U.S. FISH AND WILDLIFE SERVICE SPECIES ASSESSMENT AND LISTING PRIORITY ASSIGNMENT FORM

Scientific Name:

Streptanthus bracteatus

Common Name:

Bracted twistflower

Lead region:

Region 2 (Southwest Region)

Information current as of:

05/29/2015

Status/Action

___ Funding provided for a proposed rule. Assessment not updated.

___ Species Assessment - determined species did not meet the definition of the endangered or threatened under the Act and, therefore, was not elevated to the Candidate status.

___ New Candidate

_X_ Continuing Candidate

___ Candidate Removal

> ___ Taxon is more abundant or widespread than previously believed or not subject to the degree of threats sufficient to warrant issuance of a proposed listing or continuance of candidate status
>
> ___ Taxon not subject to the degree of threats sufficient to warrant issuance of a proposed listing or continuance of candidate status due, in part or totally, to conservation efforts that remove or reduce the threats to the species
>
> ___ Range is no longer a U.S. territory
>
> ___ Taxon mistakenly included in past notice of review

___ Taxon does not meet the definition of "species"

___ Taxon believed to be extinct

___ Conservation efforts have removed or reduced threats

___ More abundant than believed, diminished threats, or threats eliminated.

___ Insufficient information exists on taxonomy, or biological vulnerability and threats, to support listing

Petition Information

___ Non-Petitioned

_X_ Petitioned - Date petition received: 08/05/2014

90-Day Positive:

12 Month Positive:

Did the Petition request a reclassification? **No**

For Petitioned Candidate species:

Is the listing warranted(if yes, see summary threats below) **Yes**

To Date, has publication of the proposal to list been precluded by other higher priority listing? **Yes**

Explanation of why precluded:

Higher priority listing acttions, including court orders and court-approved settlement agreements; meeting statutory deadlines for petition findings or listing determinations; emergency listing evaluations and determinations; and response to litigation. We will continue to monitor the status of this species as new information becomes available. For information on listing actions taken over the past 12 months, see the discussion of Progress on Revising the Lists, in the current CNOR which can be viewed on our Internet website (http://endangered.fws.gov/).

Historical States/Territories/Countries of Occurrence:

- **States/US Territories**: Texas
- **US Counties**:County information not available
- **Countries**:Country information not available

Current States/Counties/Territories/Countries of Occurrence:

- **States/US Territories**: Texas
- **US Counties**: Bexar, TX, Hays, TX, Medina, TX, Travis, TX, Uvalde, TX
- **Countries**:Country information not available

Land Ownership:

Bracted twistflower has been documented at 16 Element Occurrences (NatureServe 2002) since 1989. The owners of these sites are summarized in Table 1.

Table 1. Ownership of bracted twistflower Element Occurrences.[1]

Owners	No. of Sites	Percent of Sites
Private	6	37.5
City of Austin, TX	4	25.0
Medina County	1	6.3
City of San Antonio, TX	1.5	9.4
TxDOT	1	6.3
TPWD	1	6.3
Dept. of Defense	0.5	3.1
Austin Community Foundation	1	6.3
TOTALS:	16	100

1. Element Occurrences are defined in NatureServe (2002) and are discussed in the historical range/distribution section (below).

Lead Region Contact:

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Lead Field Office Contact:

AUSTIN ESFO, Chris Best, 512-490-0057, chris_best@fws.gov

Biological Information

Species Description:

Species Description (adapted from McNeal 1989, p. 14 and Poole *et al*. 2007, pp. 470–471)

Bracted twistflower (*Streptanthus bracteatus*) is a herbaceous annual plant of the Mustard Family (Brassicaceae) currently reported from five counties of south-central Texas. The seeds germinate in response to fall and winter rainfall, forming basal rosettes (clusters of leaves that radiate from the root crown); the young plants resemble radish seedlings. The waxy bluish-green basal leaves, up to 15 centimeters (cm) (5.9 inches (in)) long, have broadly lobed margins. Flower stalks emerge the following spring bearing showy lavender-purple flowers; often these stalks are un-branched and 46 to 61 cm (18 to 24 in) tall, but may reach 137 cm (54 in) in height, and have several long branches.

The lower stem leaves have an elongated heart shape and the upper leaves are progressively shorter, ultimately reduced to very short, triangular bracts (modified leaves) at the base of each flower stem. Thin seed pods, known as “siliques,” are up to 12 cm (4.7 in) long and 4 millimeters (mm) (0.15 in) wide; they mature and dry during the summer, finally splitting open to release flattened seeds with narrow wings. The foliage withers as the fruits mature, and the plants die during the blazing heat of summer.

Taxonomy:

About 100 species of Streptanthus have been described, although many of these have more recently been placed in Caulanthus, Boechera, Thelypodium, or other genera (Tropicos 2011a, pp. 1â€“2). The Flora of North America treatment recognizes about 35 species from the central and western U.S. and northern Mexico (Al-Shehbaz 2011, p. 700). Gray (1848, p. 146) described Streptanthus bracteatus as a new species, based on specimens collected by Ferdinand Lindheimer near New Braunfels, Texas, in 1846. Kuntze (1891, p. 933, cited in Tropicos 2011c, p. 1) classified this taxon as Erysimum bracteatum (A. Gray) Kuntz. Nevertheless, the Flora of North America (Al-Shehbaz 2011, p. 706), Tropicos (2011b, p. 1), the Integrated Taxonomic Information Service (2011, p. 1), the International Plant Names Index (2011, p. 1), and the Plants Database (Natural Resources Conservation Service 2011, p. 1) treat this taxon as a valid species with the name Streptanthus bracteatus. Pepper (2010, p. 14) concluded that S. bracteatus is a morphologically and evolutionarily distinct species; its closest extant relative is the broadpod jewelflower, S. platycarpus, a west Texas endemic. Poole et al. (2007, p. 470) list â€œbracted twistflowerâ€ and â€œbracted jewelflowerâ€ as common names for this species. While the latter is also used by the Plants Database, the botanists and conservation organizations who work with this species primarily use the former name. For the purposes of this document, we will refer to Streptanthus bracteatus as bracted twistflower.

The Flora of North America treatment (Al-Shehbaz 2011, p. 700â€“723) distinguishes bracted twistflower from most other members of the genus on the basis of its sessile cauline leaves (leaves of the flower stalk that lack stems) and completely bracteate racemes (all flower stems have a small modified leaf at their bases). Bracted twistflower is most similar to S. platycarpus, a species of west Texas and the Mexican state of Coahuila, and is distinguished from it by the following characters: petal length, stamens, capsule size, number of ovules, and length of style.Â Â

Therefore, we concur that bracted twistflower is a distinct, valid species.

Table 2.A Characteristics distinguishing bracted twistflower and broadpod jewelflower.

Characters	Bracted twistflower	Broadpod jewelflower
Petal length	14-19 mm (0.55-0.74 in)	16-27 mm (0.63-1.06 in)
Stamens (pollen-bearing flower part)	Tetradynamous (four long and two short stamens)	Two long, two medium, and two short stamens

Capsule size	8-14.5 cm (3.1-5.7 in) long by 2.5-4 mm (0.1-0.16 in) wide	4-9.5 cm (1.6-3.7 in) long by 4.6-6.1 mm (0.18-0.24 in) wide.
Number of ovules (female sex cells in ovary of flower)	48-80 per ovary	26-42 per ovary
Length of style (stalk connecting ovary and stigmas)	1-3.5 mm (0.04-0.14 in)	0.5-2 mm (0.02-0.08 in)

Habitat/Life History:

McNeal (1989, pp. 14â16) described five Travis County bracted twistflower populations that occurred mostly at or near the tops of ridges in thin clay soils overlying limestone formations. Dense populations occupied very small areas, often in narrow bands perpendicular to the slope, where winter soil moisture was greater than in surrounding areas. However, groups of plants appeared in different portions of the same habitat from one year to the next, up to 137 meters (m) (450 feet (ft)) away from the previous yearâs location. Tree canopy cover ranged from 25 to 100 percent, and the shrub understory was often dense, but there was very little herbaceous ground cover. Bracted twistflower plants were heavily browsed by deer unless protected by dense shrubs; however, in sites protected from deer, some plants grew in more open vegetation.Â McNeal (1989, p 15) observed that most Travis County populations occur very near the Balcones fault line. Zippin (1997, p. 223) found the species over limestone of the Glen Rose, Walnut, and Edwards formations; one site, however, occurred on Quaternary alluvium. Carr (2001a, p. 1) observed that bracted twistflower may occur most often in canyons where the Edwards or similar limestone formation occurs as a thin caprock stratum overlying the Upper Glen Rose limestone formation. Pepper (2010, p. 5) describes the species as a geologic or edaphic endemic, since âall known populations occur within 1 kilometer (km) (0.6 miles (mi)) of the Balcones Fault Zone, and are perched above a thick impermeable layer of limestone or dolomiteâ. Both limestone and dolomite are sedimentary carbonate rocks; while the former is composed of calcite and/or aragonite, which are crystalline forms of calcium carbonate (CaCO3), the latter is composed of calcium magnesium carbonate (CaMg(CO3)2) (Wikipedia 2011a, p. 1; 2011b, p.1). Fowler (2014, pp. 11-12) determined that 17 occupied sites (some of which are sub-populations within the same Element Occurrence) were all within 1.85 km (1.15 mi) of the boundary between the Edwards or Devils River formations and the Glen Rose formation (see figure 2); the Edwards and Devils River formations overlie the Glen Rose. These sites averaged 843 m (0.52 mi) in horizontal distance and 29 m (95 ft) in absolute vertical distance from this boundary (absolute vertical distance assigns a positive sign to all elevation differences). Fowler (2014, p. 12) proposed two hypotheses to explain this association of bracted twistflower with the boundary between two geological formations: 1) The species depends on increased seepage between these formations; and 2) the species requires higher levels of magnesium ions that leach from dolomitic limestone in the lower strata of the Edwards formation. The Bracted Twistflower Working Group (2010, pp. 2 to 3) is seeking analyses of soil samples to determine if the species is associated with dolomite.

We received descriptions of plant species associated with bracted twistflower populations from 12 independent sources (see Appendix 1 for sources). Of the more than 100 species reported, bracted twistflower occurs most often under a tree canopy of Juniperus ashei (Ashe juniper), Quercus fusiformis (Texas live oak)), Diospyros texana (Texas persimmon), Sophora secundiflora (Texas mountain laurel), and Quercus buckleyi (Texas red oak). The species is frequently found within a dense understory of small trees and shrubs, includingÂ Rhus virens (evergreen sumac), Acacia roemeriana (Roemer acacia), Mahonia trifoliolata (agarita), Garrya ovata ssp lindheimeri (Lindheimer silk-tassel), Ageratina havanensis (thoroughwort), and Bernardia myricifolia (oreja de ratÃ³n). Nevertheless, in sites protected from white-tailed deer, the most robust bracted twistflower plants occur where woody plant cover is less dense (Damude and Poole 1989, pp. 29â30; Poole et al. 2007, p. 470). Therefore, the dense shrub thickets where the species is often found may serve as refugia from herbivory, but may not be its optimal habitat.

Zippin (1997) investigated the herbivory and population biology of bracted twistflower. In 1994 and 1995, survival rates of flowering bracted twistflower plants at several sites ranged from 40 to 98 percent (Zippin 1997, p. 57). Deer-exclusion cages significantly increased the probability of survival, reproduction, above-ground biomass, and seed set, compared to un-caged plants, at a bracted twistflower population near Mesa Drive in Austin where the deer population was very high (Zippin 1997, p. 60). Deer reduced survival by 40 percent, and selectively browsed the largest bracted twistflower plants (Zippin 1997, p. 65). Nevertheless, the rosettes (prior to flowering) were very resistant to herbivory, and plants flowered even after all rosette leaves had been eaten (Zippin 1997, pp. 62â63). The most common insect herbivore was the falcate orange-tip (Anthocharis midea, Pieridae), a Brassicaceae specialist, which fed primarily on flowering bracted twistflower plants in late April and May (Zippin 1997, p. 61). Other potential insect herbivores included flea beetles (Psylliodes, Chrysomelidae) (Zippin 1997, pp. 61â62). Deer herbivory reduced growth more than insects (Zippin 1997, p. 64). Seeds were able to germinate 1 to 2 months after dispersal, and germinated best when placed just below the soil surface (Zippin 1997, p. 187). Large numbers of plants emerged from the soil seed bank of one site following two years in which 95 percent of seeds were removed by deer or other factorsÂ (Zippin 1997, p. 226). However, no seed bank, regardless of size, will persist if not replenished for 15 (or probably fewer) years (Zippin 1997, p. 191).Â The light requirements of bracted twistflower are centrally important to the management of its habitat. Ramsey (2010, pp. 1â35) conducted controlled laboratory and outdoor experiments to compare the speciesâ growth and reproduction under different light regimes. Although survival rates were not significantly different under varying light regimes, the growth rates, biomass, and reproductive output of mature plants was significantly greater when exposed to direct sunlight for all or part of a day versus plants grown under a shade cloth that reduced sunlight intensity to 42 percent of non-shaded levels (pp. 10â13). Ramsey stated that the highly shaded environments where the species is often found are probably not ideal, and recommended that reintroduction sites have exposure to full sun for at least 60 percentÂ of the day length (p. 20). Â Lower light levels may also induce higher incidences of an Ascomycete fungus parasite (family Erysiphaceae), commonly known as a âpowdery mildew,â that frequently attacks the plants and may kill them (p. 21) (see figure 1, photograph 3).

Leonard (2010a, pp. 1â86) also compared the response of bracted twistflower to varying levels of light intensity, as well as nutrients, soil moisture, soil depth, and herbivory. Potted plants grown in wire cages with varying grades of shade cloth were exposed to 1,353 Â± 10 micro-moles per square meter per second (ÂµMm-2s-1), 919 Â± 10 ÂµMm-2s-1, 530 Â± 25 ÂµMm-2s-1, and 286 Â± 10 ÂµMm-2s-1 (Leonard 2010a, pp. 17â19). Shoot height, basal diameter, and above- and below-ground biomass all increased with increasing light levels, and above-ground, below-ground, and total biomass were significantly greater at the highest compared to the two lowest light levels (but not the second highest light level) (Leonard 2010a, pp. 30â32). Similarly, potted plants were grown in a natural setting with and without deer exclosures under full sun (1,229 Â± 10 ÂµMm-2s-1) and beneath a live oak canopy (397 Â± 45 ÂµMm-2s-1). The caged plants in full sun had significantly greater biomass than un-caged full-sun plants. Interestingly, the caged full-sun plants had greater biomass than caged shaded plants, but conversely, the unprotected plants in the shade had greater biomass than unprotected plants in full sun. This difference is probably attributable to increased herbivory of sun- versus shade-grown plants; the wild population at this site (Rancho Diana natural area) is heavily browsed by deer (Leonard 2010a, pp. 58 and 61). Leonard also observed herbivory by the checkered white butterfly (Pontia protodice) at the Eisenhower Park natural population (p. 61). Seed germination trials indicated that seeds germinate better at 21Â° to 32Â° Celsius (C) (70Â° to 90Â° Fahrenheit (F)) than at 10Â° C (50Â° F); exposure to sunlight and florescent lights also improved germination (p. 17). Recommended management of bracted twistflower populations includes excluding herbivores and thinning tree and shrub canopies; however, if deer cannot be excluded, only the tree canopy should be thinned, leaving the shrubs to protect herbaceous plants from deer (Leonard 2010a, p. 63).

Fowler (2010, pp. 1â18) investigated the response of bracted twistflower seedlings transplanted in deer-fenced plotsÂ in the spring of 2009 in a naturally-vegetated site at Vireo Preserve, Travis County, with varying degrees of canopy cover; these experimental plots and their progeny are listed as Element Occurrence 33 in the Texas Natural Diversity Database (2012).Â Â The experimental plots were protected from deer;Â however,Â severe herbivory, apparently from squirrels, continued until the plants were individually protected with wire cages (p. 7). Where there was less cover and greater light availability, the plants had higher fecundity (seed production), which is the most relevant measure to predict future population size for annual plants (Fowler 2010, p. 9). The optimal conditions at this site would have been 50 percent cover or less, which would be expected if bracted twistflower were a fire-following species (p. 10). Prior to the 20th century, frequent wildfires probably occurred in or near bracted twistflower habitats, and are now very infrequent (Bray 1904, pp. 14â15, 23â24; see discussion below). However, the fire ecology of bracted twistflower has not been investigated. Fowlerâs results (2010, p. 11) do support a recommendation to manage vegetative cover at existing populations so that it does not exceed 50 percent.

At least some of the bracted twistflower plants in Fowlerâs experimental plots at Vireo Preserve produced mature fruits that dispersed seed naturally on-site during the summer of 2009. On December 21, 2011, several volunteer plant surveyors observed numerous newly germinated bracted twistflower plants growing spontaneously in two of eight plots; since no natural populations are known from this site, they concluded that these plants were progeny of Fowlerâs experimental plants (Stewart 2012a, pp. 1â10). On the same day, these volunteers transplanted 40 nursery-grown bracted twistflower seedlings into the six plots that did not have spontaneously germinated bracted twistflower plants. Not long afterward, severe herbivory was observed on bracted twistflower plants growing within the deer exclosures; this was assumed to be caused by a rodent, most likely a tree squirrel or Mexican ground squirrel. OâDonnell (cited in Stewart 2012a) placed rodent-exclusion cages over some plants. On March 26, 2012, the only surviving plants were found inside the rodent-exclusion cages. These observations demonstrate that it is feasible to transplant bracted twistflower into suitable habitats, and that it is possible for the transplanted seedlings to flower and disperse viable seed, and for that seed to germinate spontaneously two years later. Hence, it may be possible to reintroduce and restore viable populations of this species by transplanting nursery-grown seedlings. However, herbivory by rodents, in addition to white-tailed deer, is severe enough to wipe out small populations of bracted twistflower. Therefore, the long-term success of reintroduction efforts will depend on limiting or overwhelming herbivory by white-tailed deer, rodents, and other herbivores.Â The reported populations of bracted twistflower, like many annual plants, fluctuate greatly from year to year (McNeal 1989, p. 15; Zippin 1997, p. 222). Anecdotal reports from surveyors indicate that bracted twistflower populations increase following seasons of above-average fall and winter precipitation (Zippin 1997, p. 225). However, Fowler (2011a, p.1; 2011b, pp. 1â9) compared Barton Creek population sizes and Camp Mabry precipitations from 1993 to 2005 (Camp Mabry is 9.7 km (6.0 mi) northeast of the Barton Creek population). Using Spearmanâs rank correlation coefficient, no significant correlations existed between annual population sizes and the corresponding precipitation totals from the preceding October to December, preceding January to March, or concurrent April to June (see Table 3). Similarly, Fowler found no significant correlations between the annual average reported size of six bracted twistflower populations with the corresponding seasonal precipitation averages from Austin, San Marcos, and San Antonio, Texas. Nevertheless, the failure to detect correlations between precipitation and population size may be due to different surveyors using different methods, or to other factors such as disturbance, competition, and herbivory. Of particular interest is whether bracted twistflower germination is stimulated by wildfire, disturbance to vegetation or soil, or other factors in addition to rainfall.

The above information, in synthesis, support the hypotheses that bracted twistflowersÂ are best adapted to sites with less than 50 percent cover of woody plants, and that severe herbivory by dense populations of white-tailed deer has largely extirpated the plant from its optimal habitats. It may persist for a time in the protection of dense thickets, or it may gradually decline. In addition, the germination of seeds and reproduction of bracted twistflower in the wild appears to respond to as-yet unknown triggers. This compels us to consider how historic vegetation changes may have affected bracted twistflower populations. Bray (1904, pp. 14, 22) described a very apparent, ongoing transition of Edwards Plateau uplands from grassland to woodland at the beginning of the twentieth century. At that time, the well-watered canyons supported dense forests with trees over 500 years old; stunted but continuous forest covered hills and bluffs; sparse trees were found on loose, stony slopes in the eastern Edwards Plateau (precisely where bracted twistflower populations currently occur); and trees were then invading the open prairies on the level plateau divides (uplands), which previously were free of woody vegetation (Bray 1904, pp. 14â15). He attributed this change to overgrazing and the consequent depletion of grasses, erosion, and cessation of wildfires, and stated that open prairies had been converted to dense oak scrub in a span of 25 years (Bray 1904, pp. 14â15, 22â23). These historic descriptions support a hypothesis that bracted twistflower is a relict of a woodland-grassland ecotone (transition zone) that occurred at or near the confluence of loose, stony slopes and prairie uplands. This savanna, in the broad sense of the term, would have been influenced periodically by wildfires of varying intensity and frequency. Some Streptanthus species, such as S. heterophyllus (San Diego wild cabbage), germinate following wildfires (Moreno and Oechel 1991, pp. 1999â2000), thus, fire may also be a trigger of bracted twistflower emergence.

We received 59 reports of bracted twistflower phenology from surveyors (listed in Appendix 1). Rosettes have been reported in October, November, and March, and presumably can be seen throughout the winter months. The relatively few rosette observations (five) reflects the difficulty of positive species identification at this life stage; prior to flowering, bracted twistflower is easily confused with another member of the mustard family, rock cress (Arabis petiolaris) (Damude and Poole 1990, p. 6). From 79 to 90 percent of seed germination occurs during October and November (Zippin 1997, p. 222). Flowering peaks in April and may continue into May and June. Fruits have been observed from April through June. Mature seeds have been collected most often in June, but occasionally as late as August.

Dieringer (1991, pp. 341â343) investigated the pollination ecology of one population of bracted twistflower . He determined that it is primarily an outcrossing species, although 6.3 percent of self-pollinated flowers set fruit. A locally common species of leafcutter bee, Megachile comata (family Megachilidae), was an effective pollinator. About 29 percent of un-manipulated flowers set fruit, 12 percent of fruiting plants were eaten by deer, and 11 percent of fruit capsules were damaged by seed-eating insects.Â

Pepper (2010, pp. 9â10) assessed the genetic status of 14 bracted twistflower populations in Travis, Bexar, Medina, and Uvalde counties. This investigation examined deoxyribonucleic acid (DNA) from leaf samples of 318 individuals, using microsatellite DNA markers from Caulanthus amplexicaulis var. barbarae; these markers are useful for studying genetic relationships in the Streptanthoid complex (Burrell and Pepper 2006, p. 3). Wrightâs Fst and Neiâs genetic distance showed that the species has substantial genetic differentiation (Pepper 2010, p. 11). Much of the speciesâ genetic differentiation is between rather than within populations and most populations are genetically distinct and are not undergoing appreciable inter-population gene flow (Pepper 2010, p. 11). Deviations from the expected Hardy-Weinberg values indicated the extent of inbreeding, genetic drift, gene flow, and natural selection. The Barton Creek and Cat Mountain populations are the most genetically diverse and are core reservoirs of the species diversity (Pepper 2010, p. 12). The privately owned CR 2700 and PR 2632 populations in Medina County are also genetically diverse (Pepper 2010, pp. 12â13). Geographically isolated populations are more distinct, due to genetic drift, founder effects, isolation, or lineage sorting of alleles (Pepper 2010, p. 11). The populations at Garner State Park (SP), Bright Leaf Preserve, Camp Bullis, Fall Trail, and Eisenhower Park had exceedingly low levels of genetic diversity; Mt. Bonnell also had relatively low genetic diversity. Inbreeding is most prevalent in the smaller, more isolated populations, such as Eisenhower Park (Pepper 2010, p. 15). The Cat Mountain, Barton Creek, and Mt. Bonnell populations had unexpectedly high levels of inbreeding, despite the genetic diversity of the first two mentioned; this may be due to subdivision within these larger populations (Pepper 2010, p. 14). The Ulrich population is genetically distinct from other Austin populations and may represent a remnant of the species original genetic diversity (Pepper 2010, p. 17).

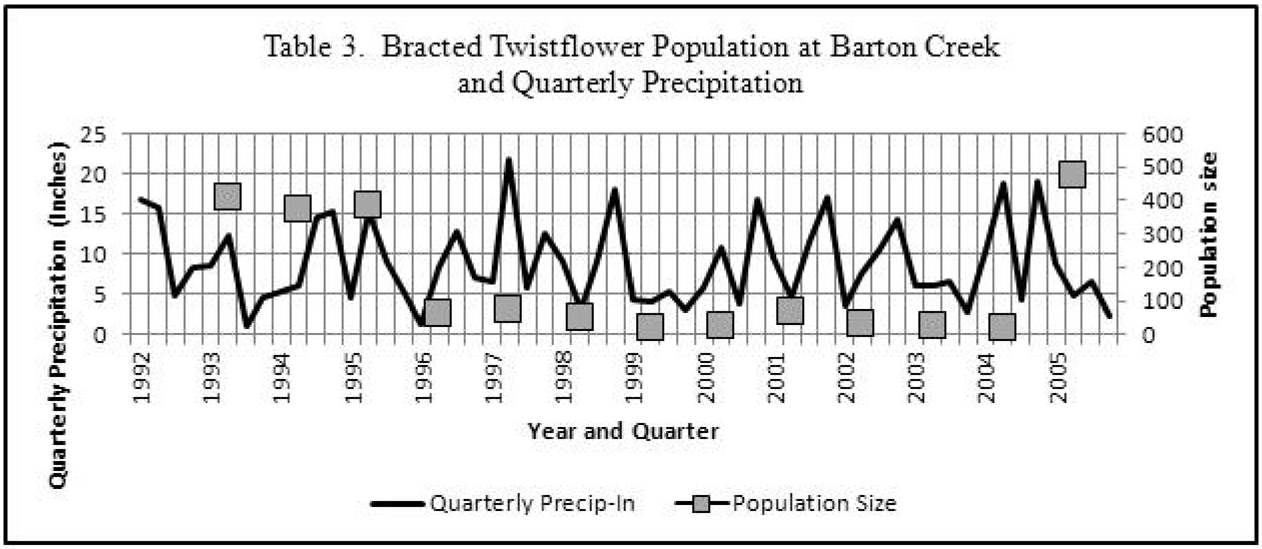

Table 3. Bracted Twistflower Population at Barton Creek and Quarterly Precipitation

Source of precipitation data: National Climate Data Center 2011.

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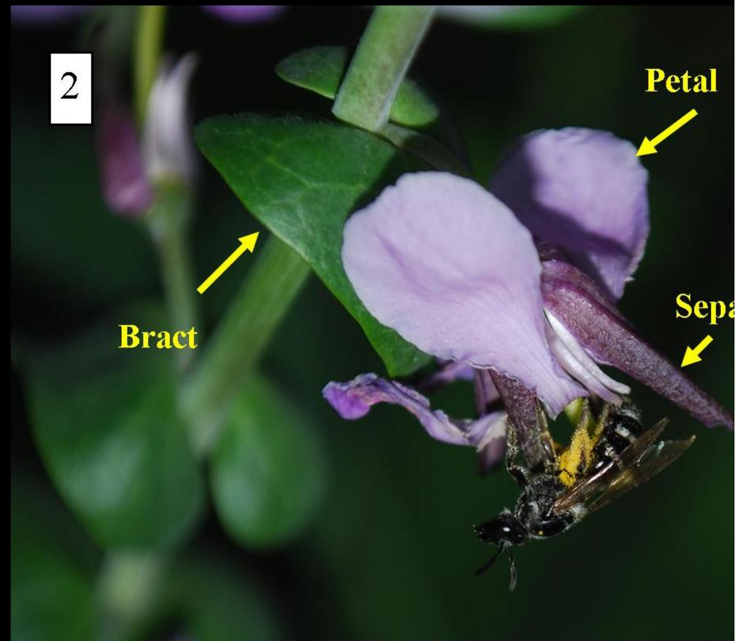
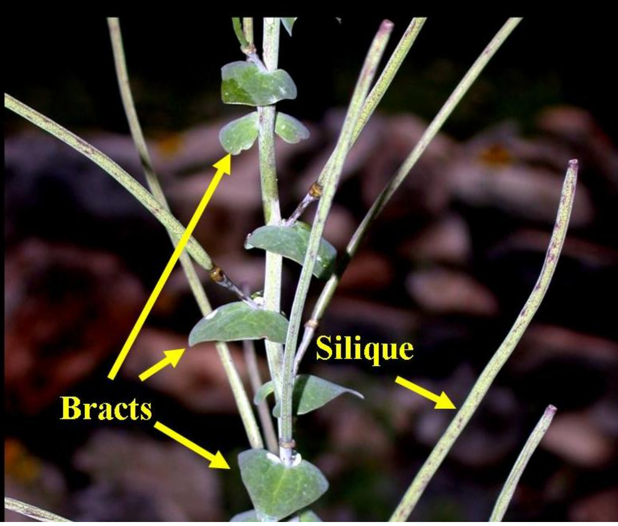
Figure 1. Images of bracted twist-flower.



1. Volunteer Walter Stewart (standing) with propagated bracted twistflower.
2. Flower and Halictid bee, possibly female *Lasioglossum* sp. (Neff 2011).
3. Lower stem leaf with powdery mildew infestation.
4. Habitat in Medina County.
5. Developing siliques (seed capsules).




Historical Range/Distribution:

For practical purposes, we distinguish the historic locations of bracted twistflower populations, which were not accurately mapped or described, from the accurately described and mapped locations of recent reports (1989 to the present). The geographic and survey data of bracted twistflower populations have been compiled in the Texas Natural Diversity Database (TXNDD), managed by Texas Parks and Wildlife Department (TPWD). The geographic sites, termed “Element Occurrences” (EOs), are defined as “areas of land and/or water in which a species or natural community is, or was, present” (NatureServe 2002, p. 1). In other words, an EO is the geographic area where a population or its habitat occurred or occurs. Element occurrences have been adopted by TPWD and our other conservation partners as a standard geographic unit for populations and habitats; we are also using the EO standard here to maintain consistency. Element occurrences are displayed as points and polygons buffered by their estimated geographic precision. Historic reports that lack precise geographic coordinates are represented by relatively large polygons; more recent survey data collected with global positioning systems (GPS) are represented by smaller polygons. The reported populations occur or occurred within, but not necessarily throughout, the polygons in the range map (Figure 2). TPWD recently revised all bracted twistflower EOs, which resulted in the consolidation of many of the previously-reported EOs (Texas Natural Heritage Database 2012 pp. 1–119). We summarize both the historic and recent population data from all sources in Tables 4 and 5, respectively.

The herbarium label from Ferdinand Lindheimer’s original collection states only “15. Streptanthus. New Braunfels. May 1846.” However, like many field botanists of that era, Lindheimer listed the location of his base of operations rather than the specific collection site (Texas Natural Diversity Database 2012, p. 108); the collection site is unknown but is assumed to have been in Comal County. Similarly, most of the historic collections listed in Table 4 cannot be ascribed to specific locations. These historic collections are represented on the range map (Figure 2) as circles rather than points; the radius of the circles indicates their estimated geographic precision.

Table 4. Historic collections of bracted twistflower listed in the Texas Natural diversity Database (2012, pp. 1–119) that have not been observed since 1989.

EO_Num[1]	EO_ID[1]	County	Site Name	Most Recent Observation	Collector, Specimen No., and Herbarium[2]
001	2210	Comal	Unknown	1846	F.J. Lindheimer 15 (GH), 5180 (MO)
027	23	Bandera/Kerr	Bandera Pass	1884	J. Reverchon s.n. (MO)
028	1989	Real	Leakey	1916	E.J. Palmer 10155 (MO)
030	3831	Bexar	14 miles SE of Comanche Spring	1849	Lindheimer 676

1. EO_Num (Element Occurrence Number) and EO_ID (Element Occurrence Identity) from Texas Natural Diversity Database 2012.
2. Herbaria: GH = Gray Herbarium (Harvard University; MO = Missouri Botanical Garden; SMU = Southern Methodist University; TEX = University of Texas-Austin; TEX-LL = University of Texas-Austin.

Current Range Distribution:

Table 5. 16 bracted twistflower EOs that have been observed since 1989. The populations are located in Travis, Hays, Bexar, Medina, and Uvalde counties.

1. EO_Num (Element Occurrence Number) and EO_ID (Element Occurrence Identity) from Texas Natural Diversity Database 2012.
2. Maximum Population: The greatest number of individuals recorded from this EO in a single year.
3. 2012 survey data provided by Cullen Hanks (TPWD) at Bracted Twistflower Working Group meeting, July 10, 2012, at the Lady Bird Johnson Wildflower Center, Austin, TX.
4. Conservation Status: NP = Not Protected; PNA = Protected Natural Area; PE = Presumed Extirpated.
5. Habitat Condition: PI = Partially Intact; I = Intact; ROW = Managed Highway Right-of-Way; D = Developed/Destroyed.

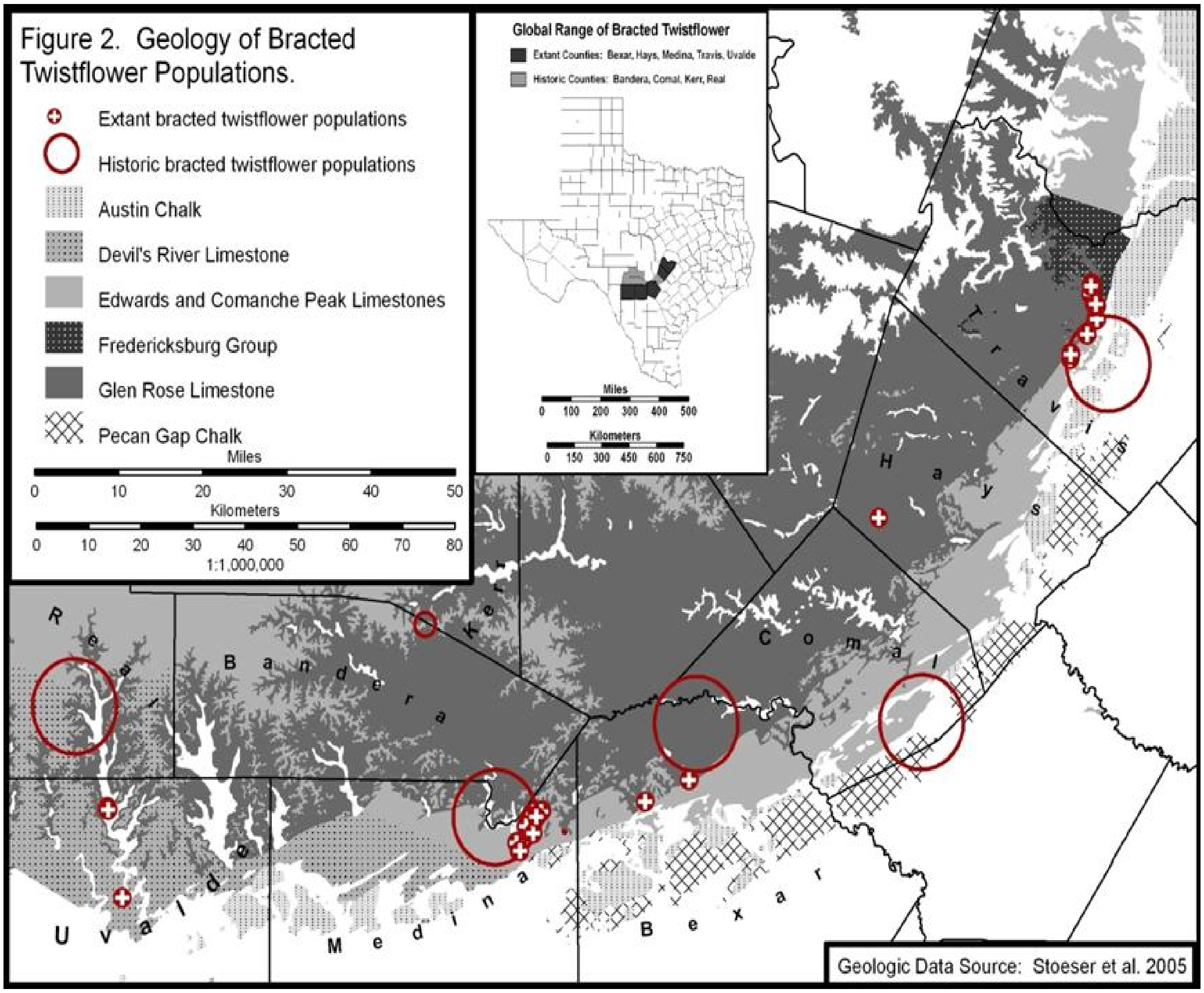


Figure 2. Geology of Bracted Twistflower Populations.

Population Estimates/Status:

It is challenging to interpret the size and trends of bracted twistflower populations due to the wide annual fluctuation in the numbers of plants growing at each site.Fall and winter rainfall appear to stimulate germination and establishment of plants, although other factors that are not yet understood may also be involved. Like other annual plants, the species persists through its “soil seed bank” (the quantity of viable, dormant seeds that are present in the soil). We do not know how many viable seeds reside in the soil seed banks nor how long the seeds remain viable in the soil, or what factors stimulate their germination. For these reasons, we estimate the potential population size of each EO as the maximum number of plants observed there in any single year; Table 5 includes these maximum population sizes.

It is also difficult to ascertain the area occupied by these populations. Within a specific site and year, the plants are often found in areas ranging from less than 0.4 ha (1 ac) to 10 ha (25 ac); in subsequent years, the plants may appear in another small portion of the same site (Damude and Poole 1990, p. 30). The plants tend to cluster in narrow horizontal bands where winter soil moisture persists longer (McNeil 1989, p. 14), suggesting that they are dependent on seepage of perched groundwater through the fissures between limestone strata. The density and type of upslope vegetative cover influences the proportion of rainfall that infiltrates into the soil and is stored as groundwater. Compared to native vegetation, impermeable surfaces impede the infiltration of rainwater and the recharge of perched groundwater, and consequently may reduce the habitat suitability for this species. Therefore, it appears that bracted twistflower is restricted to very small portions of a larger habitat mosaic, and the actual habitat required to support its populations is likely to be much larger than the finite areas the species occupies in any single year.

An obvious indication of the status of bracted twistflower populations is the condition of their habitats, including the soil structure, rock strata, and associated vegetation. It is reasonable to assume that an entire population is lost if its habitat is completely converted to pavement, structures, non-native vegetation, or other artificial surfaces. Where habitat is completely intact, the population may or may not persist, depending on other factors. It is likely that partial destruction or degradation of habitat results in at least partial loss or decline of a population. Therefore, a practical measure of this annual plant's overall status is the number of populations with intact habitat, together with their potential (maximum observed) population sizes. Another important consideration is whether the intact sites are on some form of protected or managed natural area; intact sites on private land are likely to be lost at the rate that the local economy drives development. Table 6 summarizes the maximum populations, conservation statuses, and habitat conditions of the reported EOs. In summary, of 16 EOs reported since 1989, 9 remain with intact habitat, 4 have degraded or partially destroyed habitat, and 3 are presumed extirpated. Only 7 of the intact sites are on protected natural areas. This corresponds to a loss of 960 individuals (12.5 percent) of the potential maximum population since 1989; 2,397 individuals (31.3 percent) of the potential maximum population are intact and present in protected natural areas. (Note that some of the reported populations that surveyors previously tracked separately have now been combined into individual EOs in the TXNDD, in accordance with EO standards established by NatureServe (2002, p. 1).

Table 6 summarizes habitat conditions and statuses of the 16 EOs observed since 1989. In summary, 9 EOs remain with intact habitat, 2 EOs are partially intact, 2 are on managed rights-of-way, and 3 sites have been developed and the populations are presumed extirpated. Only 7 of the intact EOs and portions of 2 EOs, representing 2,502 individuals (33 percent of the maximum populations observed since 1989), are on protected natural areas. Four EOs with 3,708 individuals (48 percent of the maximum populations) are intact but vulnerable to development and other impacts. Five EOs have been partially or completely developed, resulting in the loss of 1,449 individuals (19 percent of the maximum populations). Two EOs (32 and 02) were destroyed in 2012 and 2013, respectively.(Note that some of the reported populations that surveyors previously tracked separately have now been combined into individual EOs in the TXNDD, in accordance with EO standards established by NatureServe (2002, p. 1).

Table 6. Statuses of Element Occurrences observed since 1989.

1. Portions of two Element Occurrences were destroyed by development, but the remaining portions are within adjacent protected natural areas. Therefore, these populations are counted both

as protected and lost.

Threats

A. The present or threatened destruction, modification, or curtailment of its habitat or range:

The greatest threat to bracted twistflower is habitat loss due to urban and residential land development (McNeal 1989, p. 17; Damude and Poole 1990, p. 51; Zippin 1997, p. 229; Fowler 2010, p. 2; Pepper 2010, p. 5). Our analysis of the 16 EOs reported since 1989 indicates that 3 have been extirpated, portions of 2 have been extirpated, 2 are in disturbed habitat, and 9 are intact. Of the intact EOs, 2 are vulnerable to development, and 7 intact EOs and portions of 2 EOs, representing 33 percent of the maximum populations recorded since 1989, occur in protected natural areas (see Tables 5 and 6). The Rough Hollow population (EO32) in Hays County was discovered in 2010; by 2012, the site had been bulldozed. The Cat Mountain population (EO02) in Travis County, which was a core reservoir of the species' genetic diversity (Pepper 2010, p. 12), was located on private land that was sold in 2011 (Bracted Twistflower Working Group 2010, pp. 3–4; Stewart 2012); this site was completely bulldozed in 2013 (Fowler 2014, p. 16). Fortunately, Holder (2003a, pp. 1–3) and Stewart (2012b) collected seeds from this and several other populations (with landowner approval) for the seed bank managed by the Lady Bird Johnson Wildflower Center. Therefore, habitat loss is an imminent threat throughout the species range to the populations not on protected natural areas and is likely to continue.

In addition, changes in vegetation structure and composition, specifically the increased density of woody plant cover, appear to be detrimental to bracted twistflower (Pepper 2010, p. 5). Laboratory and field experiments conducted by Fowler (2010, pp. 10–11), Leonard (2010a, p. 63), and Ramsey (2010, p. 20) demonstrated that the species benefits from higher light intensity and duration than it receives in many of the extant populations; its persistence in dense thickets may be due to increased herbivory of the plants growing in more open vegetation (Leonard 2010a, p. 63; Ramsey 2010, p. 22). Some Streptanthus species, such as S. heterophyllus, germinate in response to wildfire (Moreno and Oechel 1991, pp. 1999 to 2000). The positive reproductive response of bracted twistflower to higher light levels is consistent with the hypothesis that it may also be a fire-adapted species (Fowler 2010, pp. 3, 10). Bray (1904, pp. 14–15, 23–24) documented the rapid transition of grasslands to woodlands in the Edwards Plateau occurring more than a century ago; he attributed this change to over-grazing, the depletion of grasses, and the cessation of wildfires. We conclude that bracted twistflower habitats were probably influenced by frequent wildfires and that the frequency of wildfires has decreased greatly since pre-settlement times; therefore, bracted twistflower may be a fire-adapted species, and the lack of wildfire may have contributed to its decline. The increase in density of woody plant cover has occurred incrementally over a span of decades, but affects most bracted twistflower populations, including those on protected natural areas, and may also have caused a gradual decline in population sizes.

Both permitted and unauthorized recreation threatens the species' survival at several protected natural areas, as well as on private lands. Hiking and mountain bike trails have impacted the populations at Mt. Bonnell City Park, Barton Creek Preserve, and Garner SP through trampling of the herbaceous vegetation and severe soil erosion where trails cut directly through occupied habitats (McNeal 1989, p. 19; Fowler 2010, p. 2; Bracted Twistflower Working Group 2010, p. 3; Pepper 2010, pp. 5, 15, 17). Unauthorized mountain bike trails have also impacted the populations on private lands at Bull Creek District Park and Cat Mountain City Park (Bracted Twistflower Working Group 2010, p. 3; Holder 2011a, p.1, 2011b, p. 1).

Therefore, based on our evaluation, we conclude that bracted twistflower is threatened by the present and threatened destruction, modification, or curtailment of its habitat and range, now and in the foreseeable future.

B. Overutilization for commercial, recreational, scientific, or educational purposes:

We are not aware of any direct use or overuse of bracted twistflower plants.

C. Disease or predation:

Severe herbivory by white-tailed deer is a major, imminent threat to bracted twistflower throughout the species' range, except where populations are protected from deer by fencing or intensive herd management (hunting) (McNeal 1989, p. 17; Damude and Poole 1990, pp. 52–53; Dieringer 1991, p. 341; Zippin 1997, pp. 39–197, 227; Leonard 2010a, pp. 36–43; Fowler 2014, pp. 17, 19) and is exacerbated by the extremely high deer densities in the Edwards Plateau of Texas (Zippin 1997, p. 227). The foliage of bracted twistflower is very palatable to many browsing animals, including squirrels (Fowler 2010, p. 7), and even humans (Kral 1990 cited in Damude and Poole 1990, p. 51). Exotic ungulate species such as aoudad (Ammotragus lervia), which have been widely introduced on game ranches and now exist in self-sustaining feral populations in central Texas, present an additional potential threat (Damude and Poole 1990, pp. 52 - 53). It is also likely that bracted twistflower populations were impacted during historic periods of poor rangeland management in central Texas, particularly by herds of goats and sheep.

Bracted twistflower is highly susceptible to attack from a powdery mildew fungus (Ascomycota, family Erysiphaceae) which may be more severe when plants grow in dense, shaded thickets (Ramsey 2010, p. 21; Leonard 2010a, p. 53). The fungus species has not yet been identified; it may be an introduced pathogen to which bracted twistflower has no resistance (Bracted Twistflower Working Group 2010, p. 2). We do not yet know the magnitude of this threat. However, Fowler (2014, p. 17) found that, contrary to expectation, the incidence of powdery mildew was positively associated with reproductive output (plants with greater degrees of powdery mildew infestation produced more viable seed).

A number of insect herbivores have been documented on bracted twistflower (Dieringer 1991, pp.

341–342; Zippin 1997, pp. 39–70; Leonard 2010a, pp. 53; Ramsey 2010, pp. 15, 21); however, the dispersed pattern of insect herbivory may be less harmful than the focused herbivory of deer and other ungulate browsers (Zippin 1997, pp. 70–71; Leonard 2010a, pp. 59–60). Consequently, insect herbivory appears to be a relatively low-magnitude threat.

Based on our evaluation, we conclude that bracted twistflower is threatened by disease and predation now and in the foreseeable future.

D. The inadequacy of existing regulatory mechanisms:

Bracted twistflower is not currently protected by existing state or federal laws, except where it occurs at Garner SP (Section 59.134 of the Texas Parks and Wildlife Code states “It is an offense for any person to willfully mutilate, injure, destroy, pick, cut, remove, or introduce any plant life except by permit issued by the director (Texas Secretary of State 2011)). Nevertheless, over 300,000 people visit Garner SP each year, and the bracted twistflower population there has declined in part due to the very heavy recreational use of its habitat (Pepper 2010, p. 5).

Based on our evaluation, we conclude that the existing regulations do not address the threats to bracted twistflower.

E. Other natural or manmade factors affecting its continued existence:

Due to the small size and isolation of bracted twistflower populations, several may already suffer from genetic bottlenecks, genetic drift, inbreeding, and loss of allelic diversity; consequently, these populations may be less able to survive and to adapt to other ongoing threats, including urbanization, increased herbivory, pathogens, vegetation change, and climate change (Pepper 2010, p. 6). Furthermore, such small populations are more vulnerable to catastrophic losses from chance events. The species as a whole still possesses sufficient genetic diversity to assure its survival, but many of the remaining populations have very little genetic diversity and relatively high levels of inbreeding (Pepper 2010, pp. 12– 5). Furthermore, several of the core reservoirs of the species’ genetic diversity occur on private lands and may be lost to development (Pepper 2010, pp. 18–19). These core populations are critical to the long-term genetic viability of the species (Pepper 2010, p. 4), and their loss would be a potential threat to the species’ survival. Several of the extant bracted twistflower populations occur on conservation lands managed as nesting habitat for the golden-cheeked warbler, a federally listed endangered species. However, since the nesting habitat of the golden-cheeked warbler consists of dense, mature stands of Ashe juniper, various oak species and other broadleaf trees (Service 2011, p.4), vegetation management for warbler nesting may be incompatible with the more open canopy required by bracted twistflower . Therefore, incompatibility with golden-cheeked warbler habitat management may be a potential threat to bracted twistflower.

The Intergovernmental Panel on Climate Change (IPCC) (2007, p. 8) predicts that the southwestern U.S. may experience the greatest temperature increase of any area in the lower 48 States, and that many semi-arid areas like the western United States will suffer a decrease in water resources, due to climate change. Milly et al. (2005, p. 347) project a 10 to 30 percent decrease in precipitation in mid-latitude western North America by the year 2050 based on an ensemble of 12 climate models. It is more difficult to predict how climate will change at the finite geographic scale of bracted twistflower populations. Furthermore, climate changes may have vastly complex, unpredictable synecological (community ecology) effects; for example, reduced rainfall may be relatively more detrimental to an invasive competitor, and therefore benefit rare plant species of concern. Nevertheless, the rapid pace of projected climate change and the proliferation of man-made barriers to migration represent potential threats to the species' continued survival.

We conclude that bracted twistflower is potentially threatened by other natural or manmade factors, including the small size and isolation of populations, the limited genetic diversity within some populations, the potential incompatibility with habitat management for the golden-cheeked warbler, and the potential effects of climate change.

Conservation Measures Planned or Implemented :

Seven extant populations (EOs) of bracted twistflower occur in protected natural areas. Deer exclosures have been installed at the Barton Creek Greenbelt site.

Bracted twistflower is not specifically protected by the Balcones Canyonlands Habitat Conservation Plan (BCCP). However, a voluntary Memorandum of Agreement between and among the Service, TPWD, City of Austin, Travis County, Lower Colorado River Authority, and Lady Bird Johnson Wildflower Center sought to protect bracted twistflower and its habitats on Balcones Canyonlands Preserve tracts (Service *et al.* 2004). These tracts include Covert Park at Mt. Bonnell, Ulrich Water Treatment Plant, and Barton Creek Greenbelt. The agreement provides for monitoring and restoration of existing populations, surveys for new populations, reintroduction, protections from deer, and public education about the need to conserve the species. While the scope of this agreement does not protect the species throughout its range, the implementaiton of these responsibilities will contribute to the species' conservation and recovery.

The recovery of bracted twistflower will require the reintroduction and augmentation of stable, healthy populations in protected sites (Pepper 2010, p. 6). The Bracted Twistflower Working Group (2006, pp. 1-30) prepared a draft reintroduction plan, and the species has been successfully propagated (p. 25). However, at least ten previous attempts to restore populations in appropriate sites failed, indicating that the species' requirements were not fully understood (Bracted Twistflower Working Group 2006, p. 18; Pepper 2010, p 6). Fowler (2010, pp. 1–18) established experimental plots at the BCCP Vireo Preserve in 2009. During the winter and spring of 2011–2012, progeny of the experimental plants germinated at the site, and some of these plants flowered and set seed (Stewart, 2012a, pp. 1–10); this indicates that it may be possible to reintroduce viable populations in appropriate sites. Stewart (2012a, pp. 1–10) developed techniques for seed increase under controlled conditions in a plant nursery, using seeds of Medina County origin that had previously been propagated for multiple generations at San Antonio Botanical Garden and consequently were considered to have little conservation value. In this initial trial 30 out of 42 seeds germinated and 22 of these plants survived to maturity, producing 1,509 siliques and 72,251 seeds. Stewart and other volunteers are currently using these methods to increase seed stock of accessions in the seed bank at Lady Bird Johnson Wildflower Center. The source seeds were collected a decade ago and several source populations have subsequently been lost to development. Working in coordination with the Bracted Twistflower Working Group, these volunteers hope to expand the seed stock of lost populations – while they are still viable – to replenish and augment the seed bank and to conduct pilot reintroductions at protected sites. This group initiated a pilot reintroduction at Vireo Preserve in Travis County by transplanting nursery-grown seedlings into deer- and rodent-fenced plots on December 21, 2011 (Stewart 2012a, pp. 1–10).

Summary of Threats :

The continued survival of bracted twistflower is imminently threatened by habitat destruction from urban development, severe herbivory from very dense herds of white-tailed deer as well as small mammals, and the increased density of woody plant cover. Additional ongoing threats include erosion and trampling from foot and mountain bike trails, a pathogenic fungus of unknown origin, and the inadequacy of existing regulations to protect the species from development, herbivory, vegetation change, erosion, trampling, and pathogenic fungi. Furthermore, due to the small size and isolation of remaining populations and lack of gene flow between them, several populations are now inbred and may have insufficient genetic diversity for long-term survival. Although seven EOs and portions of 2 EOs are protected from development in Protected Natural Areas, these populations are nevertheless threatened by herbivory, vegetation change, erosion, trampling, pathogenic fungi, isolation and fragmentation of populations, and low genetic diversity. Optimal vegetation management of bracted twistflower populations may be incompatible with the management of nesting habitat of the endangered golden-cheeked warbler. The species is potentially threatened by as-yet unknown impacts of climate change.

We find that bracted twistflower is warranted for listing throughout all of its range, and therefore, find that it is unnecessary to analyze whether it is threatened or endangered in a significant portion of its range.

For species that are being removed from candidate status:

_____ Is the removal based in whole or in part on one or more individual conservation efforts that you determined met the standards in the Policy for Evaluation of Conservation Efforts When Making Listing Decisions(PECE)?

Recommended Conservation Measures :

- Continue to search for new populations on public conservation land as well as private lands (with landowner permission).
- Provide technical guidance and material support to private landowners who voluntarily wish to conserve the species on their land.
- Manage the existing populations on protected natural areas more rigorously, including installation of deer exclosures, closing illicit foot and mountain bike trails, enforcing applicable regulations that protect the habitats on public property, and conducting public outreach.
- To the extent allowed under the existing habitat management plans or applicable regulations, maintain less than 50 percent cover of woody plants at occupied habitats.
- Protect multiple populations within each area of the species' genetic diversity in Medina and Travis counties (Pepper 2010, p. 15).
- Continue to investigate the species' ecology and optimal habitat requirements, particularly the fire ecology, geology, and associated vegetation structure.
- Conduct pilot reintroductions to determine effective methods of population reintroduction and augmentation.
- Continue to collect seeds from extant populations for seed bank storage and propagation, in accordance with USFWS policy on controlled propagation of endangered species (FR 65: 56916). Propagate plants from the representative genetic ecotypes (genotypes that are specifically adapted to a specific ecological area) and produce seed for experimental and reintroduction efforts (to prevent excessive collection from wild sources and depletion of the soil seed bank at extant populations).
- Reintroduction and augmentation must use seeds from ecotypes adapted to the sites. Avoid translocating propagules of an ecotype into sites that support a genetically distinct ecotype (Pepper 2010, p. 17).

Priority Table

Magnitude	Immediacy	Taxonomy	Priority
High	Imminent	Monotypic genus	1
		Species	2
		Subspecies/Population	3
	Non-imminent	Monotypic genus	4
		Species	5
		Subspecies/Population	6
Moderate to Low	**Imminent**	Monotypic genus	7
		Species	**8**
		Subspecies/Population	9
	Non-Imminent	Monotype genus	10
		Species	11
		Subspecies/Population	12

Rationale for Change in Listing Priority Number:

Magnitude:

The principle threats to bracted twistflower are habitat loss, severe herbivory by white-tailed deer, increased density of woody plant cover, and habitat degradation from harmful recreational uses. Habitat loss affects bracted twistflower populations on private land throughout the species' range; 3 populations documented since 1989 are presumed extirpated, 4 have been disturbed or partially extirpated, and 2 are intact but vulnerable to development. Although 7 documented populations occur in protected natural areas in Travis and Bexar Counties, they are nevertheless threatened by herbivory, increased woody plant cover, and other threats. Significant new populations were discovered as recently as 2010 at Garner SP in Uvalde County, Rancho Diana City Park in Bexar County, and private land in Hays County, and it is reasonable to assume that more populations exist and may be discovered in the future. White-tailed deer herbivory potentially affects all populations but can be alleviated with exclusion fencing and/or intensive deer herd management. Woody plant cover is too dense at many of the populations, including those on protected natural areas, and may be causing a gradual decline in populations. However, this threat can be alleviated through improved vegetation management of populations on protected natural areas and through voluntary agreements with private landowners. Unauthorized mountain bike and foot trails have impacted some populations, but can be prevented by enforcing existing laws and regulations, including state trespass laws. The magnitude of these threats is currently moderate.

Imminence :

Habitat loss, white-tailed deer herbivory, increased woody plant cover, and unauthorized recreational use are all imminent, ongoing threats to bracted twistflower. Potential and long-term threats include depletion of genetic diversity, the pathogenicity of a powdery mildew fungus, incompatibility with gold-cheeked warbler habitat management, inability to reintroduce or augment populations in protected sites, and possible impacts of climate change.

__Yes__ Have you promptly reviewed all of the information received regarding the species for the purpose of determination whether emergency listing is needed?

Emergency Listing Review

__No__ Is Emergency Listing Warranted?

Description of Monitoring:

Botanists and trained volunteers from TPWD, The Nature Conservancy, the Lady Bird Johnson Wildflower Center, the cities of Austin and San Antonio, the Balcones Canyonlands Preserve, and academic institutions, as well as private individuals, have conducted surveys for bracted twistflower and monitoring of known populations consistently since 1989. Under the terms of the Memorandum of Agreement described above (Service et al. 2004), the Lady Bird Johnson Wildflower Center has coordinated the efforts of the organizations and individuals concerned with the conservation of this rare plant. This consortium was initially called the Streptanthus Conservation Corps but has more recently adopted the name “Bracted Twistflower Working Group” (Bracted Twistflower Working Group 2010). Appendix 1 (below) lists the sources of monitoring data that were provided to us by various members of the Bracted Twistflower Working Group that were used and cited in the current review. The members of this group intend to continue annual surveys and monitoring of this species, and have made frequent recommendations on its conservation, research needs, and recovery.

Indicate which State(s) (within the range of the species) provided information or comments on the species or latest species assessment:

Texas

Indicate which State(s) did not provide any information or comment:

none

State Coordination:

The Texas Parks and Wildlife Department compiled and provided Element Occurrence data from the Department’s Natural Diversity Database. We also consulted with Jackie Poole of the Department’s Wildlife Diversity Program.

Literature Cited:

Al-Shehbaz, I.A. 2011. Streptanthus. In: Flora of North America Editorial Committee, eds. 1993+. Flora of North America North of Mexico 7:700 to 723. http://www.efloras.org/ Accessed: March 2, 2011.

Bracted Twistflower Working Group. 2006. Proposed Reintroduction Plan: Streptanthus bracteatus (bracted twistflower) draft. 30 pp.

Bracted Twistflower Working Group. 2010. Notes from June 17, 2010 meeting at Bright Leaf Preserve.

Bray, W.L. 1904. The timber of the Edwards Plateau of Texas; its relation to climate, water supply, and soil. U.S. Department of Agriculture Bureau of Forestry Bulletin no. 49. Washington, D.C. 30 pp.

Burrell, A.M. and A.E. Pepper. 2006. Primers for 10 polymorphic microsatellites from Caulanthus amplexicaulis var. barbarae, and cross-amplification in other species within the Streptanthoid Complex (Brassicaceae). Molecular Ecology Notes 6:770 to 772.

Carr, W.R. 2001a. Email to Charmaine Delmatier, Jeff Hershey, Mary Ruth Holder, Donald Koehler, Flo Oxley, and Dana Price, August 20, 2001. 4 pp.

Carr, W.R. 2001b. Notes on a small population of bracted twistflower at Brightleaf State Natural Area, Travis County, Texas. Report to The Nature Conservancy. 5 pp.

Damude, N. and J.M. Poole. 1990. Status Report on Streptanthus bracteatus. Texas Parks and Wildlife Department, Austin Texas. 86 pp.

Dieringer, G. 1989. Report on the reproductive biology of Streptanthus bracteatus (Brassicaceae). Submitted to Austin Parks and Recreation Department. Austin, Texas. 7 pp. + 2 attachments.

Dieringer, G. 1991. Pollination ecology of Streptanthus bracteatus (Brassicaceae): A rare central Texas endemic. The Southwestern Naturalist 36:341 to 343.

Fowler, N. 2010. Habitat requirements of the bracted twistflower, Streptanthus bracteatus (Brassicaceae), a rare plant of central Texas. Final report: Grant no. TX E-96-R. Texas Parks and Wildlife Department. 18 pp. + 8 pp. of figures and tables.

Fowler, N. 2011a. Email sent to Chris Best, U.S. Fish and Wildlife Service, March 14, 2011. 1 p.

Fowler, N. 2011b. PDF document attached to email sent on March 14, 2011 to Chris Best, U.S. Fish and Wildlife Service. 9 pp.

Fowler, N. 2011c. Locations of Streptanthus Plants. Summary of geographic locations sent to Chris Best, U.S. Fish and Wildlife Service. 3 pp.

Gray, A. 1848. Genera Florae Americae Boreali-Orientalis Illustrata 1: 146, pl. 60.

Holder, M.R. 2003a. Seed Collection Form, Streptanthus bracteatus, Cat Mountain, June 23, 2003. Submitted to LadyBird Johnson Wildflower Center. 3 pp.

Holder, 2003b. Seed Collection Form, Streptanthus bracteatus, 7000 Valburn Dr., June 21, 2003. Submitted to Lady Bird Johnson Wildflower Center. 3 pp.

Holder, M.R. 2004. Seed Collection Form, Streptanthus bracteatus, 7000 Valburn Dr., July 18, 2004. Submitted to Lady Bird Johnson Wildflower Center. 3 pp.

Holder, M.R. 2010. Streptanthus Occurrences (Microsoft Office Excel Worksheet). 8 pp (as printed).

Holder, M.R. 2011a. Email to Chris Best, U.S. Fish and Wildlife Service, March 31, 2011. 1 p.

Holder, M.R. 2011b. Email to Chris Best, U.S. Fish and Wildlife Service, April 1, 2011. 1 p.

Integrated Taxonomic Information Service. 2011. Streptanthus bracteatus Gray. http://www.itis.gov. Accessed March 2, 2011.

Intergovernmental Panel on Climate Change. 2007. Fourth Assessment Report Climate Change 2007: Synthesis Report Summary for Policymakers. Released on 17 November 2007. Available at: http://www.ipcc.ch/pdf/assessment-report/ar4/syr/ar4_syr_spm.pdf

International Plant Names Index. 2011. Streptanthus bracteatus A. Gray. http://www.ipni.org/ Accessed: March 4, 2011.

Kral, R. 1990. Personal communication from Dr. Robert Kral, Curator of the Herbarium, Vanderbilt University, with N. Damude and J.M. Poole, Texas Parks and Wildlife Department.

Kuntze, C.E.O. 1891. Erysimum bracteatum (A. Gray) Kuntze. Revisio Generum Plantarum 2:933.

Leonard, W.J. 2008. Streptanthus bracteatus: May 30, 2008. Report on the population at Eisenhower Park. 1 p.

Leonard, W.J. 2009. 2009 Streptanthus bracteatus report. Report on the population at Eisenhower Park. 3 pp.

Leonard, W.J. 2010a. Bracted twistflower (Streptanthus bracteatus): The ecology of a rare Texas endemic. Master's thesis. University of Texas – San Antonio. San Antonio, Texas. 86 pp + xiv.

Leonard, W.J. 2010b. Texas Natural Diversity Database Reporting Form. Streptanthus bracteatus at Rancho Diana Natural Area, June 21, 2010. 3 pp.

Leonard, W.J. 2011a. Eisenhower Park's Streptanthus bracteatus data from 2000-2010. 1 p.

Leonard, W.J. 2011b. Bracted twist-flower (Streptanthus bracteatus) report for City of San Antonio Natural Areas 2009-2010. 6 pp.

Marr, M. 2010. Texas Natural Diversity Database Reporting Form. Streptanthus bracteatus at …. Ranch, Hays County, June 21, 2010. 3 pp.

Marr, M. and S. Ito. 2007a. Seed Collection Form, Streptanthus bracteatus, CR 270 Loop Right of Way, Medina County, June 20, 2007. Submitted to Lady Bird Johnson Wildflower Center.

Marr, M. and S. Ito. 2007b. Seed Collection Form, Streptanthus bracteatus, CR 2700 Right of Way, 0.8 miles north of CR 1283, Medina County, June 20, 2007. Submitted to Lady Bird Johnson Wildflower Center.

Marr, M. and S. Ito. 2007c. Seed Collection Form, Streptanthus bracteatus, CR 2700 Right of Way, 0.1 mile north of CR 1283, Medina County, June 20, 2007. Submitted to Lady Bird Johnson Wildflower Center.

Marr, M. and S. Ito. 2007d. Seed Collection Form, Streptanthus bracteatus, CR 1283 Right of Way, Medina County, June 20, 2007. Submitted to Lady Bird Johnson Wildflower Center.

McNeal, P. 1989. Status of Streptanthus bracteatus, Philadelphus ernestii and Amorpha roemerana in Travis County: A report for the Austin Regional Habitat Conservation Plan. Texas Parks and Wildlife Department, Austin, Texas.. 58 pp.

Merritt, J. and D. Bahr. 2005. Streptanthus bracteatus data sheet. Survey data for Eisenhower Park, March 22 to May 18, 2005. 6 pp.

Milly, P.C.D., K.A. Dunne and A.V. Vecchia. 2005. Global pattern of trends in streamflow and water availability in a changing climate. Nature. The Nature Publishing group. Vol. 438. November 17, 2005. pp. 347 to 350.

Moreno, J.M. and W.C. Oechel. 1991. Fire intensity effects on germination of shrubs and herbs in southern California chaparral. Ecology 72: 1993 to 2004.

National Climate Data Center. 2011. Texas Weather Data. http://ww7.ncdc.noaa.gov/IPS/cd/cd.html. Accessed: March 9, 2011.

Natural Resources Conservation Service. 2011. The PLANTS Database. Streptanthus bracteatus A. Gray. Bracted jewelflower. http://plants.usda.gov/ National Plant Data Center, Baton Rouge, LA 70874-4490 USA. Accessed: 4 March, 2011.

NatureServe. 2002. NatureServe Element Occurrence Standard. http://www.natureserve.org/explorer/glossary/gloss_e.htm. Accessed: April 27, 2011.

Neal, J. and J. Merritt. 2006. Streptanthus bracteatus data sheet. Survey data for Eisenhower Park, March 15 to May 1, 2006. 2 pp.

Neff, J.L. 2011. Email to Mike Quinn forwarded to Chris Best, U.S. Fish and Wildlife Service (identifications of bee photographs). April 18, 2011.

Pepper, A. 2010. The genetic status of the bracted twistflower, Streptanthus bracteatus (Brassicaceae), an imperiled species of the Balcones canyonlands. Final Report: Grant TX E-89-R. Texas Parks and Wildlife Department, Austin, Texas. 24 pp.

Poole, J.M., W.R. Carr, D.M. Price, and J.R. Singhurst. 2007. Rare Plants of Texas. Texas A&M University Press, College Station, Texas. 640 pp.

Price, D. 2005. Barton Creek plant list. Microsoft Word file. 1 p. as printed.

Price, D., J. Merritt, and J. Neal. 2007. Texas Natural Diversity Database Reporting Form. Streptanthus bracteatus at Eisenhower Park, April 16 and June 19, 2007.

Ramsey, C.A. 2010. Effects of light availability on Streptanthus bracteatus, a rare annual plant, and implications for reintroduction. Master's Thesis. University of Texas, Austin Texas. 35 pp.

Stewart, W. 2012a. Re: Need clarification on the Vireo Preserve Projects. Email from Walter Stewart to Chris Best, U.S. Fish and Wildlife Service. April 6, 2012. 10 pp.

Stewart, W. 2012b. Cat Mountain. Email from Walter Stewart to Chris Best, U.S. Fish and Wildlife Service. April 30, 2012. 1 p.

Stoeser, D.B., G.N. Green, L.C. Morath, W.D. Heran, A.B. Wilson, D.W. Moore, and B.S. Van Gosen. 2005. Txgeol_dd_polygon.shp. U.S. Geological Survey, Denver, CO. http://pubs.usgs.gov/of/2005/1351/. Accessed: May 27, 2010.

Texas Natural Diversity Database. 2012. Element occurrence printouts for Streptanthus bracteatus. Wildlife Diversity Program of Texas Parks and Wildlife Department. April 12, 2012.

Texas Secretary of State. 2011. State Administrative Code. http://www.sos.state.tx.us/tac/index.shtml. Accessed April 25, 2011.

Tropicos. 2011a. Missouri Botanical Garden. Streptanthus Nutt. Subordinate taxa. http://www.tropicos.org/ Accessed: March 25, 2011.

Tropicos. 2011b. Missouri Botanical Garden. Streptanthus bracteatus A. Gray. http://www.tropicos.org/ Accessed: March 2, 2011.

Tropicos. 2011c. Missouri Botanical Garden. Erysimum bracteatum (A. Gray) Kuntze. http://www.tropicos.org/ Accessed: May 3, 2011.

U.S. Fish and Wildlife Service. 2011. Golden-cheeked warbler (Dendroica chrysoparia). http://ecos.fws.gov/speciesProfile/profile/speciesProfile.action?spcode=B07W. Accessed: April 25, 2011.

U.S. Fish and Wildlife Service, Texas Parks and Wildlife Department, City of Austin, Travis County, Lower Colorado River Authority, and the Lady Bird Johnson Wildflower Center. 2004. Memorandum of Agreement. FWS number 201813K912. 16 pp plus 1 amendment.

Wikipedia. 2011a. Dolomite. http://en.wikipedia.org/wiki/Dolomite. Accessed: April 22, 2011.

Wikipedia. 2011b. Limestone. http://en.wikipedia.org/wiki/Limestone. Accessed: 22 April, 2011.

Zippin, D.B. 1993. List of bracted twistflower clusters on the Mesa Valley Subdivision. May 30, 1993. 5 pp.

Zippin, D.B. 1997. Herbivory and the population biology of a rare annual plant, the bracted twistflower. Ph. D. Dissertation. The University of Texas, Austin Texas. 265 pp.

Appendix

Appendix 1. Sources of data on populations, surveys, geographic locations, phenology, and associated vegetation.

Citation	Year	Page	Population Surveys	Geographic Data	Phenology	Associated Vegetation
Carr	2001	1-2	X	X	X	X
Damude and Poole	1990	8-12, 27-29, 31-41	X	X	X	X
Dieringer	1989	1-3	X		X	X
Fowler	2011b	1-3		X		
Holder	2003a	1-3	X	X	X	X
Holder	2003b	1-3	X		X	X
Holder	2004	1-2	X	X	X	
Holder	2010	1-8	X	X	X	
Leonard	2008	1	X			
Leonard	2009	1-3	X		X	
Leonard	2010b	1-3	X	X		X
Leonard	2011a	1	X		X	
Leonard	2011b	1-6	X		X	
Marr	2010	1-2	X	X	X	
Marr and Ito	2007a	1-2	X	X	X	
Marr and Ito	2007b	1-2	X	X	X	
Marr and Ito	2007c	1-2	X	X	X	
Marr and Ito	2007d	1-2				
McNeal	1989	14-15, 24-25, 27-28	X	X	X	X
Merritt and Bahr	2005	1-6	X	X	X	
Neal and Merritt	2006	1-2	X	X		
Poole et al.	2007	470-471			X	X
Price	2005	1				X
Price et al.	2007	1-3	X	X	X	X
Texas Natural Diversity Database	2012	1-119	X	X	X	
Zippin	1993	1-5	X	X	X	
Zippin	1997	221-225			X	X

Approval/Concurrence:

Lead Regions must obtain written concurrence from all other Regions within the range of the species before recommending changes, including elevations or removals from candidate status and listing priority changes; the Regional Director must approve all such recommendations. The Director must concur on all resubmitted 12-month petition findings, additions or removal of species from candidate status, and listing priority changes.

Approve: 06/03/2016
Date

Concur: 11/14/2016
Date

Did not concur: ______________________ ________
Date

Director's Remarks: