitat has been surveyed, it is likely that other populations exist. Landowners are receptive to conserving this species, and many have modified their land uses to avoid or minimize threats to the known populations. The human population density and projected growth rates within the species' range are relatively low, compared to the entire state; consequently, the threat from urban and residential development may be less imminent than the threats from conversion of the native grassland habitat to improved pastures of introduced grasses. The absence of natural wildfires, and prior periods of poor rangeland management, may also contribute to a gradual conversion of native grassland to woodland vegetation that does not support the species.

A series of small-scale experimental reintroductions indicates that reintroduction is feasible, and may be necessary in order to attain the recovery criterion of 20 viable populations. Surveys for the species have identified numerous sites that possess the appropriate range of soil and vegetation characteristics, and whose landowners are highly receptive to conserving the species. Therefore, a large-scale reintroduction program may become a valuable tool for recovery of the species.

Dr. Paula Williamson, together with her graduate students Gena Corlies Janssen, Carolyn Grace Meredith, and Jacqueline Goodson, has contributed enormously to research and conservation of large-fruited sand-verbena. Dr. Williamson believes that full recovery of this species is possible, though the time frame may be longer than projected in the recovery plan (Williamson, pers. comm. 2010). Reformulating the recovery criteria to reduce the area of 10 ha (25 ac) per population and raise the minimum viable population of 600 individuals to an amount closer to 1,550 or more individuals is recommended by Dr. Williamson to capture a more ecologically appropriate picture of this species. She recommends that recovery efforts now focus on improving and expanding reintroduction efforts, putting into practice all that has been learned about the species. We concur with Dr. Williamson's recommendations to revise the recovery plan and to augment reintroduction at appropriate sites.

3.0 RESULTS

3.1 Recommended Classification:

____ Downlist to Threatened
____ Uplist to Endangered
____ Delist
____ *Extinction*
____ *Recovery*
____ *Original data for classification in error*
__X__ No change is needed

3.2 New Recovery Priority Number: 8.

A Recovery Priority Number of 8 is indicative of a taxon with a moderate degree of threat, a high recovery potential, and the taxonomic standing of a species.

Brief Rationale:

When *A. macrocarpa* was listed as endangered, only three populations were known; the degree of threat to the species was determined to be high. Nine populations totaling almost 95,000 individuals have now been documented. Relatively little urban or residential development is occurring within the species' range. Competition from introduced invasive grasses and the conversion of open grassland to dense woodland are significant, continuing threats to the species. Although all known populations occur on privately-owned land, landowners have been very receptive to conserving these populations. Therefore, we now determine that the degree of threat is moderate. The discovery of new populations, the increased knowledge of the species' reproduction and ecology, the ample genetic diversity, the demonstrated success of several pilot reintroduction projects, and the receptiveness of local landowners to conservation and reintroduction of the species, all confirm that the recovery potential is high. The taxon continues to be recognized as a valid species. Since the appropriate conservation measures are generally compatible with most current land uses, recovery is not likely to conflict with economic activity. Therefore, the Recovery Priority Number is now 8.

4.0 RECOMMENDATIONS FOR FUTURE ACTIONS

The most important recovery actions during the next five years include, but are not limited to, the following:

- Revise the recovery plan and recovery criteria to reflect new information on the species' biology, ecology, and range, incorporating the most recent recovery planning guidance (National Marine Fisheries Service 2007). Specifically, the criterion of a minimum viable population area of 10.1 ha (25 ac) is unrealistic, since the known viable wild populations occupy much smaller areas. However, it is important to distinguish between the area requirements of both occupied and unoccupied potential habitat. *Abronia macrocarpa* inhabits sparsely-vegetated, unstable sandy soil formations; anecdotal observations indicate that the populations respond favorably to occasional light disturbance. Therefore, it is possible that this plant is narrowly adapted to a specific seral stage that continually shifts location as these inland sand dunes form and recede. If this is the case, the area requirement for unoccupied but intact potential habitat will be much greater than the area occupied by the species at any given time; long-term survival would require landscape-scale conservation.

- Increase the minimum viable population size of 600 individuals for the recovery criteria, as this appears to be too small (McGlaughlin et al. 2002, Williamson, pers. com. 2010).

- Continue to promote public support for conservation and recovery of the species through local schools and news media, non-governmental conservation organizations, and other forms of public outreach.

- Continue periodic monitoring and surveys of the known populations to track demographic trends, and to detect and attempt to alleviate threats to these populations.

- Support conservation of wild populations on private lands through the USFWS Partners for Fish and Wildlife Program and section 6-funded grants, and through cooperative efforts with Natural Resources Conservation Service and other state and federal agencies. Establish a private landowner support group, similar to the group now actively working to conserve Texas snowbells (*Styrax platanifolius* ssp. *texanus*).

- Continue to search for wild populations. Use GIS technology to identify areas of high-potential habitat, and seek landowner permissions to survey those areas.

- Conduct scientific investigation of the species' fire ecology.

- Continue to develop reintroduction techniques to improve establishment rates in the field and cost effectiveness. Once suitable techniques have been demonstrated through pilot reintroductions, implement a reintroduction program on a scale sufficient to recover the species.

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PHOTOGRAPHIC CREDITS

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GLOSSARY OF TECHNICAL TERMS

Achene	A small, dry, indehiscent, one-seeded, usually hard fruit in which the ovary wall is free from the seed. (Correll and Johnston 1979).
Allozyme	Alternate forms of an enzyme coded by different alleles at the same locus. (Wikipedia 2010).
Anther	The pollen-bearing part of the stamen. (Correll and Johnston 1979).
Anthesis	The period when a flower is receptive to fertilization.
Anthocarp	A structure in which the fruit proper is united with the perianth or receptacle. (Correll and Johnston 1979).
Autecology	Ecology of individual species.
Callose	Possessing hardened thickenings (Correll and Johnston 1979).
Capitulum	An inflorescence having numerous flowers arranged radially around a central point.
Centripetal	In botany, the maturation of flowers starting at the periphery and proceeding toward the center of an inflorescence.
Chloroplast	A double-membrane organelle found in higher plants in which photosynthesis takes place.
Clade	The scientific classification of living and fossil organisms to describe a monophyletic group, defined as a group consisting of a single common ancestor and all its descendants (Wikipedia 2010).
Crepuscular	Active at dawn and dusk.
Dehiscent	Structure that naturally splits open along lines of mechanical weakness.
Delist	Remove a species from the list of threatened and endangered species.

Demography	Scientific study of populations.
Direct seeding	Direct placement of seeds for germination in a growth medium or a field site (as opposed to transplantation of a germinated plant).
Diurnal	Active during the day.
Duplicate gene	See Gene duplication.
Downlist	Reclassify a species from endangered to threatened.
Edaphic	Adjective referring to soil.
Electrophoresis	A method of separating chemical substances based on the different rates they travel through a gel or other medium when exposed to an electric field.
Embryology	The study of embryo development.
Endemic	An organism restricted to a specific habitat or geographic range.
Eocene	The geological epoch extending from 56 to 34 million years before the present (Wikipedia 2010).
Gene	A specific region of a chromosome that controls a single heritable trait.
Gene duplication	Gene duplication (or chromosomal duplication or gene amplification) is any duplication of a region of DNA that contains a gene (Wikipedia 2010).
Gene silencing	An epigenetic processes of gene regulation in which a gene is turned off (prevented from expression) by cellular rather than genetic mechanisms. (Wikipedia 2010).
Genetic bottleneck	An event which greatly restricts an organism's genetic diversity.
Germ bank	Genetic repository consisting of living tissues of organisms.
GPS, d-GPS	Global Positioning System; electronic system for calculating geographic position using satellite data. D-GPS is differentially-corrected GPS, which uses a reference position of known geographic location to increase accuracy.
Habitat	Ecological or environmental area that is inhabited by a particular species of animal, plant or other type of organism (Wikipedia 2010).
Hardy-Weinberg equilibrium	A state in which both allele and genotype frequencies in a population remain constant—that is, they are in equilibrium—from generation to generation unless specific disturbing influences are introduced (Wikipedia 2010).
Heterozygous	An diploid (or polyploid) organism possessing two (or more) alleles at a specific gene locus on homologous chromosomes.
Inflorescence	A plant structure bearing two or more flowers.
Invasive	Species that is non-native (or alien) to the ecosystem under consideration and whose introduction causes or is likely to cause economic or environmental harm or harm to human health (Executive Order 13112 - 64 FR 6183).
Locus	The specific position of a gene on a chromosome.
Microclimate	The climate of a very specific or fine-scale location.
Micro-habitat	Very specific or fine-scale portion of a habitat that is occupied by a species.

Minimum viable population	The fewest individuals required for a 95% probability of survival over 100 years (Pavlik 1996; Mace and Lande 1991).
Nocturnal	Active at night.
Outcross	In plants, sexual fertilization involving a different individual.
Ovule	In botany, diploid maternal tissue within the ovary that gives rise to the haploid tissue of the female gametophyte (Wikipedia 2010).
Peduncle	The stem of an inflorescence.
Perenniate	To become perennial; to endure longer than a single year.
Perianth	The floral envelopes collectively; usually used when calyx and corolla are not clearly differentiated. (Correll and Johnston 1979).
pH	A measure of the acidity or basicity of a solution approximately equal to p[H], the negative logarithm (base 10) of the molar concentration of dissolved hydronium ions (H3O+). (Wikipedia 2010).
Phenology	Seasonal pattern of plant growth, development and reproduction.
Phylogeny	The study of evolutionary relatedness among various groups of organisms (e.g., species, populations), which is discovered through molecular sequencing data and morphological data matrices (Wikipedia 2010).
Polymorphism	In genetics, a gene locus for which multiple alleles exist.
Polyploid	Having more than two chromosome sets.
Population	Collection of inter-breeding organisms of a particular species (Wikipedia 2010).
Population structure	The proportions of a population comprised by different age groups or reproductive stages.
Proboscis	The tubular feeding and sucking organ of certain invertebrates such as insects (e.g., moths and butterflies), worms (including proboscis worms) and gastropod mollusks. (Wikipedia 2010).
Psammophile	An organism specifically adapted to living in sandy soil.
Ramet	An individual, genetically-identical plant reproduced as a clone of the parent plant.
Recovery team	A team of experts appointed by U.S. Fish and Wildlife Service or National Marine Fisheries Service to make recommendations on the recovery of federally-listed species.
Reintroduction	Establishment or restoration of populations of a species within its former range and habitat.
Relative cover	The cover of an individual species divided by the cover of all species in a specified area.
Relative density	The density of an individual species divided by the density of all species in a specified area.
Relative frequency	The frequency of an individual species divided by the frequency of all species in a specified area.
Rosette	A radially-symmetrical whorl of leaves formed at the base of a plant stem, usually during a vegetative (non-reproductive) growth phase.
Ruderal	Early stage of succession (colonization).

Seed bank	Genetic repository consisting of viable plant seeds.
Semi-arid	Climatic region intermediate between mesic and arid, where moisture is insufficient for plant growth for a portion of the growing season.
Seral	An intermediate developmental stage in ecological succession (Wikipedia 2010).
Site	Fairly precise geographic location where one or more individuals of the species have been found.
Sporophyte	The portion of the plant life cycle when cells contain two (or more) sets of chromosomes, compared to the single set found in the gametophyte generation.
Stigma	The receptive part of the pistil on which the pollen germinates. (Correll and Johnston 1979).
Stratification	Seed treatment consisting of maintaining specific conditions, such as temperature and moisture levels, for specified periods of time.
Succession	Ecological succession is the change in composition and structure of an ecological community over time.
Synecology	Ecology of groups of coexisting organisms.
Taxonomy	Scientific classification of living organisms.
Tribe	A taxonomic rank between family and genus, sometimes subdivided into subtribes. (Wikipedia 2010).
Type locality	The location where a type specimen was collected.
Voucher specimen	A plant or animal specimen deposited in a collection to confirm the species identification and location.
Xenogamy	Sexual fertilization between different, unrelated individuals.
Xerophyte	A plant specifically adapted to arid environments.

U.S. FISH AND WILDLIFE SERVICE
5-YEAR REVIEW of *ABRONIA MACROCARPA*

Current Classification: Endangered.

Recommendation resulting from the 5-Year Review:

____ Downlist to Threatened
____ Uplist to Endangered
____ Delist
_X_ No change needed

Appropriate Listing/Reclassification Priority Number, if applicable:

Review Conducted By: Chris Best, Austin Ecological Services Field Office.

FIELD OFFICE APPROVAL:

Lead Field Supervisor, U.S. Fish and Wildlife Service

Approve Edith Erfling, acting Date 10/29/2010

REGIONAL OFFICE APPROVAL:

Acting
Assistant Regional Director, Ecological Services, U.S. Fish and Wildlife Service

Approve ______________________ Date 11/19/2010