Pyne's ground-plum
(Astragalus bibullatus)

5-Year Review:
Summary and Evaluation

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U.S. Fish and Wildlife Service
Southeast Region
Cookeville Ecological Services Field Office
Cookeville, Tennessee

5-YEAR REVIEW
Pyne's ground-plum/*Astragalus bibullatus*

I. GENERAL INFORMATION

A. Methodology used to complete the review: In conducting this 5-year review, we relied on the best available information pertaining to historic and current distributions, life history, and habitat of this species. Our sources include the final rule listing this species under the Endangered Species Act; published reports and unpublished field observations by Service, National Park Service, Tennessee Valley Authority, State and other experienced biologists; unpublished survey reports; and notes and communications from other qualified biologists or experts. We published an announcement in the *Federal Register* requesting information on this species on July 29, 2008 (73 FR 43947), and a 60-day comment period was opened.

B. Reviewers

Lead Region: Southeast Region – Kelly Bibb, 404-679-7132

Lead Field Office: Tennessee Ecological Services Field Office – Geoff Call, 931-528-6481, ext. 213

C. Background

1. FR Notice citation announcing initiation of this review: July 29, 2008, 73 FR 43947

2. Species status: Stable – 2011 Recovery Data Call.

3. Recovery achieved: 2 (2=26-50% recovery objectives achieved).

4. Listing history
Original Listing
FR notice: 56 FR 48748
Date listed: September 26, 1991
Entity listed: Species
Classification: Endangered

5. Review History:
Recovery Data Call: 2011, 2010, 2009, 2008, 2007, 2006; 2005; 2004; 2003; 2002; 2001; 2000
Recovery Plan: 2011

6. Species' Recovery Priority Number at start of review (48 FR 43098):
2. This ranking is based on a high degree of threat, a high recovery potential, and its status as a species.

7. Recovery Plan:
Recovery Plan for *Astragalus bibullatus* (Pyne's ground-plum)
July 20, 2011

II. REVIEW ANALYSIS

A. Application of the 1996 Distinct Population Segment (DPS) policy: The Act defines species as including any subspecies of fish or wildlife or plants, and any distinct population segment of any species of vertebrate wildlife. This definition limits listing DPS to only vertebrate species of fish and wildlife. Because the species under review is a plant and the DPS policy is not applicable, the application of the DPS policy to the species listing is not addressed further in this review.

B. Recovery Criteria

1. **Does the species have a final, approved recovery plan containing objective, measurable criteria?** Yes

2. **Adequacy of recovery criteria.**

   a. **Do the recovery criteria reflect the best available and most up-to-date information on the biology of the species and its habitat?** Yes

   b. **Are all of the 5 listing factors that are relevant to the species addressed in the recovery criteria (and is there no new information to consider regarding existing or new threats)?** Yes

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**.

The goal of the recovery plan is to ensure the long-term viability of *Astragalus bibullatus* in the wild, allowing initially for reclassification of this plant to threatened status, and ultimately, to remove this plant from the *Federal List of Endangered and Threatened Plants* (50 CFR 17.12). The numbers of occurrences required below for reclassification to threatened is based on the assumption that protecting the eight extant *A. bibullatus* occurrences and replacing the three occurrences known to have been extirpated would result in the species no longer being at risk of extinction within the foreseeable future throughout all or a significant portion of its range. These additional occurrences could be either the result of introduction or newly discovered wild occurrences. The additional five

occurrences required for delisting are intended to provide additional redundancy on the landscape to minimize the potential that *A. bibullatus* would revert to threatened status following delisting.

Because the goal of this plan is ensuring long-term viability of the species in the wild, we have declined to set firm population abundance targets. As noted above, preliminary analyses of available monitoring data indicate that *Astragalus bibullatus* exhibits density-dependent regulation of population growth (Albrecht 2010). Further, the role of the seed bank in maintaining population viability is not yet well understood. Long-term monitoring data will be needed to better understand how demographic processes and environmental factors regulate population growth in this species. Establishing minimum population abundance thresholds as part of recovery criteria at this time would, therefore, be arbitrary. Instead, we will judge the viability of populations on the basis of population growth trends and whether observed population structure is likely to maintain those trends for the foreseeable future.

Astragalus bibullatus will be considered for reclassification to threatened status when there are 11 viable, protected occurrences distributed throughout the cedar glade ecosystem of the Stones River Basin within Davidson, Rutherford, or Wilson counties. Viability of each occurrence should be determined using a population viability analysis framework. Populations considered viable for recovery purposes should exhibit either stable or increasing long-term population growth trends and have been shown through at least 10 consecutive monitoring events to possess suitable population structure for maintaining observed population growth into the foreseeable future. In order for an *A. bibullatus* occurrence to be considered protected, it should be located:

- on lands owned and managed by a public agency, with a written plan committing resources to conservation of the cedar glade ecosystem and *A. bibullatus*, or
- on private lands protected by a permanent conservation easement, State Natural Area registry, or other legally binding agreement, with a written plan committing resources of the organization responsible for management of the site to conservation of the cedar glade ecosystem and *A. bibullatus*.

Astragalus bibullatus will be considered for delisting when there are 16 viable, protected occurrences that are distributed throughout the cedar glade ecosystem of the Stones River Basin within Davidson, Rutherford, and Wilson counties.

These recovery criteria have not been met; though, considerable progress has been made towards accomplishing them since the time that *Astragalus bibullatus* was listed. Five of the eight extant occurrences of this species are located on public conservation lands. A cooperative project involving the National Park Service, Missouri Botanical Garden, The Nature Conservancy, Tennessee Department of Environment and Conservation, and the Service, is addressing recovery tasks

related to propagation, establishing new populations through introductions, investigating factors regulating population growth, and monitoring population trends.

Listing/Recovery Factors Addressed by Recovery Tasks: Tasks listed below with each listing/recovery factor are examples of actions that may reduce or remove the identified threats.

Listing/Recovery Factor A: The Present or Threatened Destruction, Modification, or Curtailment of a Species Habitat or Range. To ensure the long-term recovery needs of *Astragalus bibullatus* and provide adequate assurance of population stability, threats to the ground-plum's habitat must be removed or minimized (see Reasons for Listing and Ongoing Threats for a discussion of applicable threats). This can be accomplished by the following actions:

a) Acquire habitat. (Task 1.1)
b) Pursue protection with landowners. (Task 1.2)
c) Develop and implement adaptive management plans for each occurrence. (Task 1.3)
d) Monitor population structure, demographic processes, and threats and assess population growth rates and viability. (Tasks 3.2 and 3.3)
e) Identify suitable unoccupied habitat and establish new occurrences. (Tasks 5.2 and 5.3)
f) Communicate with local officials to coordinate city and county planning. (Task 6)

Listing/Recovery Factor B: Overutilization for Commercial, Recreational, Scientific, or Educational Purposes. Little or no commercial trade in *Astragalus bibullatus* is known to exist at this time, and it is not anticipated that it will become an issue in the future. Likewise, overutilization for recreational, scientific, or educational purposes is not known to be an issue. However, Task 5.1 calls for maintaining a seed source *ex situ* for this species. These stored seeds could be used for reintroductions to replace extirpated occurrences if suitable habitat remains, for establishing new occurrences as part of recovery efforts, or for augmenting existing occurrences, where necessary.

Listing/Recovery Factor C: Disease or Predation. Albrecht and McCue (2010) observed that some spring transplants were browsed, and Walck (2007) observed herbivory or signs of it at three sites. We will monitor the severity of this potential threat through Task 3.2. Cages will be used in attempts to establish new populations or augment existing populations (Tasks 5.3 and 5.4), to protect plants from herbivory until they become reproductive adults.

Listing/Recovery Factor D: The Inadequacy of Existing Regulatory Mechanisms. *Astragalus bibullatus* is typically found growing on land that has a

high potential for residential or commercial development. Existing regulatory mechanisms do not protect these open, non-Federal lands from conversion to other uses such as residential or commercial development. The following actions can help to overcome these inadequacies and lead to recovery:

a) Pursue protection with landowners through land acquisition, conservation easements, or State Natural Area registries. (Tasks 1.1 and 1.2)
b) Communicate with local officials to coordinate city and county planning. (Task 6)
c) Develop and implement public education plans. (Task 7)

Listing/Recovery Factor E: Other Natural or Manmade Factors Affecting Its Continued Existence. Small population sizes likely diminish the resiliency of *Astragalus bibullatus* occurrences to stochastic disturbances, and the lack of redundancy across the landscape leaves the species at greater risk of extinction due to potential extirpation of these vulnerable occurrences. Management efforts to address this threat are constrained by limited knowledge of ecological and life history characteristics of the species. The following recovery actions should improve resilience of individual occurrences and provide sufficient redundancy to buffer the species against potential losses of individual occurrences:

a) Develop and implement adaptive management plans for each occurrence. (Task 1.3)
b) Search for new populations. (Task 2)
c) Study life history, ecological requirements, reproductive biology, and pollination ecology. (Tasks 4.1 and 4.2)
d) Maintain plant and seed sources *ex situ*. (Task 5.1)
e) Identify suitable unoccupied habitat. (Task 5.2)
f) Establish new occurrences within the historic range. (Task 5.3)
g) Augment existing occurrences, where necessary. (Task 5.4)

C. Updated Information and Current Species Status

1. Biology and Habitat

a. Abundance, population trends, demographic features, or demographic trends:

Astragalus bibullatus is endemic to the cedar glades of middle Tennessee and is presently known from 8 extant occurrences, all occurring in the Stones River watershed in the vicinity of Murfreesboro, Rutherford County, Tennessee (refer to II.C.e for further detail on glades). Five of the eight *A. bibullatus* occurrences are located on public lands. Four of these sites on public lands are within Designated State Natural Areas (DSNAs) owned by Tennessee Department of Environment and Conservation (TDEC), three of which were purchased using Recovery Land

Acquisition grants funded through section 6 of the Endangered Species Act and extend into adjacent private lands. One of these occurrences was planted into a cedar glade within the Stones River National Battlefield in March 2001 in a cooperative attempt by the Service, TDEC, National Park Service (NPS), and Missouri Botanical Garden (MBG) to establish a new occurrence. Absent further augmentation of this occurrence, its long-term viability is doubtful, as only four seedlings were found surviving in 2010 out of the 110 that were originally planted. The three remaining occurrences are located entirely on privately owned land. Table 1 provides a general summary of all extant and historic (i.e., extirpated) *A. bibullatus* occurrences.

Albrecht (2010) used count-based population viability analysis (PVA) to quantify population growth trends for three *Astragalus bibullatus* populations, based on a temporally limited dataset available from monitoring efforts. While population growth rates were slightly negative for all three occurrences, none of these estimates was statistically significant due to the large variances observed over the years in which monitoring occurred (Albrecht 2010). Despite the lack of a detectable trend in population growth, growth rates and population density were negatively correlated, suggesting density-dependent regulation of population growth.

The extant occurrences of *A. bibullatus* are typically small, consisting of tens to hundreds of individuals (Table 1). Only one occurrence has ever been estimated to include greater than 1,000 individuals. It is possible that many of the extant populations are reduced in size from historic levels, and are likely less resilient in the face of environmental stochasticity than they previously were. Morris et al. (2002) found lower densities of seeds and higher heterozygote deficiencies in shallow (i.e., presumably more recent) seed bank deposits of *A. bibullatus* occurrences compared to deeper seed bank deposits. They interpreted the apparent reduction in seed density of shallow deposits as evidence that contemporary rates of seed input have been lower than earlier rates. The differences in heterozygote deficiency, they concluded, were likely the result of increased incidence of inbreeding, which would decrease the effective population size.

Table 1. Summary of all extant and historic (i.e., extirpated – denoted with an "*") occurrences of *Astragalus bibullatus*. The column labeled "EO Number" refers to the element occurrence number assigned by TDEC. Site names are provided only for element occurrences on public lands. Population data are primarily from TDEC (2005) and represent approximate ranges from counts or estimates of abundance; where given, population data for extirpated occurrences are historic.

EO Number	*Ownership*	*Site Name*	*Population Data*
1	TDEC	Flat Rock Cedar Glades and Barrens DSNA	1,000 – 2,800
2*	Private		<100

3	TDEC and Private	Flat Rock Cedar Glades and Barrens DSNA	50 – 200
4	TDEC	Overbridge DSNA	10 – 45
5	Private		20 – 200
6	Private		100 – rumored to have been planted
8*	Public		n/a
9	Public	Manus Road Cedar Glade DSNA	250 – 520
10*	Private		n/a
13	NPS	Stones River NB	110 individuals planted in 2001; 2 found in 2008
16*	TDEC	Sunnybell Cedar Glade DSNA	Failed introduction
18	Private		<300

b. Genetics, genetic variation, or trends in genetic variation:

Investigations of genetic structure in *Astragalus bibullatus* using both isozymes (Baskauf and Snapp 1998) and amplified fragment length polymorphisms (AFLP) (Baskauf and Burke 2009) yielded comparable estimates of low levels of differentiation among populations; though, the AFLP study produced higher estimates of overall diversity and estimates of expected heterozygosity nearly twice those found with isozymes. Further, the AFLP study revealed no unique alleles in any of the populations. The results of these studies indicate that the origin of the seeds or plants used in establishing any new occurrences is probably not crucial. Baskauf and Burke (2009) concluded that, despite a history of small and fluctuating populations reported by Somers and Gunn (1990), the fact that the species is a perennial with a long-lived seed bank might have helped to reduce the rate of loss of genetic variability in populations of *A. bibullatus*.

In contrast to the studies of genetic variability from samples of vegetative material, Morris et al. (2002) investigated temporal and spatial genetic variability in the seed bank of *A. bibullatus* using allozyme analysis. They found high levels of among-site variability and the highest heterozygote deficiencies examining genetic structure in the seed banks within the top centimeter (cm) [0.4 inches (in)]of soil (i.e., within a stratum containing more recently deposited seeds). They did not detect significant differences among sites for the deepest (i.e., oldest) soil seed layers. Morris et al (2002) concluded that the among-site genetic structure they detected within the youngest soil seed layers was likely attributable to an increased incidence of inbreeding over time, due to the isolation of populations caused by fragmentation. They cited evidence that cedar glades were likely more widespread and had lower densities of trees in the past and that land use changes in the last century led to increased shading and fragmentation of habitats due to woody plant encroachment. Morris et al. (2002) surmised that, because of these

environmental changes, *A. bibullatus* populations were reduced in size and gene flow among them was likely restricted, leaving them vulnerable to effects of genetic drift and inbreeding.

c. Taxonomic classification or changes in nomenclature:

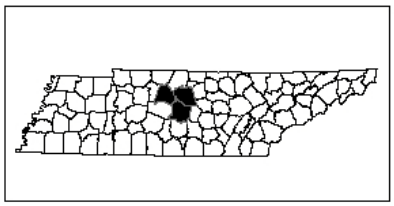
Specimens that are now assigned to *A. bibullatus* were apparently first collected as early as 1881 by the Tennessee botanist, Augustin Gattinger. For over 100 years, this material was assigned to *A. crassicarpus*, a related but morphologically and geographically distinct species that occurs approximately 750 kilometers (466 miles) to the west. Milo Pyne discovered the Rutherford County, Tennessee, site in 1979, which later became the type locality for the species. Botanists familiar with the genus *Astragalus* determined that the plants found by Pyne might represent a new species. In 1985, flowering and fruiting material from the type locality was sent by Jerry Baskin to Rupert Barneby, a monographer of the genus at the New York Botanical Garden. Barneby concluded that this was a new species, *A. bibullatus*, and described it with Edwin Bridges (Barneby and Bridges 1987). Kartez (1994) recognizes *A. bibullatus* as the correct name for plants in Tennessee.

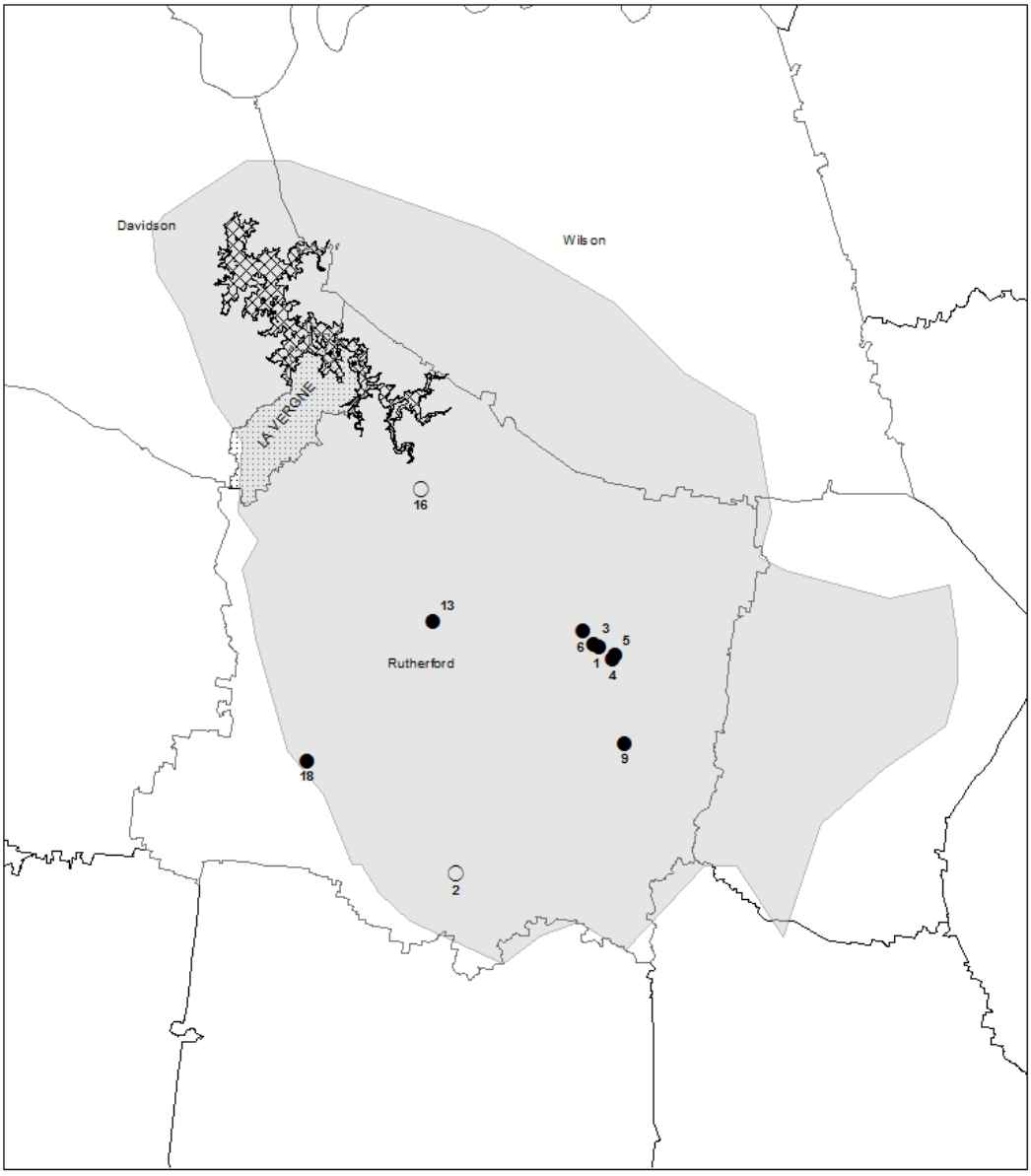
d. Spatial distribution, trends in spatial distribution, or historic range:

Until 2006, the known occupied range of *A. bibullatus* was restricted to an approximately 90 km^2 (35 mi^2) area, and no occurrences were separated by a distance greater than approximately 18 km (11 mi). An occurrence that TVA biologists discovered during a 2006 survey of a powerline right-of-way extended the currently known range approximately 16 km (10 mi) to the southwest and expanded the area encompassing the species' current range to approximately 235 km^2 (90 mi^2). All known occurrences are located within approximately 25 km (15 mi) of one another in Rutherford, County, Tennessee. The occurrence discovered in 2006 raises two important considerations. First, most of the surveys conducted for recovery efforts have focused on habitats in close proximity to existing occurrences. Second, TVA discovered the occurrence in a small opening in an otherwise heavily wooded cedar forest, which would likely not have been recognized as suitable habitat for recovery surveys. This survey was required for TVA's analysis of environmental effects from a proposed powerline right-of-way. The discovery of this occurrence, in a small opening within a matrix of presumably unsuitable habitats, approximately 16 km (10 mi) from the nearest historic or extant occurrence of *A. bibullatus*, provides evidence that we should consider the entire formerly continuous cedar glade ecosystem within Davidson, Rutherford, and Wilson counties as the geographic range for recovering this species (Figure 1). In addition, we must consider the potential for occurrences to exist in areas where habitat conditions have degraded due to vegetation succession in the absence of disturbance. Doing so is appropriate from a biogeographic perspective and increases opportunities for discovering currently unknown occurrences or establishing new occurrences on publicly owned

conservation lands, as discussed under task E.2 in the Recommendations for Future Actions section in Part IV of this review.

Figure 1. Known locations of extant (filled circles) and extirpated (empty circles) occurrences of *A. bibullatus* in relation to Stones River watershed (shaded gray), the city of La Vergne, and Davidson, Rutherford, and Wilson counties. J. Percy Priest Reservoir is shown with cross hatching. Extirpated EO numbers 8 and 10 are omitted because precise locations are not known.





There are believed to be three extirpated natural occurrences of *Astragalus bibullatus* (Table 1), all from Rutherford County. The first was collected near the city of La Vergne by Augustin Gattinger, probably in 1881 (Barneby and Bridges 1987), and is represented by a specimen in the Smithsonian Institution [Gattinger s.n. (US-70229)] (Wurdack 2011). Several surveys have been conducted in this area, which has seen extensive residential and commercial development, and all failed to locate any plants of this species. Vegetative material collected in 1948 from a site near the Rutherford/Davidson County line by botanists from the University of Tennessee at Knoxville is represented in the University of Tennessee Herbarium (TENN) by duplicate sheets labeled "Rutherford Co., N. of Lavergne, calcareous barrens, 19 June 1948, S. Fairchild, E. Clebsch, A. J. Sharp 7592" (Wofford 2011). The site from which the plant was collected is now under the waters of J. Percy Priest Reservoir (Figure 1). Note that this site was described in the final listing rule for *A. bibullatus* as being located just north of the Rutherford/Davidson County line (Service 1991), but that description conflicts with the herbarium label. Examinations of glades in both counties adjacent to this part of the reservoir have failed to locate any *A. bibullatus*. The third site occurred on private land that was commercially developed in the mid-1990s. Recent surveys in this area have failed to locate any *A. bibullatus*. It is unlikely that this species still exists at these three sites. Occurrence number 16 is listed as extirpated in Table 1, but actually represents a failed attempt to establish a new occurrence on a DSNA by transplanting nursery propagated plants into the habitat.

e. Habitat or ecosystem conditions:

All known occurrences are associated with limestone cedar glade ecosystems in middle Tennessee, a rare community type which has an extraordinarily high number of endemic and disjunct Midwestern plant species. These cedar glades are located in the inner Central Basin, which is characterized by karst topography with little relief and limestone sinkholes and outcrops influencing surface and subsurface drainage (DeSelm 1959). It should be noted that the most recently discovered occurrence was found in a small opening in a closed cedar forest, suggesting the potential for long-term persistence of *A. bibullatus* in less than ideal conditions provided that habitat is not destroyed.

Cedar glades often have a striking zonal pattern of plant distribution, based primarily upon depth of soil, microtopographic relief, and degree of shading from surrounding woody vegetation (Somers et al. 1986). A shade intolerant species, *Astragalus bibullatus* has been found growing and reproducing vigorously along old roadbeds and in natural and man-made open areas in woodlands adjacent to glades. Typically, this species is found in very restricted habitat occurring in transition zones at the edges of either glades or tree/shrub islands within the glades. Moderate shading and slightly deeper soils in these areas of glades likely temper the drought conditions typical of glades in summer months. Mosses are

commonly seen in association with *A. bibullatus* and possibly influence germination and seedling establishment rates of this species.

The glade areas in the inner Central Basin of Tennessee are open, rocky areas generally developing on Lebanon and Ridley limestone of Ordovician age. This limestone is thin-bedded and fossiliferous with thin shale partings and minor amounts of magnesium limestone appearing as small irregular mottlings and thin bands. It weathers to "worm-eaten" flagstones that eventually break down to form a thin, gravelly layer over much of the bedrock. DeSelm (1959) describes the Central Basin of Tennessee as a topographic depression in the Interior Low Plateau ranging in altitude from 500 to 700 feet, with the surrounding Highland Rim having an altitude as great as 1,000 feet. The Ordovician limestone strata now exposed in the Basin were deposited on the slopes of the Nashville dome (a broad area of geologic uplift caused by forces deep within the earth). Geologists have suggested that this dome at one time was connected to the Ozark dome and sediments from the Mississippian period [i.e., 350 to 325 million years ago (mya)] were deposited over the limestone. In the Miocene or early Pliocene, middle Tennessee was thought to be a low-lying plain at a level similar to that of the current Highland Rim. Down-cutting by the Cumberland River and tributaries caused the present topography of the area, with Ordovician limestone remaining exposed and the Mississippian deposits eroded away (DeSelm 1959). Central Basin bedrock is composed of Middle Ordovician Ridley and Lebanon limestones of the Stones River Group.

Soil types generally associated with rock outcrops in Rutherford County are the Gladeville and Talbott series. The Gladeville series soils are formed in material derived from thin-bedded flaggy limestone, while the Talbott series soils are formed in material weathered from limestone. Glades are often included in areas where these series are mapped together as the Gladeville-Rock outcrop-Talbott association. The Gladeville soil in this association is on nearly bare rocky places (glades). The land surface is relatively smooth, and 7 to 30 cm (3 to 12 in) of clayey material overlay thinly bedded limestone. Thin flags of limestone 5 to 25 cm (2 to 10 in) long commonly are scattered over the surface and throughout the soil. The Talbott soil in this association is generally in strips between the bouldery limestone outcrops. This mapping unit has a low potential for farming and trees (USDA/SCS 1977). In general, slope angles on cedar glades seldom exceed 5 percent (Somers and Gunn 1990), and soil depths are estimated to range from 0 to 20 cm (0 to 8 inches) (Quarterman 1986).

The exposed bedrock, poor drainage, thin soils, and lack of vegetative cover in cedar glade habitats, combined with seasonal weather patterns of Middle Tennessee, create microenvironmental conditions that typically are wet in winter and early spring, and dry and hot in the summer (Quarterman 1986). While microclimatic data are not available for sites supporting *A. bibullatus*, data from weather stations maintained in cedar glades for short periods of time by Dr. Thomas Hemmerly (1976) revealed that temperature differences between the

glade stations and the nearest National Oceanic and Atmospheric Administration weather stations during winter were slight, but that at other seasons the glade maxima generally ranged between 10 to 30 degrees Fahrenheit higher. The highest glade temperature he recorded (on June 28, 1970) was 129 degrees Fahrenheit, compared to a temperature of 98 degrees Fahrenheit at the nearest NOAA station.

Baskauf and Reppuhn (unpublished data) found that *Atragalus bibullatus* grows best under medium to high levels of light and soil moisture. Specifically, the average number of leaves per plant was greatest under medium light in both medium and high soil moisture treatments. However, total dry biomass was greatest under both medium and high soil moisture and light treatments. These results are consistent with the observation by Albrecht (2010) that most *A. bibullatus* plants are distributed in the glade transition zone, where they often are in partial shade of nearby woody plants as opposed to the full sunlight conditions found in the central portions of glades. In contrast to the positive growth response to soil moisture, Baskauf and Reppuhn (unpublished data) documented the ability of *A. bibullatus* to survive under quite dry soil conditions in very extreme heat, as evidenced by the fact that the species lowered its water potential by a factor of as much as 5.4 under dry conditions as compared to moist conditions.

f. Conservation Measures: Conservation measures provided for *A. bibullatus* include Federal and state regulatory protection; investigating the species biology, ecology, and life history; preserving germplasm and establishing or augmenting occurrences; site protection and management; and surveys and monitoring.

Federal Regulatory Protection

Section 7(a)(2) of the Act requires Federal agencies to consult with the Service prior to authorizing, funding, or carrying out activities that may affect Federally listed species. Section 7(a)(1) also requires these agencies use their authorities to further the conservation of Federally listed species, which resulted in the introduction of a new occurrence into cedar glades at the Stones River National Battlefield in a cooperative effort among the National Park Service (NPS), TDEC, the Missouri Botanical Garden (MBG), and the Service.

Sections 9 and 10 of the Act and the corresponding implementing regulations found in 50 CFR 17.61, 17.62, and 17.63 set forth a series of prohibitions and exceptions that apply to all plants listed as endangered under the Act. These prohibitions, in part, make the following activities illegal for any person subject to the jurisdiction of the United States: import or export; transport in interstate or foreign commerce; sell or offer for sale this species in interstate or foreign commerce; remove and reduce to possession this species from areas under Federal jurisdiction; and maliciously damage or destroy this species on any other area in knowing violation of any state law or regulation in the course of any violation of a state criminal trespass law. These regulations apply to any part of the plant,

including seeds, roots, and other parts. The Act provides for the issuance of permits for scientific purposes or for the enhancement of propagation and survival of the endangered species.

State Regulatory Protection

The State of Tennessee lists the species as endangered under the authority of the "Rare Plant Protection and Conservation Act of 1985 (TDEC 2008)." Commercial exploitation or willful destruction of *Astragalus bibullatus* by persons other than the landowner could result in a fine of not more than $1,000 or imprisonment for not more than six months, or both. This law does not prevent a landowner from disturbing or destroying plants on his land, nor can it be used to impede public works projects such as highway construction. It is also not a violation to destroy the plants in the course of routine forestry or agricultural practices.

Preserving Germplasm and Establishing Occurrences

The MBG, acting as a member institution of the Centers for Plant Conservation, has collected seeds of *Astragalus bibullatus* as recently as June 2009 and currently holds seed collections from all but one of the extant occurrences. Early attempts to grow *A. bibullatus* plants from seed were hampered for this species by use of a growing medium that retained excessive amounts of moisture. Using a medium that more closely mimics the well-drained soils of cedar glades, the MBG has established reliable protocols for propagating *A. bibullatus* from seed (McCue et al. 2001).

The production of plants from seed facilitated two attempts by partners including MBG, The Nature Conservancy (TNC), NPS, the Service, and TDEC to establish new occurrences using cultivated plants. One of these efforts was initiated with the planting of 110 individuals into cedar glades at Stones River National Battlefield. The second introduction attempt occurred at the Sunnybell Cedar Glade DSNA, which at the time was a TNC preserve, and failed. Despite the fact that a viable population has not been established at Stones River National Battlefield, a positive outcome from this attempt was that many insights were gained through careful monitoring of the transplanted occurrences (Albrecht and McCue 2010):

- Seedling survival rates did not differ among the populations from which seeds were collected for nursery propagation; however, seed germination varied among populations.
- Fall transplants experienced higher survival rates and greater probability of transitioning to sexual maturity than spring transplants.
- Transplant survivorship and growth varied among sites, despite the fact that all transplants were located at the glade ecotone and appeared to be

floristically and edaphically similar, suggesting that as yet unknown microsite factors limit growth and survival of *Astragalus bibullatus*.

- During the first three years following planting, the introduced population achieved a couple demographic benchmarks: (1) the proportion of plants that became reproductive adults at some sites exceeded proportions observed in wild populations, and (2) the number of legumes per plant (i.e., reproductive output) was equal to or greater than rates observed in wild populations. However, seedling establishment was isolated to a single event in year five following introduction.

Albrecht and McCue (2010) proposed that future reintroduction attempts with *Astragalus bibullatus* use seedlings from multiple source populations, a fall transplanting season, multiple introduction sites, and protection from herbivory until plants become reproductively mature. They also suggested that repeated plantings might be necessary to buffer against demographic stochasticity. Additional work is needed to refine parameters used to identify suitable habitats for population introductions and the procedures for transplanting nursery reared plants into sites and caring for them until they become established. Given the small sizes of most *A. bibullatus* occurrences, the possibility of augmenting some occurrences with nursery grown plants should be considered. Attempts to do so could provide insight into the care that is needed following transplanting to promote survival of transplanted individuals into sites known to be suitable for the species.

Site Protection and Management

Five of the eight *A. bibullatus* occurrences are located on public lands. Four of these are Designated State Natural Areas (DSNAs) owned by TDEC, three of which were purchased using Recovery Land Acquisition grants funded through section 6 of the Endangered Species Act and extend onto adjacent private lands. The State of Tennessee's Natural Area Preservation Act (T.C.A. 11-14-01) protects DSNAs from vandalism and forbids removal of threatened and endangered species from these areas. One occurrence was planted on Federal property at the Stones River National Battlefield. A sixth occurrence is managed under a SNA registry, which is a non-binding agreement between TDEC and a private landowner. This differs from a DSNA, in that a SNA registry is not owned by the State of Tennessee and not provided equivalent protection under the state's Natural Area Preservation Act. The remaining two occurrences are entirely on privately owned lands and are not protected by conservation agreements.

Sites on lands protected either solely by TDEC or cooperatively by TDEC and private landowners are managed as necessary to conserve *A. bibullatus* and other cedar glade endemics. Management activities on these sites have included maintaining desired vegetation structure and composition using mechanical and manual clearing, prescribed burning, and judicious application of herbicides.

Management plans specifically devoted to *A. bibullatus* have either been completed or are under development for these sites.

All of the landowners and managers of the known occurrences have been contacted about the presence of *A. bibullatus* on their property. Acquisition of habitat from willing landowners, conservation easements, SNA registries, and development of cooperative management plans will be utilized to recover this species.

Surveys and Monitoring

Despite an intensive search for additional populations of *Atragalus bibullatus* in 1994 and numerous searches for other limestone cedar glade species that have taken place within apparently suitable habitat, few new occurrences have been found. However, discovery of an occurrence by a private landowner in 1999 and another by TVA biologists, during a 2006 survey of a proposed powerline right-of-way, indicate that additional survey work is warranted. The population found in 2006 is located approximately 10 miles from the nearest known occurrence and was found in a small clearing within a matrix of seemingly unsuitable forested habitat. This discovery underscores the need to carefully search for isolated occurrences even in marginal habitats when conducting surveys within the range of *A. bibullatus*.

Informal monitoring of *Astragalus bibullatus* occurrences, in the form of site visits to identify threats and count or estimate the number of plants present, began in the early 1980s following the rediscovery of the species. More intensive quantitative monitoring (Level 2 monitoring, sensu Menges and Gordon 1996) began in 2004, when TDEC initiated sampling to quantitatively track population size, condition, and structure in permanently marked 1 m^2 plots. Sample sizes have varied over time (Table 2) (Albrecht 2010). The following variables are sampled in each plot:

- numbers of seedlings/juveniles (1-stemmed plants), vegetative adults (multi-stemmed plants), and reproductive adults (multi-stemmed plants with fruits)
- number of stems per vegetative and reproductive adult
- number of inflorescences and flowers per plant
- number of plants exhibiting signs of herbivory

Table 2. *Astragalus bibullatus* monitoring sites and sample sizes as of 2010 for population (Level 2) and demographic (Level 3) monitoring.

EO Number	*Site*	*Sample Size*	
		Level 2	*Level 3*
1	Alexander	2004 (5), 2005 (2), 2008 (2), 2010 (4)	
1	Airport	2004 (4), 2005 (6), 2010 (6)	69
3	Davenport	2008 (2), 2010(2)	East – 35, West – 25
4	Overbridge	2008 (2), 2010 (2)	
5	Davis	n/a	7
9	Manus	2004 (3), 2005 (8), 2010 (8)	109

Demographic monitoring (Level 3 monitoring, sensu Menges and Gordon 1996) of *Astragalus bibullatus* began in 2001 with tracking of tagged plants that were introduced into cedar glades at the Stones River National Battlefield and Sunnybell Cedar Glade DSNA. The MBG (2005) and TDEC expanded this demographic monitoring in 2005, tagging a variable number of plants at each of three natural occurrences from which seeds had been collected to use in propagating plants that were used to attempt introductions. Albrecht (2010) increased sample sizes at two of these sites and initiated demographic monitoring at a third occurrence. In doing so, Albrecht (2010) included a broader range of stage/size classes and increased the number of individuals to a minimum of 20 tagged plants in each stage class (seedling, juvenile, and adult) needed for matrix population models. Data collected from each permanently marked individual are:

- number of stems
- length of the longest leaf
- presence/absence of herbivory
- number of flowers per reproductive plant
- number of fruits per reproductive plant

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

The Service listed *A. bibullatus* as endangered throughout its range primarily due to threats of habitat loss or alteration posed by development, encroachment of competing vegetation, livestock grazing, intensive right-of-way maintenance activities, off-road-vehicle (ORV) traffic, and trash dumping; the Service also identified as a threat potential impacts to the characteristically small *A. bibullatus* populations from extended drought (51 FR 48748; Service 1991). The following analysis details past and continuing threats to this species as they relate to the five listing factors outlined in section 4(a)(1) of the Act.

a. Present or threatened destruction, modification or curtailment of its habitat or range:

Astragalus bibullatus is extremely vulnerable because of its limited range and its specific limestone cedar glade habitat. The primary threat to *Astragalus bibullatus* and other cedar glade endemics is the loss, alteration, or degradation of habitat from residential, commercial, or industrial development; livestock grazing and trampling; encroachment of competing vegetation; and potential for illegal ORV use.

All the occurrences of *Astragalus bibullatus* are within a short distance of the rapidly growing middle Tennessee city of Murfreesboro. Five of the occurrences are located on public lands and as such are protected from development threats. However, the three remaining occurrences are located on private lands where development pressures are great. Limestone cedar glades are relatively flat and clear areas that often attract developers. One occurrence (population 2 in the listing rule) has been either destroyed or significantly altered by commercial development since *A. bibullatus* was listed and is now believed to be extirpated.

Only one of the eight known occurrences of *Astragalus bibullatus* is currently threatened by impacts from livestock grazing. This threat has been reduced at this occurrence through the establishment of a State Natural Area (SNA) registry between TDEC and the private landowner, which resulted in construction of a fence around the habitat containing *A. bibullatus* and regular monitoring of the fence and occurrence.

All the known *Astragalus bibullatus* occurrences are threatened by the encroachment of more competitive herbaceous vegetation and/or woody plants, such as eastern redcedar, that produce shade and compete for limited water and nutrients. The Service did not cite the threat of habitat alteration or degradation due to invasive exotic species as a factor in the decision to list *A. bibullatus* as endangered (Service 1991), but we recognize this as part of the threats currently posed to the species by encroaching vegetation. Invasive exotic species that currently are either being managed or have been noted as potential threats at *A. bibullatus* occurrences include spotted knapweed (*Centaurea biebersteinii*), Japanese honeysuckle (*Lonicera japonica*), privet (*Ligustrum* spp.), and sericea lespedeza (*Lespedeza cuneata*), among others. Active management to reduce or eliminate vegetation encroachment is required to ensure that the species continues to survive at all the sites.

Biologists from the Tennessee Valley Authority (TVA) discovered an occurrence of *Astragalus bibullatus* during surveys of a proposed powerline right-of-way that were completed in 2006. Through section 7 consultation with the Service, TVA identified measures to avoid impacts to this occurrence. See the Conservation Measures section for a discussion on Federal Regulatory Protection and agency obligations to consult with the Service regarding projects that might affect threatened and endangered species.

Habitat degradation due to ORV use of sites on private lands remains a potential threat, as does illegal ORV use on sites protected by public ownership. Sites in public ownership are reasonably well protected from this threat by the construction of fences and regular monitoring that would detect increasing levels of ORV usage.

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

No commercial trade in this species is known to occur. We are not aware of collections for wildflower gardening or other recreational purposes affecting this species. While one occurrence is rumored to have been established by a private landowner, this has not been confirmed. Collections for scientific or educational purposes are limited, and this activity is typically coordinated by TDEC in cooperation with the Service.

c. Disease or predation:

Herbivory has been observed to varying degrees during monitoring of *A. bibullatus* occurrences. Albrecht and McCue (2010) observed that some spring transplants were browsed, and Walck (2007) observed herbivory or signs of it at three sites.

d. Inadequacy of existing regulatory mechanisms:

With the exception of the protection that the Act affords listed plants on Federal lands and in matters pertaining to interstate commerce, state and Federal laws provide little or no protection to plants. *Astragalus bibullatus* is listed as endangered by the State of Tennessee (TDEC 2008) and is protected under the Tennessee Rare Plant Protection Act of 1985 (T.C.A. 51-901), which forbids persons from knowingly uprooting, digging, taking, removing, damaging, destroying, possessing, or otherwise disturbing for any purpose, any endangered species from private or public lands without the written permission of the landowner. While this legislation does not forbid the destruction of *A. bibullatus* or its habitat with landowner permission, neither does the Endangered Species Act afford such protection to listed plants on private lands. Those colonies located in DSNAs are afforded additional protection by the State of Tennessee's Natural Area Preservation Act, which protects DSNAs from vandalism and forbids removal of threatened and endangered species from these areas.

Section 7(a)(2) of the Endangered Species Act requires Federal agencies to consult with the Service prior to authorizing, funding, or carrying out activities that may affect Federally listed species. Section 7(a)(1) also requires these agencies use their authorities to further the conservation of Federally listed species, which resulted in the introduction of a new occurrence into cedar glades at the Stones River National Battlefield in a cooperative effort among the National

Park Service (NPS), TDEC, the Missouri Botanical Garden (MBG), and the Service.

Sections 9 and 10 of the Act and the corresponding implementing regulations found in 50 CFR 17.61, 17.62, and 17.63 set forth a series of prohibitions and exceptions that apply to all plants listed as endangered under the Act. These prohibitions, in part, make the following activities illegal for any person subject to the jurisdiction of the United States: import or export; transport in interstate or foreign commerce; sell or offer for sale this species in interstate or foreign commerce; remove and reduce to possession this species from areas under Federal jurisdiction; and maliciously damage or destroy this species on any other area in knowing violation of any state law or regulation in the course of any violation of a state criminal trespass law. These regulations apply to any part of the plant, including seeds, roots, and other parts. The Act provides for the issuance of permits for scientific purposes or for the enhancement of propagation and survival of the endangered species.

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

The Service identified extended drought conditions as a threat to *Astragalus bibullatus*, because of the likely reduced resilience of the three small populations that were known at the time of listing to endure such stochastic environmental events (56 FR 48750, Service 1991). The occurrence of severe drought in middle Tennessee, during the summers of 2007 and 2008, provides an opportunity to assess effects of drought to populations that are periodically monitored. It is possible that alterations in precipitation and drought frequency or severity that might accompany climate change could pose a growing threat to *A. bibullatus* in the future.

Estimates of the effects of climate change using available climate models lack the geographic precision needed to predict the magnitude of effects at a scale small enough to discretely apply to the range of *Astragalus bibullatus*. However, data on recent trends and predicted changes for the Southeast United States (Karl et al. 2009) provide some insight for evaluating the potential threat of climate change to *A. bibullatus*. Since 1970, the average annual temperature of the region has increased by about 2^{o}F, with the greatest increases occurring during winter months. The geographic extent of areas in the Southeast region affected by moderate to severe spring and summer drought has increased over the past three decades by 12 and 14 percent, respectively (Karl et al. 2009). These trends are expected to increase.

Rates of warming are predicted to more than double in comparison to what the Southeast has experienced since 1975, with the greatest increases projected for summer months. Depending on the emissions scenario used for modeling change, average temperatures are expected to increase by 4.5^{o}F to 9^{o}F by the 2080s (Karl et al. 2009). While there is considerable variability in rainfall predictions

throughout the region, increases in evaporation of moisture from soils and loss of water by plants in response to warmer temperatures are expected to contribute to increased frequency, duration, and intensity of droughts (Karl et al. 2009).

Effects of drought and other natural factors, including tornadoes and catastrophic fire, could be compounded by (1) diminished resilience of individual occurrences due to their small sizes, and (2) diminished ability of the species to endure stochastic disturbances due to limited representation across the landscape, as only eight occurrences are known to exist. While it is unlikely that a single tornado or catastrophic fire would affect all populations, prolonged or severe drought could affect populations throughout the geographic range of *Astragalus bibullatus*.

Small population sizes and fragmentation of cedar glade habitats could influence genetic structure of *Astragalus bibullatus* populations. As noted above, Morris et al. (2002) concluded that the among-site genetic structure they detected within the youngest soil seed layers of *A. bibullatus* occurrences was likely attributable to an increased incidence of inbreeding over time, due to the isolation of populations caused by fragmentation. They surmised that, because of increased fragmentation of cedar glade habitats and increased shading due to vegetation encroachment in those that remain, *A. bibullatus* populations were reduced in size and gene flow among them was likely restricted, leaving them vulnerable to effects of genetic drift and inbreeding.

D. Synthesis

Astragalus bibullatus (Pyne's ground-plum) is federally listed as endangered. It is currently known from only eight extant occurrences (specific locations or sites), all of which are located within approximately 25 km (15 mi) of one another in Rutherford County, Tennessee, in an area encompassing approximately 235 km^2 (90 mi^2). There are believed to be three extirpated natural occurrences of *A. bibullatus* (Table 1). All known occurrences are associated with limestone cedar glade ecosystems in middle Tennessee, a rare community type which has an extraordinarily high number of endemic and disjunct Midwestern plant species. These cedar glades are located in the inner Central Basin, which is characterized by mild karst topography with limestone sinkholes and outcrops influencing surface and subsurface drainage (DeSelm 1959). The number of individuals at most of these occurrences ranges in the tens to hundreds; only one occurrence has been observed to consist of greater than 1,000 individuals (Table 1). Genetic studies of samples from living plants have revealed no evidence of long-term divergence among these occurrences; however, an allozyme study of the seed bank detected among-site genetic structure within the youngest soil seed layers, which is likely attributable to an increased incidence of inbreeding over time due to the isolation of populations caused by fragmentation (Morris et al. 2002).

Conservation measures that have been implemented for *A. bibullatus* include Federal and state regulatory protection; investigating the species biology, ecology, and life history;

preserving germplasm and establishing or augmenting occurrences; site protection and management; and surveys and monitoring. Five of the eight *A. bibullatus* occurrences are located on public lands. Four of these are Designated State Natural Areas (DSNAs) owned by TDEC, three of which were purchased using Recovery Land Acquisition grants funded through section 6 of the Endangered Species Act. Of the remaining four occurrences, one was planted at the Stones River National Battlefield, one is located on private lands and managed under a SNA registry, and three others on private lands are unprotected. TDEC manages habitats at the occurrences on DSNAs and at the site managed under a SNA registry.

Astragalus bibullatus is extremely vulnerable because of its limited range and its specific limestone cedar glade habitat. The primary threat to *A. bibullatus* and other cedar glade endemics is the loss, alteration, or degradation of habitat from residential, commercial, or industrial development; livestock grazing and trampling; encroachment of competing vegetation; and illegal ORV use. Only one of the eight known occurrences of *A. bibullatus* is currently threatened by impacts from livestock grazing. All the known *A. bibullatus* occurrences are threatened by the encroachment of more competitive herbaceous vegetation and/or woody plants, such as eastern redcedar, that produce shade and compete for limited water and nutrients. The Service did not cite the threat of habitat alteration or degradation due to invasive exotic species as a factor in the decision to list *A. bibullatus* as endangered (51 FR 48748, Service 1991), but we recognize this as part of the threats currently posed to the species by encroaching vegetation. Drought continues to pose a potential threat to this species, as evidenced by recent occurrence of the most severe drought in recorded history in middle Tennessee, during the summer of 2007. While the Service listed drought as a threat at the time of listing, it might be more appropriate to characterize the threat as a combination of likely (1) diminished resilience of individual occurrences due to their small sizes, and (2) diminished ability of the species to endure stochastic disturbances due to limited redundancy across the landscape, as only eight occurrences are known to exist. It is possible that alterations in precipitation and drought frequency or severity that might accompany climate change could pose a growing threat to *A. bibullatus* in the future.

We believe that *A. bibullatus* still meets the definition of an endangered species because of its extremely limited distribution, low abundance at most occurrences, the persistence of the threats of habitat destruction at some sites, and the potential for habitat degradation in the absence of management at protected sites. Because the threats of low population size and potential for habitat degradation affect all known occurrences of this species, but the recovery potential remains high, we believe the recovery priority number should remain as 2.

III. RESULTS

A. Recommended Classification:

____ Downlist to Threatened

____ Uplist to Endangered
____ Delist
__X_ No change is needed

IV. RECOMMENDATIONS FOR FUTURE ACTIONS – See the 2011 Recovery Plan for *Astragalus bibullatus* (Pyne's ground-plum) for a narrative outline of tasks to be completed in recovering this species – available at the following link:

http://ecos.fws.gov/docs/recovery_plan/20110722b_Pynes%20ground%20plum_RP_final_1.pdf

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U.S. FISH AND WILDLIFE SERVICE
5-YEAR REVIEW of *Astragulus bibullatus*

Current Classification Endangered
Recommendation resulting from the 5-Year Review

__X__ **No change is needed**

Review Conducted By Geoff Call

FIELD OFFICE APPROVAL:

Lead Field Supervisor, Fish and Wildlife Service

Approve Mary C Jennings Date 9/12/11

The lead Field Office must ensure that other offices within the range of the species have been provided adequate opportunity to review and comment prior to the review's completion. The lead field office should document this coordination in the agency record.

REGIONAL OFFICE APPROVAL:

The Regional Director or the Assistant Regional Director, if authority has been delegated to the Assistant Regional Director, must sign all 5-year reviews.

Lead Regional Director, Fish and Wildlife Service

Approve _____ Date 10/20/11

The Lead Region must ensure that other regions within the range of the species have been provided adequate opportunity to review and comment prior to the review's completion. If a change in classification is recommended, written concurrence from other regions is required.

APPENDIX A: Summary of peer review for the 5-year review of Pyne's ground-plum (*Astragalus bibullatus*)

A. Peer Review Method: The Service prepared this 5-year review for *Astragalus bibullatus* concurrently with the completion of the species' recovery plan during 2011, and the information included herein was taken from the recovery plan and peer reviewed as part of the approval process for the recovery plan. We published a notice of availability of the Technical/Agency Draft Recovery Plan for Pyne's ground-plum in the *Federal Register* on April 1, 2010 (75 FR 16499). We received two comment letters from the general public. The Service requested four peer reviewers from academia to review and provide comments. We received comments from two peer reviewers: Dr. Jeffrey L. Walck of Middle Tennessee State University and Dr. Matthew A. Albrecht of Missouri Botanical Garden.

B. Summary of Peer Review Comments/Report – Both of the public commenters provided comments that were either editorial in nature or brought to our attention recent publications containing data that were referenced in the draft but were cited from unpublished reports. One of the public commenters questioned the draft recovery criteria and expressed concern over some of the cost projections for recovery and the implementation schedule. Dr. Walck provided a literature citation, several editorial comments, and suggested points of clarification, which we have incorporated where appropriate. Dr. Albrecht also provided editorial comments, which we have incorporated where appropriate. Dr. Albrecht suggested minor changes to the recovery actions, which we have incorporated in the recovery plan. Drs. Walck and Albrecht questioned the rationale behind the numbers and sizes of occurrences required for the reclassification and delisting criteria.

C. Response to Peer Review – We have incorporated suggested editorial changes where appropriate and have updated citations and literature cited in this 5-year review to include recent publications in peer reviewed literature. Comments related to recovery criteria and tasks, estimated costs, and implementation schedule were addressed in revisions to the draft recovery plan.