Recovery Plan for

Astragalus bibullatus

(Pyne's ground-plum)

(Pyne's ground plum, NPS photo from Stones River National Battlefield)

(Pyne's ground plum leaf, S. Baskauf 2003 photo)

RECOVERY PLAN

for

Astragalus bibullatus (Pyne's Ground-plum)

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Approved: 
Regional Director, U.S. Fish and Wildlife Service

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Recovery plans delineate reasonable actions that are believed to be required to recover and/or protect listed species. Plans published by the U.S. Fish and Wildlife Service (Service) are sometimes prepared with the assistance of recovery teams, contractors, State agencies, and other affected and interested parties. Plans are reviewed by the public and submitted for additional peer review before they are adopted by the Service. The objectives of the plan will be attained and any necessary funds made available subject to budgetary and other constraints affecting the parties involved, as well as the need to address other priorities. Recovery plans do not obligate other parties to undertake specific tasks and may not represent the views nor the official positions or approval of any individuals or agencies involved in developing the plan, other than the Service. Recovery plans represent the official position of the Service **only** after they have been signed by the Regional Director as approved. Approved recovery plans are subject to modification as dictated by new findings, changes in species' status, and the completion of recovery tasks.

By approving this recovery plan, the Regional Director certifies that the data used in its development represent the best scientific and commercial information available at the time it was written. Copies of all documents reviewed in the development of the plan are available in the administrative record, located at the Tennessee Field Office in Cookeville, Tennessee.

Literature citations should read as follows:

U.S. Fish and Wildlife Service. 2011. Recovery Plan for *Astragalus bibullatus* (Pyne's Ground-plum). Atlanta, Georgia. 43 pp.

Additional copies of this plan can be obtained from:

U. S. Fish and Wildlife Service
Tennessee Field Office
446 Neal Street
Cookeville, TN 38501
Telephone: 931/528-6481

Recovery plans can be downloaded from Service website:
http://www.fws.gov/endangered/species/recovery-plans.html

EXECUTIVE SUMMARY

Current Species Status: *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 kilometers (15 miles) of one another in Rutherford County, Tennessee, in an area encompassing approximately 235 square kilometers (90 square miles).

Habitat Requirements and Limiting Factors: This rare plant, a perennial legume, is currently restricted to edges of limestone cedar glades and open areas in surrounding cedar woodlands in full to moderate light in the vicinity of Murfreesboro, Rutherford County, Tennessee. This is a small area of the Central Basin section of the Interior Low Plateau in Tennessee. Factors contributing to its endangered status are an extremely limited range, alteration or loss of habitat, and small population sizes. Encroachment of woody vegetation decreases the suitability of sites for this plant. These sites are also threatened by rapid urban development in Rutherford County.

Recovery Objective: The goal of this recovery plan is to ensure the long-term viability of Pyne's ground-plum in the wild, and ultimately, remove this plant from the *Federal List of Endangered and Threatened Plants* (50 CFR 17.12).

Recovery Criteria: 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.

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 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 to conserve *A. bibullatus* and the cedar glade ecosystem on that site, that includes necessary resources, management recommendations, etc, for the site, or
- on private lands protected by a permanent conservation easement, State Natural Area registry, or other legally binding agreement, with a written plan committing to conserve *A. bibullatus* and the cedar glade ecosystem on that site, that includes necessary resources, management recommendations, etc, for the site.

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.

Actions Needed:
1. Protect and manage existing occurrences and habitats.
2. Search for new occurrences.
3. Conduct long-term monitoring and assess population growth rates and viability.
4. Conduct biological and ecological research.
5. Develop protocols for establishing new occurrences or augmenting existing ones.
6. Communicate with local officials to coordinate city and county planning.
7. Develop and implement public education materials.
8. Periodically assess the success of recovery efforts for the species.

Estimated Cost of Recovery ($000): $2710

Date of Recovery: The estimated date for recovery completion is 2025, provided that funds are available to accomplish the required recovery tasks needed to meet the recovery criteria.

Year	Need 1	Need 2	Need 3	Need 4	Need 5	Need 6	Need 7	Need 8	Total
1	360.0	50.0	40.0	150.0	51.0	1.0	5.0	1.0	658.0
2	360.0	50.0	40.0	150.0	51.0	1.0	5.0	1.0	658.0
3	360.0	50.0	10.0	50.0	51.0	1.0	5.0	1.0	528.0
4	360.0	0.0	10.0	50.0	31.0	1.0	5.0	1.0	458.0
5	360.0	0.0	10.0	00.0	31.0	1.0	5.0	1.0	408.0
Total	**1800.0**	**150.0**	**110.0**	**400.0**	**215.0**	**5.0**	**25.0**	**5.0**	**2710.0**

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PART I. INTRODUCTION

BACKGROUND

Astragalus bibullatus Barneby and Bridges (formerly called Guthrie's ground-plum, but now commonly referred to as Pyne's ground-plum) is a rare, perennial member of the pea family (Fabaceae) and is endemic to the limestone cedar glades in the Central Basin Section of the Interior Low Plateau. This species is currently known from only eight extant occurrences (specific locations or sites treated as separate populations for recovery purposes), all in the vicinity of Murfreesboro, Rutherford County, Tennessee. This species also used to occur near the Rutherford County line, at a site that is now under the waters of the J. Percy Priest Reservoir, and likely occurred in other cedar glades in the Central Basin as discussed below.

The U.S. Fish and Wildlife Service (i.e., Service) listed *Astragalus bibullatus* as an endangered species on September 26, 1991 (56 FR 48748; Service 1991) under the Endangered Species Act of 1973, as amended (16 U.S.C. 1531 *et seq*.; hereinafter called the Act). The State of Tennessee (Tennessee Department of Environment and Conservation (TDEC) 2008) also lists this species as endangered under the Rare Plant Protection and Conservation Act of 1985 (T.C.A. 51-901). The recovery priority number for this species is 2, which means it is highly threatened but also has a high recovery potential.

SPECIES DESCRIPTION AND TAXONOMY

Astragalus is a genus of the Fabaceae or pea family, consisting of approximately 2,500 mostly perennial species distributed primarily around the northern hemisphere and South America. The habitats of *Astragalus* species in the southeastern U.S. tend to be on rocky or sandy soils, providing a more arid contrast to the generally moist habitats found in the region (Weakley 2008), and this is true of native *Astragalus* in Tennessee. Specimens that are now assigned to *A. bibullatus* were apparently first collected as early as 1881 by the early 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.

The following description of *Astragalus bibullatus* is adapted from Barneby and Bridges (1987) and Somers and Gunn (1990): a herbaceous perennial, stems simple, 5 to 15 centimeters (cm) (2 to 6 inches (in)) tall, loosely tufted and arising from a shallowly buried root-crown attached to a stout vertical taproot, glabrous (smooth, having no hairs, projections, or pubescence) and leafless at base, usually bearing 5 to 10 leaves with petioles (the stalk of a leaf) 2 cm (0.79 in), once-pinnate (resembling a feather in structure with the parts arranged on both sides of an axis) with 19 to 27 elliptic (broadening at or about the center and narrowing equally toward each end) or elliptic-obovate (having the broad end upward or toward the apex) leaflet. Stems and leaves are considered glabrous but have thinly scattered fine appressed (lying flat) hairs, stipules (one of a pair of usually leaf-like lateral appendages found at the base of the petiole of many leaves) membranous to thinly herbaceous forming a sheath (a tubular covering surrounding an organ or part of a plant) around the stem. The inflorescence (a group of flowers borne on a single stem) is a raceme (an unbranched inflorescence of stalked flowers) supporting 10 to 16 purple flowers. The plants flower in April and May. During flowering, the peduncle (the stalk of a single flower) supporting the inflorescence arches upward. After flowering, and as the fruits mature, this peduncle gradually arches downward. The fruits are fleshy pods that usually mature in May and June. At maturity, the pods are colored red above and yellow below.

Astragalus bibullatus superficially resembles the widespread *A. tennesseensis* (Tennessee milk-vetch), a State-listed special concern species widespread in the cedar glades of middle Tennessee. However, *A. tennesseensis* can be readily distinguished by its yellow rather than purple flowers, its yellow-brown rather than reddish-topped fruits, and the copious number of hairs found on the plant (Somers and Gunn 1990). These two species often grow in the same restricted cedar glade habitat, sometimes growing next to each other. *Astragalus tennesseensis* does appear to have a wider range of environmental tolerance and occasionally is found scattered throughout the glade (Baskin et al. 1972).

DISTRIBUTION AND POPULATION TRENDS

Astragalus bibullatus is endemic to the cedar glades (described in Habitat section below) 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. 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. 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, 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, whereas 110 plants were originally introduced. 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.

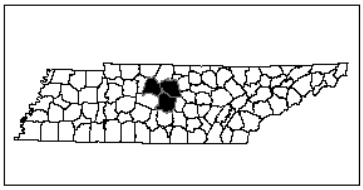
Table 1. Summary of all extant and historic (i.e., extirpated – denoted with an "*") occurrences of *Astragalus bibullatus*. The column labeled "EO Number" refers to the element occurrence number assigned by TDEC. Site names are provided only for element occurrences on public lands. Population data are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

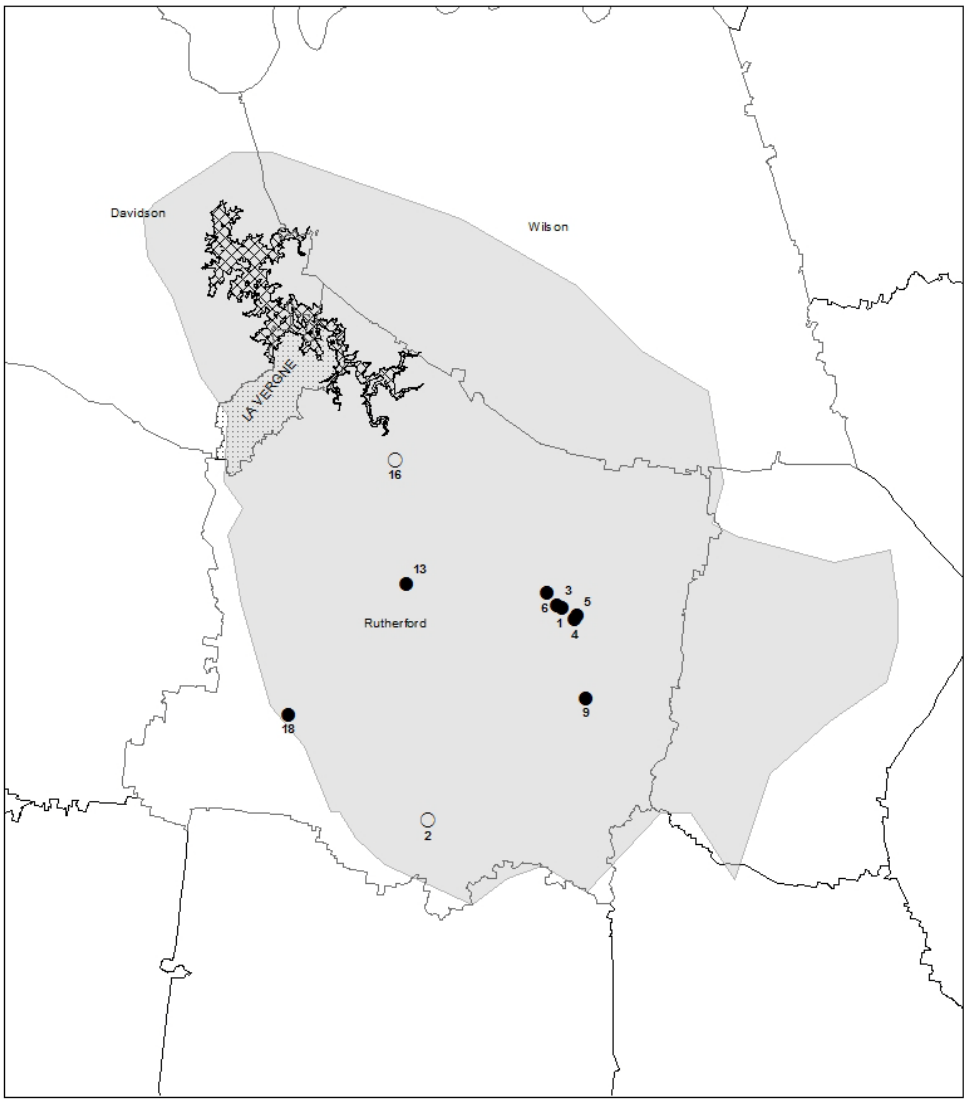
EO Number	*Ownership*	*Site Name*	*Population Data*
1	TDEC	Flat Rock Cedar Glades and Barrens DSNA	1,000 – 2,800
2*	Private		<100
3	TDEC and Private	Flat Rock Cedar Glades and Barrens DSNA	50 – 200
4	TDEC	Overbridge DSNA	10 – 45
5	Private		20 – 200
6	Private		100 – rumored to have been planted
8*	Public		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

Until 2006, the known occupied range of *Astragalus 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). This discovery 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 biologists 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 10 miles from the nearest historic or extant occurrence of *A. bibullatus*, provides evidence that we should consider the cedar glade ecosystem of the Stones River

Basin within Davidson, Rutherford, and Wilson counties as the geographic range for recovering this species (Figure 1). Doing so is appropriate from a biogeographic perspective and increases opportunities for establishing new occurrences on publicly owned conservation lands, as discussed under recovery tasks 5.2 and 5.3 in the Narrative Outline section in Part II of this plan.

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 wild 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.

HABITAT

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 *Astragalus bibullatus* in less than ideal conditions provided that habitat is not destroyed.

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 *Astragalus bibullatus*, data from weather stations maintained in cedar glades for short periods of time by Dr. Thomas Hemmerly (1976) revealed that temperature differences between his glade stations and the nearest National Oceanic and Atmospheric Administration weather stations "were slight or nonexistent in the winter but at other seasons the glade maxima were generally 10 degrees Fahrenheit and 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.

Geology

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 (Luther 1977). In the Miocene (23.8 to 5.3 mya) or early Pliocene (5.3 to 2.6 mya) epoch, 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 period (500 to 430 mya) 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.

Soils

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).

Associated Vegetation

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.

Woody and herbaceous associates of *Astragalus bibullatus* are species typical of limestone cedar glades in the Central Basin and include some endemics and near-endemics restricted to this region (Baskin and Baskin 1986; Barneby and Bridges 1987). Tree and shrub species include: *Juniperus virginiana* (eastern redcedar), *Carya carolinae-septentrionalis* (southern shagbark hickory), *Fraxinus americana* (white ash), *Fraxinus quadrangulata* (blue ash), *Quercus muehlenbergii* (chinkapin oak), *Frangula caroliniana* (Carolina buckthorn), *Rhus aromatica* (fragrant sumac), *Hypericum frondosum* (St. Johnswort), *Ulmus alata* (winged elm), *Cercis canadensis* (eastern redbud), *Symphoricarpos orbiculatus* (coralberry), and *Forestiera ligustrina* (privet). Some of the herbaceous species include: *Pediomelum subacaule* (whiterim scurfpea), *Dalea gattingeri* (purpletassels), *Hypericum sphaerocarpum* (roundseed St. Johnswort), *Aristida longispica* (slimspike threeawn), *Sporobolus vaginiflorus* (poverty dropseed), *Manfreda virginica* (false aloe), *Onosmodium molle* subsp. *molle* (softhair marbleseed), *Onosmodium molle* subsp.*subsetosum* (softhair marbleseed), *Hedyotis nigricans* (diamondflowers), *Astragalus tenneessensis* (Tennessee milk-vetch), *Heliotropium tenellum* (pasture heliotrope), *Erigeron strigosus* (daisy fleabane), *Viola egglestonii* (glade violet), *Evolvulus nuttallianus* (shaggy dwarf morning-glory), *Scutellaria parvula* (small skullcap), *Solidago nemoralis* (gray goldenrod), *S. missouriensis* var. *fasiculata* (Missouri goldenrod), *Grindelia lanceolata* (Gulf gumweed), *Oxalis priceae* subsp. *priceae* (tufted yellow woodsorrel), *Helianthus hirsutus* (hairy sunflower), *Ruellia humilis* (wild petunia), *Desmanthus illinoensis* (Illinois bundleflower), *Croton capitatus* (doveweed), *C. monanthogynus* (oneseeded croton), *Euphorbia dentata*

(toothed euphorbia), *Opuntia compressa* var. *compressa* (common pricklypear), *Satureja glabella* (called glade mint), *Oenothera macrocarpa* (bigfruit evening-primrose) and *Verbena canadensis* (homestead purple).

ECOLOGY AND LIFE HISTORY

Astragalus bibullatus is a perennial and flowers in late April through early May. Fruiting begins in early May with seed dispersal beginning around the first of June. As many as 26 above ground stems and 50 fruits have been observed on one plant. Dispersal mechanisms appear to be limited to abiotic factors including gravity and water (Morris et al. 2002). At a few of the sites, bush-hogging to control woody vegetation encroachment appears to have facilitated an increase in the number of plants, likely due to reduction of shade and enhanced seed dispersal.

Characteristics of *Astragalus bibullatus* seeds and habitat favor the development of a large, persistent seed bank that is stratified by age (Morris et al. 2002). The seeds of *A. bibullatus* have a hard, impermeable seed coat that imposes a strong physical germination barrier. Soils in the cedar glade habitats where *A. bibullatus* is found contain an abundance of unconsolidated rock fragments in a soil matrix that is granular in structure (USDA/SCS 1977), which, in combination with repeated frost heaving and sedimentation processes, would promote migration of *A. bibullatus* seeds down through the soil column over time, likely stratifying seeds of different ages (Morris et al. 2002).

There are noticeable differences in vigor and fruit production between populations. Morris et al. (2002) found that the number of *Astragalus bibullatus* seeds in soil samples varied substantially among sites. Degree of shading from woody plant encroachment may be a significant factor. It appears that shaded plants tend to have more vigorous vegetative growth but less fruit set, while plants in full sun often have copious fruit production but go dormant much earlier. The fruits of "older plants" appear to be much larger than the fruit of "young plants." If woody encroachment is a significant factor in the extinction of vegetative populations of *A. bibullatus*, then residual seed populations may exist at many sites in this region where habitat conditions are currently inhospitable to their growth and survival (Morris et al. 2002). The pollinating agents for this plant are not known, but flying insects play a role in many other legumes.

Factors relating to population structure and dynamics have not been researched. Population size seems to fluctuate dramatically in colonies from year to year, possibly in response to the amount of rainfall and the amount of disturbance (Somers and Gunn 1990).

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 *Astragalus 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 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 landuse 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.

REASONS FOR LISTING AND ONGOING THREATS

The Service listed *Astragalus 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 (Service 1991). The following analysis details threats to this species as they relate to the five listing factors outlined in section 4(a)(1) of the Act.

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 red cedar, 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.

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.

Disease or Predation

Herbivory has been observed to varying degrees during monitoring of *Atragalus bibullatus* occurrences. However, we do not believe that herbivore pressure constitutes a substantial threat to *A. bibullatus* at this time.

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 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 and Conservation 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. See the Conservation Measures section below for summaries of state and Federal regulatory protection for listed plants. Those colonies located in DSNAs are afforded additional protection by the State of Tennessee's Natural Area Preservation Act (T.C.A. 11-14-01), which protects DSNAs from vandalism and forbids removal of threatened and endangered species from these areas.

Other Natural or Manmade Factors

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, provided 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°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°F to 9°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.

CONSERVATION MEASURES

Conservation measures provided for *Astragalus 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 that 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. (Note: four seedlings were observed in 2010, following publication of Albrecht and McCue 2010).

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, protection from herbivory until plants become reproductively mature, and repeat plantings 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 *Astragalus 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 government 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 (T.C.A. 11-14-01). The remaining three 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 *Astragalus 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 *Astragalus bibullatus* on their property. Acquisition of habitat from willing landowners, conservation easements, SNA registries, and development of cooperative management plans will be utilized to help 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

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. This has implications for establishing population targets for use in recovery criteria, as discussed below. Additional monitoring will be necessary to reduce the large variance in population growth estimates and improve the robustness of the data for future statistical analyses.

PART II. RECOVERY

RECOVERY STRATEGY

To ensure the long-term survival of *Astragalus bibullatus*, it is important to protect and manage the eight known occurrences and any others that are discovered. Management plans should be developed for each occurrence and should include some type of management regime to prevent encroachment of vegetation into *A. bibullatus* habitat that might out-compete and/or shade *A. bibullatus*. Three of the known occurrences of *A. bibullatus* are located on privately owned land and five occurrences are on land owned by the State of Tennessee and/or the Federal government.

Protection of privately owned occurrences should be achieved through land acquisitions or permanent conservation easements. State Natural Area registries and cooperative management agreements should be pursued and implemented with private landowners if permanent measures cannot be immediately achieved. Protecting and managing habitat is critical for the survival of the species. Development pressures in Rutherford County pose a threat to this species. Surveys for new occurrences should continue both through recovery projects funded under section 6 or other sources and through surveys for threatened and endangered species that are recommended for Federal agency projects. The establishment of new occurrences into suitable protected habitat within the species' range will also be an important component of recovery for this species. A coordinated outreach program will also be important to inform landowners that this plant occurs on their property and of the management required to perpetuate its existence.

RECOVERY OBJECTIVE AND CRITERIA

The goal of this 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, 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 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 to conserve *A. bibullatus* and the cedar glade ecosystem on that site, that includes necessary resources, management recommendations, etc, for the site, or
- on private lands protected by a permanent conservation easement, State Natural Area registry, or other legally binding agreement, with a written plan committing to conserve *A. bibullatus* and the cedar glade ecosystem on that site, that includes necessary resources, management recommendations, etc, for the site.

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.

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. These tasks are described in more detail in the Narrative Outline section that follows.

> **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)

NARRATIVE OUTLINE

1: Protect and manage existing occurrences and habitats.

1.1 Acquire habitat. Four occurrences are located in DSNAs, though three of these extend onto adjacent private lands, and one occurrence is located at the Stones River National Battlefield. The remaining three known occurrences are entirely on privately owned land. Protection of the extant occurrences that are located on private land is an essential step in recovery of this species and would preferably be accomplished by acquiring properties where *Astragalus bibullatus* occurs.

1.2 Pursue protection with landowners. Landowners of all properties harboring known occurrences of *Astragalus bibullatus* have been contacted and encouraged to protect *A. bibullatus* on their property. During contacts with private landowners, their potential willingness to sell or donate properties harboring *A. bibullatus* should be discussed. If acquisition is not feasible, the most effective alternative protection is conservation easements; however, many landowners are not agreeable to the permanent restrictions on potential uses of their properties that conservation easements require. Conservation agreements may be acceptable instruments for protecting populations in instances where landowners are unwilling to either sell or donate their property or enter into a conservation easement. One privately owned occurrence has been registered as a SNA, which is an example of a non-binding agreement.

1.3. Develop and implement adaptive management plans for each occurrence. While studies documenting responses to management actions are lacking for *Astragalus bibullatus,* general knowledge concerning the importance of disturbance regimes in maintaining cedar glade habitats suggests that management for each site should promote open areas and limit encroachment of competing vegetation, especially at the glade ecotone where the species typically occurs. Based on field observations, habitat disturbance appears to enhance vigor and increase plant densities, abundance, and spatial extent of *A. bibullatus* occurrences. Management treatments that have been applied to *A. bibullatus* occurrences include prescribed fire, bush-hogging, mechanical and manual removal of woody vegetation, and chemical control of woody vegetation and invasive exotic species. As knowledge is gained by monitoring responses of *A. bibullatus* to management activities, management plans can be modified to include site-specific objectives. Plans must consider past and present land use in order to maintain or to enhance the conditions at each site. Plans should, at a minimum, address the following: 1) describe the desired ecological condition at the site, including structure and composition of vegetation; 2) identify threats; 3) outline management strategies for abating threats; and 4) provide a schedule of management or identify thresholds (e.g., percent cover of competing vegetation,

declines in population growth trends or specific life-history stages) that would result in specific management responses. An important goal of management plans for *A. bibullatus* should be to apply management treatments at scales extending beyond the immediate area currently occupied by *A. bibullatus*.

An occurrence was found in 1999 in an area that had been regularly, but unsuccessfully, surveyed for additional occurrences since 1979. This occurrence only became apparent after the landowner commenced regular mechanical removal of the woody vegetation in the area. It is possible that vegetative individuals had persisted at this site, but were overlooked during surveys, or that seeds were dispersed from the adjacent site. Morris et al. (2002) offered a more likely explanation: the high density of seeds they found throughout the soil strata indicated that a large population of *Astragalus bibullatus* was present at this site at some point in the past and that the majority of the extant population was probably derived from the soil seed bank within the last few years. The emergence of these plants following habitat disturbance adjacent to an existing occurrence underscores the importance of applying management treatments at scales extending beyond the immediate area currently occupied by *A. bibullatus*. Managing at larger scales should not only increase the chance of stimulating germination of dormant seed banks, it will also expand restoration of the cedar glade ecosystem that *A. bibullatus* shares with numerous at-risk species.

2: Search for new occurrences. As discussed above, few new occurrences of *Astragalus bibullatus* have been found despite numerous surveys since 1994. However, discovery of occurrences by a private landowner in 1999 and 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 away 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 for carefully searching for isolated occurrences even in marginal habitats when conducting surveys within the range of *A. bibullatus*, especially in cases where proposed projects would destroy potentially suitable habitat.

3: Conduct long-term monitoring and assess population growth rates and viability. Dramatic population fluctuations have been observed at several colonies, but until recently data have not been collected in a way that permits analysis of population dynamics of this species and the effects that habitat manipulation and environmental variation have upon these dynamics. An effective monitoring program is needed for documenting trends in population abundance and demographic structure, spatial extent of occurrences, and threats at wild and introduced occurrences, to provide feedback for adaptive management. Demographic monitoring of *Astragalus bibullatus* is necessary for identifying vulnerable life-history stages that could require intensive management for introductions to succeed or for naturally occurring populations to persist or grow,

determining whether responses to management treatments vary among life-history stages, and for identifying populations at risk of extinction in the near future using stochastic population growth models. By monitoring the fate of plants in various life history stages, we will better understand how stage-specific responses to environmental variables influence the trends we observe through monitoring directed at population structure and demographic processes.

3.1 Develop a written protocol for monitoring *Astragalus bibullatus* occurrences. To ensure that the monitoring program is well-designed and will be consistently implemented, a monitoring protocol should be written. The protocol should clearly articulate what the questions are that will be answered through monitoring; goals and objectives concerning the levels of change the monitoring program should allow managers to detect; step-by-step procedures for collecting, managing, and analyzing data; and include a schedule of the years that monitoring will be conducted and the specific dates within which monitoring should happen to ensure consistency among years.

The sampling methodology should be designed to assess population demographic features such as abundance, density, recruitment, age to reproductive maturity, and longevity, as well as measures of individual vigor such as number of vegetative stems, flowering stems, and fruit. The monitoring program for *Astragalus bibullatus* should also include regular assessment of threats to the occurrences, such as documenting incidences of herbivory, identifying sites where management is needed to maintain desired vegetation structure and composition, and ensuring that fences are maintained to prevent impacts from ORV access or livestock grazing.

No studies have been done to determine the long-term effects of disturbance regimes on growth, reproduction, and survival of *Astragalus bibullatus*. Monitoring protocols should include measures to provide feedback loops for adaptive management programs that are designed to maintain desired vegetation structure and composition. Such monitoring programs should not only measure responses in *A. bibullatus* occurrences, they should measure variables that are thought to be important in defining suitable habitat conditions. Examples include measures of stem densities or percent cover of competing vegetation in multiple vertical strata, degree of litter accumulation at the ground surface, and, in the case of herbicide applications, apparent effects of chemicals on vigor and abundance of non-target species, including *A. bibullatus*.

3.2 Monitor population structure, demographic processes, and threats. Using the protocol developed to accomplish task 3.1, *Astragalus bibullatus* occurrences should be monitored at a frequency that is sufficient for assessing population growth rates, determining whether these rates are influenced by cyclical or environmental variability, and understanding the role that seedlings/juveniles,

vegetative adults, and reproductive adults play in controlling observed growth rates. Threats monitoring should be focused on identifying factors that could limit population growth or lead to declines (e.g., vegetation encroachment, invasive species, herbivory).

3.3 Assess population growth rates and viability. This task provides for monitoring data analysis and report preparation. In judging whether a species and its constituent populations are currently secure and likely to persist into the foreseeable future, analyses of long-term datasets must be undertaken to determine average growth rates, variability in those rates, and how these two interact with other limiting factors to influence the probability that populations will persist for a given time period.

4: Conduct biological and ecological research. In order to successfully manage the species, it is important to understand its basic biology and the species' relationship to its environment. Research should be conducted on the species' life history, ecological requirements, reproductive biology, and pollination ecology.

4.1 Study life history and ecological requirements. Work has been conducted on temporal and spatial variability in abundance and genetic structure of seed banks for *Astragalus bibullatus* (Morris et al. 2002). McCue et al. (2001) published a propagation protocol for *A. bibullatus* that included details on germination requirements, seed viability, and seedling establishment in the lab. Baskauf and Rappuhn (unpublished data) studied light and moisture requirements of the species in a laboratory setting. However, additional studies to investigate the role of the seed bank in population maintenance and microenvironmental variables that influence seed germination and recruitment of seedlings into vegetative and reproductive life history stages are needed, both for improving management of existing populations and for establishing new populations. Microenvironmental data should be collected and analyzed in relation to data on population structure and demographic processes to identify factors potentially limiting transitions among life history stages and affecting population growth rates. To improve our understanding of factors influencing success of attempted reintroductions, they should include experimental placement of replicates among discrete microenvironmental settings in which light, vegetative cover, and soil depth, moisture, and fertility are quantified. The potential role of soil borne symbionts in facilitating establishment of introduced populations should be explored.

4.2 Study reproductive biology. The breeding system for *Astragalus bibullatus* is currently not known. Based on available genetic evidence, it seems likely that *A. bibullatus* is an obligate out-crosser; however, studies are needed to determine whether the species is self-compatible and, if so, whether the services of a

pollinator are necessary to facilitate transfer of pollen from the stamens to the stigma.

4.3 Study pollination ecology. Pollinators should be identified and the frequency of visits determined. Once pollinators are known, literature searches or studies should be conducted to determine the dispersal ability of species providing this function. Knowledge of pollinator dispersal ability should be considered when selecting sites for establishing new occurrences and in assessing connectivity among *Astragalus bibullatus* occurrences.

5: Develop protocols for establishing new occurrences or augmenting existing ones. While surveys to discover populations of *Astragalus bibullatus* should continue, it is important to guard against natural or human destruction or extirpation of populations by enhancing existing colonies, if warranted based on genetic or demographic evidence, or by establishing new colonies from propagated plants or collected seeds. Studies have revealed that there is little genetic variability among contemporary *A. bibullatus* populations (Baskauf and Snapp 1998, Morris et al. 2002, Baskauf and Burke 2009), leaving them vulnerable to effects of genetic drift and inbreeding. However, Morris et al. (2002) concluded from their study of seed bank genetic structure that, while contemporary *A. bibullatus* populations were reduced in size and gene flow among them was likely restricted, the higher rates of genetic diversity found in the seed bank as a whole indicated that seeds from historical populations were formed under conditions of a higher rate of gene flow. They suggested that reduced levels of gene flow observed in contemporary seed bank layers could be due to changes in aspects of the physical and biological environment of *A. bibullatus.* They cited evidence that cedar glades were likely more widespread and had lower densities of trees in the past and that landuse changes in the last century led to increased shading and fragmentation of habitats due to woody plant encroachment. These findings suggest that a critical component of recovering *A. bibullatus* will be to: establish new occurrences to increase redundancy of *A. bibullatus* on the landscape; where possible, do so in strategically located sites that would enhance potential for connectivity among all occurrences; and to determine whether any occurrences should be augmented with propagated individuals to enhance their resilience to stochastic disturbances.

5.1 Maintain plant and seed sources *ex situ*. The MBG leads *ex situ* conservation efforts for *Astragalus bibullatus* in coordination with the Service. Staff from the MBG most recently collected seed from three populations in June 2009. To ensure redundancy of *ex situ* seed accessions, MBG has provided seeds from *A. bibullatus* populations to the USDA Agricultural Research National Seed Storage Laboratory in Fort Collins, Colorado. Seeds collected for *ex situ* conservation should be tested for viability upon collection and periodically thereafter. If declines in viability of seed accessions are observed, new collections should be acquired to supplement existing holdings. Propagation of plants for potential

reintroductions, introductions, or population augmentations, or to conduct research into life history, ecology, or reproductive biology, should be initiated as needed to meet the demands of specific projects.

5.2 Identify suitable unoccupied habitat. Suitable *Astragalus bibullatus* habitat should be identified within the cedar glade ecosystem of the Stones River Basin within Davidson, Rutherford, and Wilson counties, which we consider the geographic range for recovering this species (Figure 1). The specific habitat requirements of *A. bibullatus* are not known, beyond a recognition that the species is associated with cedar glade habitats and tends to be located in transition zones between the open glade and adjacent woodlands or in small openings within the woodland matrix. The results of studies accomplished under recovery action 4 should be used to develop criteria for identifying suitable unoccupied sites and specific microenvironments within those sites.

The Tennessee Department of Environment and Conservation manages several DSNAs within the Central Basin for the purpose of conserving cedar glade habitats. Two of these are located in Davidson County, eight in Rutherford County (one of which extends into Wilson County), and four are entirely in Wilson County. The DSNAs in Wilson County are located within 15 miles of extant occurrences in Rutherford County. Most of these DSNAs contain at least one other federally listed cedar glade endemic and have played an instrumental role in protecting habitats needed for their recovery. Surrounding J. Percy Priest Reservoir in these three counties, the U. S. Army Corps of Engineers owns land that contains limestone cedar glades. Efforts to identify suitable unoccupied habitats should emphasize these lands because they are already in public ownership and contain some of the best remaining examples of cedar glade habitats.

5.3 Establish new occurrences. In 2001, MBG, NPS, TDEC, TNC, and the Service collaborated on attempts to establish two new occurrences on conservation lands. One of these introductions was located at the Sunnybell Cedar Glade DSNA, but no plants survive there today. This natural area is named for the sunnybells (*Schoenolirion croceum*) that are prominent in wet calcareous limestone washes of cedar glades, which characterize the habitat at this site. Such habitat is likely wetter during spring and early summer months than habitats where *Astragalus bibullatus* is typically found. The other introduction took place at Stones River National Battlefield and cannot at this time be considered successful, as only four seedlings were found surviving in 2010. Approximately 110 nursery-grown plants were transplanted to this site. Despite the lack of success in these early attempts, it is important that efforts to establish new occurrences in this plant's historic range continue in order to increase representation of this species across the landscape.

5.4 Augment existing occurrences, where necessary. The extant occurrences of *Astragalus bibullatus* are typically small, consisting of tens to hundreds of individuals. 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. Monitoring programs should be designed to evaluate relative seed production in relation to occurrence size and determine whether larger populations are reproductively more successful than smaller ones. Further genetic studies might be warranted to estimate what level of demographic change in populations might have been associated with the reduction of heterozygosity observed in shallow seed bank deposits compared to older ones. Such an investigation might provide an indication of the population sizes that would be necessary to prevent further reductions in genetic variability within occurrences.

6: Communicate with local officials to coordinate city and county planning. Meet periodically with local city and county officials to solicit their participation in the conservation of the species.

7: Develop and implement public education materials. Educating the public should be accomplished by providing information to landowners, government agencies, local parks, schools, nature centers and the media. This education could lead to the discovery of new populations and promote an understanding of the importance of conserving endangered species. Because the species is geographically restricted, the recovery of this species will depend largely on the support of the local landowners and local government. The Center for Cedar Glade Studies, which was established at Middle Tennessee State University in 2005 using Environmental Protection Agency funds, should be engaged as a partner in developing educational materials and opportunities for the public.

8: Periodically assess the success of recovery efforts for the species. Timely review of new information and evaluation of ongoing programs are essential to ensure that full recovery occurs as rapidly and efficiently as possible.

REFERENCES

Albrecht, M. 2010. Letter. Geoff Call, Recovery Coordinator, Cookeville Ecological Services Field Office. Peer review comments re: Technical Agency Draft Recovery Plan for Pyne's ground-plum (*Astragalus bibullatus*). Plant Conservation Ecologist, Center for Conservation & Sustainable Development, Missouri Botanical Garden, May 13, 2010.

Albrecht, M. A. 2010. Demographic monitoring of natural populations of Pyne's ground-plum (*Astragalus bibullatus*). Unpublished report to Tennessee Department of Environment and Conservation. December 2010. 33 pp.

Albrecht, M.A. and K.A. McCue. 2010. Changes in demographic processes over long time scales reveal the challenge of restoring an endangered plant. Restoration Ecology 18:235-243.

Allendorf, F. W. and G. Luikart. 2007. Conservation and the Genetics of Populations. Blackwell Publishing. Malden, MA. 642 pp.

Barneby, R. C. and E. L. Bridges. 1987. A new species of *Astragalus* (Fabaceae) from Tennessee's Central Basin. Brittonia 39(3): 358-363.

Baskauf, C. J., and S. Snapp. 1998. Population genetics of the cedar-glade endemic *Astragalus bibullatus* (Fabaceae) using isozymes. Annals of the Missouri Botanical Garden 85:90-96.

Baskauf, C. J. and J. M. Burke. 2009. Population genetics of *Astragalus bibullatus* (Fabaceae) using AFLPs. Journal of Heredity 11:424-431.

Baskin, J. M. and C. C. Baskin. 1986. Distribution and geographical/evolutionary relationships of cedar glade endemics in Southeastern United States. ASB Bulletin 33: 138 - 154.

Baskin, C. C, J. M. Baskin, and E. Quarterman. 1972. Observations on the ecology of *Astragalus tennesseensis.* American Midland Naturalist 88(1):167-182.

DeSelm, H. 1959. A new map of the Central Basin of Tennessee. Journal of the Tennessee Academy of Science 34(1): 66-72.

Hemmerly, T. E. 1976. Life cycle strategy of a highly endemic cedar glade species: *Echinacea tennesseensis* (Compositae). Ph.D. Dissertation,Vanderbilt Univ., Nashville. 187 pp.

Karl, T. R., J. M. Melillo, and T. C. Peterson (eds.). 2009. Global Climate Change Impacts in the United States. Cambridge University Press. 190 pp. Available online at http://www.globalchange.gov/publications/reports/scientific-assessments/us-impacts/full-report .

Kartez, J.T. 1994. A Synonomized Checklist of the Vascular Flora of the United States, Canada, and Greenland. Second Edition. Timber Press, Portland, Oregon. 622 pp.

Luther, E. T. 1977. Our Restless Earth, the Geologic Regions of Tennessee. University of Tennessee Press, Knoxville, Tennessee. 94 pp.

McCue, K. A., E. Belt, and M. Yurlina. 2001. Propagation protocol for *Astragalus bibullatus*. Native Plant Journal 2(2):131-132.

Menges, E. S. and D. R. Gordon. 1996. Three levels of monitoring intensity for rare plant species. Natural Areas Journal 16:227-237.

Missouri Botanical Garden. 2005. Monitoring introduced and natural populations of *Astragalus bibullatus*in Tennessee. Unpublished report to the Tennessee Department of Environment and Conservation. 14 pp + Appendices.

Morris, A. B., R. S. Baucom, and M. B. Cruzan. 2002. Stratified analysis of the soil seed bank in the cedar glade endemic, *Astragalus bibullatus*: Evidence for historical changes in genetic structure. American Journal of Botany 89:29-36.

Quarterman, E. 1986. Biota, ecology, and ecological history of cedar glades: introduction. ASB Bulletin 33(4): 124-127.

Somers, P., L. R. Smith, P. B. Hamel and E. L. Bridges. 1986. Preliminary analyses of plant communities and seasonal changes in cedar glades of Middle Tennessee. ASB Bulletin 33: 178-192.

Somers, P. and S. C. Gunn. 1990. Status report, *Astragalus bibullatus* Barneby and Bridges. Unpublished report to the Southeast Region, U.S. Fish and Wildlife Service. 33 pp.

Tennessee Department of Environment and Conservation. 2008. Tennessee Natural Heritage Program Rare Plant List. Prepared by Todd Crabtree, Nashville, Tennessee. 50 pp.

Tennessee Department of Environment and Conservation. 2005. *Astragalus bibullatus, Dalea foliosa,* and *Echinacea tennesseensis* Population Monitoring. Unpublished report to the U.S. Fish and Wildlife Service. 29 pp.

U. S. Dept. of Agriculture/Soil Conservation Service. 1977. Soil Survey of Rutherford County. United States Department of Agriculture, Soil Conservation Service, in cooperation with the University of Tennessee Agricultural Experiment Station. 95 pp.

U. S. Fish and Wildlife Service. 1991. Endangered and threatened wildlife and plants; *Astragalus bibullatus* (Guthrie's Ground-plum) determined to be endangered. Federal Register 56(187): 48748.

Walck, J. L. 2007. Final report – demographic monitoring of Pyne's ground-plum (*Astragalus bibullatus*). Unpublished report to Tennessee Department of Environment and Conservation. May 2, 2007. 8 pp.

Weakley, A. S. 2008. Flora of the Carolinas, Virginia, Georgia, Northern Florida, and Surrounding Areas. University of North Carolina, Chapel Hill, NC. Working draft of April 7, 2008. 924 pp.

Wofford, E. 2011. E-mail. Geoff Call, Recovery Coordinator, Tennessee Ecological Services Field Office. RE: inquiry about *A. bibullatus* specimen. Research Associate Professor, University of Tennessee, March 23, 2011.

Wurdack, K. 2011. E-mail. Geoff Call, Recovery Coordinator, Tennessee Ecological Services Field Office. RE: inquiry about specimens of *Astragalus bibullatus*. Research Scientist and Associate Curator, Botany Department, Smithsonian Institution, March 24, 2011.

PART III. IMPLEMENTATION SCHEDULE

Recovery plans are intended to assist the Service and other stakeholders in planning and implementing actions to recover and/or protect endangered and threatened species. The following Implementation Schedule indicates task priorities; task numbers; task descriptions; task duration; potential stakeholders and responsible agencies; and, lastly, estimated costs. It is a guide for planning and meeting the objectives discussed in Part II of this plan. The Implementation Schedule outlines recovery actions and their estimated costs for the first 5 years of this recovery program. The estimated date of recovery is 2025, provided that funds are available to accomplish the required recovery tasks and that the recovery criteria are met. The costs are broad estimates and identify foreseeable expenditures that could be made to implement the specific recovery tasks during a 5-year period. Actual expenditures by identified agencies and other partners will be contingent upon appropriations and other budgetary constraints.

Priorities in column 1 of the following Implementation Schedule are assigned as follows:

1. Priority 1 - An action that must be taken to prevent extinction or to prevent the species from declining irreversibly in the foreseeable future.

2. Priority 2 - An action that must be taken to prevent a significant decline in species population/habitat quality or some other significant negative impact short of extinction.

3. Priority 3 - All other actions necessary to meet the recovery objective.

While the Act assigns a strong leadership role to the Service for the recovery of listed species, it also recognizes the importance of other Federal agencies, States, and other stakeholders in the recovery process. The “Responsible Agency” column of the Implementation Schedule identifies partners who can make significant contributions to specific recovery tasks. The identification of agencies and other stakeholders within the Implementation Schedule does not constitute any additional legal responsibilities beyond existing authorities (e.g., Act, CWA). Recovery plans do not obligate other stakeholders to undertake specific tasks and may not represent the views nor the official positions or approval of any agencies or stakeholders involved in developing the plan, other than the Service.

KEY TO ABBREVIATIONS

MBG – Missouri Botanical Garden
ES – Ecological Services Division, U.S. Fish and Wildlife Service
TDEC - Tennessee Department of Environment and Conservation
R4 – Region 4 (Southeast Region), U.S. Fish and Wildlife Service
NPS – National Park Service
PVT – A university, research center, or private landowner
TNC – The Nature Conservancy
CTY – Murfreesboro City Government
CNTY – Rutherford County Government

Astragalus bibullatus Recovery Implementation Schedule											
Priority	**Task Number**	**Task Description**	**Task Duration**	**Responsible Agency**		**Cost Estimates ($000s)**					**Comments**
				FWS	**Other**	**FY1**	**FY2**	**FY3**	**FY4**	**FY5**	
1	1.1	Acquire habitat.	Continuous	R4/ES	TDEC, TNC, CTY, CNTY	300	300	300	300	300	
1	1.2	Pursue protection with landowners.	Continuous	R4/ES	TDEC, TNC, CTY, CNTY	10	10	10	10	10	
1	1.3	Develop and implement adaptive management plans for each occurrence.	Continuous	R4/ES	TDEC, PVT	50	50	50	50	50	
2	2	Search for new occurrences.	Continuous	R4/ES	TDEC, PVT	50	50	50			
2	3.1	Develop a written protocol for monitoring *A. bibullatus* occurrences.	2 years	R4/ES	TDEC, MBG, PVT	10	10				
2	3.2	Monitor population structure, demographic processes, and threats.	Continuous	R4/ES	TDEC, MBG, NPS, PVT	15	15	15	15	15	
2	3.3	Assess population growth rates and viability.	Continuous	R4/ES	TDEC, MBG, NPS, PVT	15	15	15	15	15	
2	4.1	Study life history and ecological requirements.	4 years	R4/ES	TDEC, MBG, PVT	50	50	50	50		
2	4.2	Study reproductive biology.	2 years	R4/ES	TDEC, MBG, NPS, PVT	50	50				
2	4.3	Study pollination ecology.	2 years	R4/ES	TDEC, MBG, NPS, PVT	50	50				
2	5.1	Maintain plant and seed sources *ex situ*.	Continuous	R4/ES	TDEC, MBG	1	1	1	1	1	
2	5.2	Identify suitable unoccupied habitat.	3 years	R4/ES	TDEC, MBG, NPS, PVT	20	20	20			
2	5.3	Establish new occurrences.	Continuous	R4/ES	TDEC, NPS, MBG, PVT	20	20	20	20	20	
2	5.4	Augment existing occurrences, where necessary.	Continuous	R4/ES	TDEC, MBG, PVT	10	10	10	10	10	
3	6	Communicate with local officials to coordinate city and county planning.	Continuous	R4/ES	TDEC, CTY, CNTY	1	1	1	1	1	
3	7	Develop and implement public education plans.	Continuous	R4/ES	TDEC, TNC, CTY, CNTY	5	5	5	5	5	
3	8	Periodically assess the success of recovery efforts for the species.	Continuous	R4/ES	TDEC	1	1	1	1	1	

PART IV. LIST OF RECIPIENTS

Copies of this recovery plan were made available to the following agencies, organizations, and individuals. This does not imply that they provided comments or endorsed the contents of this plan.

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APPENDIX I. PUBLIC AND PEER REVIEW

The Service 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 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.

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 this recovery plan. Drs. Walck and Albrecht questioned the rationale behind the numbers and sizes of occurrences required for the reclassification and delisting criteria. We have revised the recovery criteria in response to input from Drs. Walck and Albrecht, and one of the public commenters. Specifically, we have increased the number of occurrences of *Astragalus bibullatus* that would be necessary to meet the criteria for both reclassification to threatened or delisting, in order to provide greater redundancy on the landscape and reduce the likelihood that a stochastic event, such as drought, would eliminate the species from all or a significant portion of its range. We also have incorporated the use of population viability analyses for estimating the risk of extinction based on observed demographic structure and population growth rates, rather than setting an arbitrary minimum population target as was done in the draft recovery plan.

We have incorporated suggested editorial changes where appropriate and have updated citations and literature cited in this recovery plan to include recent publications in peer reviewed literature. One of the public commenters questioned the draft recovery criteria. We have revised the recovery criteria in this recovery plan in response to input from this reviewer and two peer reviewers. This public commenter also expressed comments over some of the cost projections for recovery. We have revised these cost projections in the implementation schedule where appropriate.