

**Status Report for *Arenaria cumberlandensis* Wofford & Kral
(*Minuartia cumberlandensis* (Wofford & Kral) McNeill)
Cumberland Sandwort**



Prepared for U.S. Fish and Wildlife Service

**TN Department of Environment and Conservation
Division of Resource Management, TN Heritage Program**

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Introduction

Arenaria cumberlandensis Wofford & Kral (*Minuartia cumberlandensis* (Wofford & Kral) McNeill), Cumberland sandwort, is a member of the Caryophyllaceae (Pink family) and endemic to the Cumberland Plateau of north-central Tennessee and south-central Kentucky. The first and last status report for this species was written in 1980 by B. Eugene Wofford and David K. Smith (1980). Five populations of *A. cumberlandensis* were identified in Tennessee by the authors, two in Fentress County, one in Morgan County, one in Pickett County, and one in Scott County. Within these 5 populations, a total of 10 element occurrences (EOs) were delineated and mapped by the Tennessee Natural Heritage Program (TNHP), two in Fentress, six in Pickett, one in Scott, and one in Morgan. The first Kentucky population in McCreary County was discovered in 1984 after the status report was written.

It was not until 2000 that many of the *A. cumberlandensis* occurrences were resurveyed and a monitoring protocol was first established by TNHP. Additional systematic surveys and monitoring were conducted from 2006-2009 with new occurrences discovered, all within the known range of the species. In addition to these surveys, two new EOs were discovered in Fentress County in the winter of 2010 and are included in this report. After a span of three decades, the 2010 status report for Cumberland sandwort has been developed to provide the following updated information:

- Number of EOs and their distribution among the five counties range-wide in Tennessee and Kentucky
- Length of time these EOs are known to have persisted
- Immediate and potential threats
- Protection and management efforts that have been undertaken and that will be needed in the future

The ultimate goal of the status report is to provide data that will help determine if recovery criteria have been met for *A. cumberlandensis*. The species is considered rare because it is a narrow endemic requiring specific habitat conditions; it occurs in rockhouses that have the potential to be disturbed by various human activities; and, the populations are somewhat isolated and confined to a 28-mile (45 km) area.

History and Description of the Species

Wofford and Kral (1979) described *Arenaria cumberlandensis* in 1979. The species was later transferred to *Minuartia cumberlandensis* (McNeill 1980). The Flora of North America (FNA 2005) recognizes this classification as well as the Kentucky and Tennessee rare plant programs. However, USFWS continues to use the name *Arenaria cumberlandensis*.

Arenaria cumberlandensis is a perennial plant with leafy rosettes or tufts that overwinter and are visible throughout the year. The plants are extremely fragile with shallow roots. The upright leafy flowering stems, appearing in spring and summer, are 10 - 15 cm (3.9 - 6.25 inches) tall. The flowers are small with five white petals. Flowering occurs from May through August and sometimes into early fall. The fruit is a capsule with numerous reticulate seeds, 0.5 - 0.7 mm (0.02 - 0.03 inches) long.

The first collections of this taxon were made in 1941 from Hazard Cave at Pickett State Park, in Fentress County, Tennessee by Dr. Jesse Shaver. This collection and subsequent Tennessee collections prior to the 1979 Wofford and Kral description of the new species *A. cumberlandensis* were referred to as either *Arenaria glabra* or *Arenaria patula*. Because of the similarities in morphology and cytology, *A. cumberlandensis* is placed in the *Arenaria groenlandica* complex consisting of *A. glabra* and *A. groenlandica*. *A. groenlandica* grows in alpine areas and occurs in high elevations in the southern Appalachians. The range of *A. glabra* is more widespread although it does occur on the Cumberland Plateau on dry sandstone outcrop habitats, it has not been found in rockhouses. *A. cumberlandensis* only grows on the floor and ledges of sandstone rockhouses or overhanging cliffs and requires shade, moisture and low temperatures. There are no known contiguous populations of *A. cumberlandensis* and *A. glabra* and little likelihood of genetic exchange between them. Walck et al. (1996) describe *A. cumberlandensis*, *Ageratina luciae-brauniae*, *Solidago albopilosa* (currently only known from Kentucky) and *Thalictrum mirabile*, all rockhouse endemic species, as neoschizoendemics, or ancient relics that have restricted geographic ranges due to their youth and have putative ancestors in nearby habitats outside of rockhouses. However, they state that although *A. cumberlandensis* is classified as a neoschizoendemic, its origin remains obscure.

The first collections of Cumberland sandwort in Kentucky were made in 1984 in McCreary County along Rock Creek. The second Kentucky occurrence was found in 1989 at Big Spring Hollow, McCreary County. After several systematic searches, no new EOs have been discovered in Kentucky although potential habitat does exist.

Present Legal Status, National Status and State Status

Arenaria cumberlandensis was listed by The U.S. Fish and Wildlife Service (USFWS) as endangered on June 23, 1988 (USFWS 1988). The Recovery Plan was approved in 1996 and the species was given a Recovery Priority Number 8 (USFWS 1996). The taxon is listed as state endangered in Tennessee and Kentucky as *Minuartia cumberlandensis* (KY State Nature Preserves Commission 2010; TDEC 2010). The Global Status is G2G3 and the State Status is S1 in Kentucky and S2 in Tennessee. The TNHP is responsible for the determination of the global and state rank and for the maintenance of the occurrence records and location maps for Cumberland sandwort in the BIOTICS database provided by NatureServe (TDEC 2010).

General Environment and Habitat Information

Cumberland sandwort occurs on the Cumberland Plateau in Tennessee and Kentucky within the river gorges and steep walled valleys in the South Fork Cumberland watershed and the Obey River watershed. Although restricted to a small area of the Plateau and two watersheds, localized populations can contain thousands of perennial individuals.

The preferred habitat for *A. cumberlandensis* is cliff-lines and sandstone cave-like recesses, or, rockhouses (or rockshelters), formed from differential weathering of Pennsylvanian sandstone of the Pottsville Formation (Tennessee) and Breathitt and Lee Formations (Kentucky). These formations create environmental conditions that provide an ecological niche which supports a unique endemic flora. Ecological requirements for *A. cumberlandensis* appear to be abundant soil moisture, cool temperatures,

high humidity and deep shade. The small delicate plants occur in scattered patches on shaded sandy floors, sandstone ledges, and solution pockets outside and inside the rockhouses. Elevations range from 1150 ft. (just one EO) to 1680 ft. with the majority between 1400 ft. and 1500 ft. The floor of the rockhouses may receive little or no direct sunlight depending on the aspect of the cliff and the vegetation cover in and around the overhangs. Rockfall commonly occurs inside the rockhouse from the ceiling that scatters various sized boulders on the sandy floor. Rockfall also occurs on the cliff-lines outside rockhouses where plants can occur in scattered patches on ledges and on sheer bluffs or cliff-lines that usually receive more direct light.

The habitat conditions range from dry to wet, with the wet rockhouses generally having waterfalls or lateral groundwater seeps and drainages. Although *A. cumberlandensis* is never the dominant cover, it is more abundant in the wetter rockhouses. Water drips from the outermost ledge of the ceiling overhang and forms the drip line that creates pools or drainages on the sandy or rocky floor. Leaf litter accumulates in the drip line and woody vegetation tends to grow in this area of the rockhouse and *Arenaria* is usually absent from these disturbed areas. Inside these moist and shaded rock overhangs and rockshelters, where the ideal habitat for *A. cumberlandensis* occurs, the temperatures are cool in summer and the relative humidity is high and evaporation low. In the winter, the inside temperatures are relatively warmer as the rockhouse floor and ledges are somewhat protected from ice, snow and rainfall. These factors can vary depending on aspect, elevation, and surrounding vegetation. The drier and more open habitats usually support poor or marginal occurrences. Natural decline in numbers of plants can usually be attributed to a change in the moisture or light conditions. For example, the ice storm of 1998 caused severe damage to trees and shrubs on the cliffs and ledges and potentially allowing more sunlight in some of the rockhouses. The southern pine beetle infestation in the late 1990s and early 2000s resulted in the death of many pines and caused noticeable changes in light intensity at some *A. cumberlandensis* sites including the Swinging Bridge and the Natural Bridge sites in Pickett State Park.

Vegetation and Associated Species

The wet, shady rockhouse habitat harbors a unique plant assemblage with several Cumberland Plateau endemic plant species, some of which are state listed in Tennessee and Kentucky. The Cumberland Plateau Rockhouse Community (CEGL004301) is ranked by NatureServe as a G2 community (NatureServe 2010). The vegetation cover in the rockhouse found on the back wall, ceiling and sandy floor is sparse consisting of a varied herbaceous layer and few woody taxa. Trees and shrubs are located mostly outside the rockhouses on the sandstone cliff face and ledges. Less than 100 plant taxa have been recorded for rockhouses in the Eastern US including various species of graminoides, ferns, mosses and lichens. Some of the taxa that occur with *A. cumberlandensis* are *Epigaea repens*, *Mitchella repens*, *Gaultheria procumbens*, *Athyrium filix-femina* ssp. *asplenioides*, *Smilax* spp., *Vaccinium* spp., *Clethra acuminata*, *Ilex opaca*, *Rhododendron maximum*, *Kalmia latifolia*, *Tsuga canadensis*, *Parthenocissus quinquefolia*, *Toxicodendron radicans*, *Vitis* spp., and *Campsis radicans*. Endemic taxa that are restricted to these rockhouse habitats and are important indicator species for *A. cumberlandensis* include *Silene rotundifolia*, *Thalictrum clavatum* (*mirabile*), *Heuchera parviflora*, *Ageratina luciae-brauniae* (TN state listed threatened; KY state listed special concern), *Stenanthium diffusum* (TN state listed endangered), and the bryophytes *Vittaria appalachiana*, *Bryoxiphium norvegicum* (TN state listed threatened), and *Scopelophila cataractae* (TN state listed special concern). Associated species can vary at each rockhouse depending on the environmental conditions (Walck et al. 1996).

Geographical Distribution

The largest populations of Cumberland sandwort can be found in north-central Tennessee on state and federal lands in Pickett State Park (PSP) and Pickett State Forest (PSF) and in the western sections of the Big South Fork National River and Recreation Area (BSFNRRRA) in Fentress, Scott, Pickett, and Morgan Counties. The populations in Kentucky are within the BSFNRRRA in McCreary County near the Tennessee state line (Figure 1). All of the known occurrences are located within 28 miles (45 kilometers) of each other. The majority of the EOs occurs within 6 miles (10 kilometers) of PSP, Tennessee. The southern-most population is located about 15 miles (25 kilometers) from PSP at Peter's Bridge and the northern-most population (Big Hollow Springs) is located in Kentucky about 14 miles (22 kilometers) from PSP. The populations are located in the South Fork Cumberland Watershed and the Obey Watershed.

When the recovery plan was completed in 1996 there were 28 known occurrences of *A. cumberlandensis* in Tennessee and Kentucky in Pickett, Scott, Fentress, and Morgan Counties, Tennessee, and McCreary County, Kentucky. In 2000, TNHP conducted a survey and monitoring project resulting in many new occurrences for a total of 57 EOs reported in Tennessee (Bailey and Shea 2000). This doubled the number of EOs for the species.

A survey and monitoring project for *A. cumberlandensis* was conducted from 2006-2008 in Tennessee resulting in a total of 62 EOs delineated in Tennessee. In early 2010, two new occurrences were discovered bringing the total to 64 EOs with 19 EOs located in Fentress County, 39 EOs in Pickett County, 5 EOs in Scott County, and one historic EO in Morgan County. Of these 64 occurrences, 27 occur at least partially within BSFNRRRA (owned by NPS), 20 within PSF (owned by Dept. of Agriculture, Division of Forestry-TDF), nine within PSP (owned by TDEC), three within Pogue Creek Designated State Natural Area (owned by TDEC), and five on private lands. The survey did not include the two occurrences located in Kentucky within the BSFNRRRA.

Table 1 presents a summary of the status of the 66 EOs in Tennessee and Kentucky. The table is organized by state and by population. There are 64 EOs within 16 extant populations in Tennessee and there is one extant EO and one population in Kentucky. The second occurrence/population in Kentucky is considered extirpated based on frequent recent surveys. In addition, there is one introduced population in Kentucky that has not been mapped as an EO (KSNPC 2010). In Tennessee, one EO may consist of one or more rockhouses, adjacent ledges, rock outcrops, or cliff faces. These are designated on Table 1 as rockhouse a,b,c or 1,2,3, etc, based on how they were labeled in the field notes. The EO viability rank (EO Rank) has been assigned to each EO and is discussed in a later section of this report. The element occurrence reports and maps for each EO are arranged by population in Appendix I, Figures 1-9.

Figure 1: Geographical Distribution of *Arenaria cumberlandensis* Populations

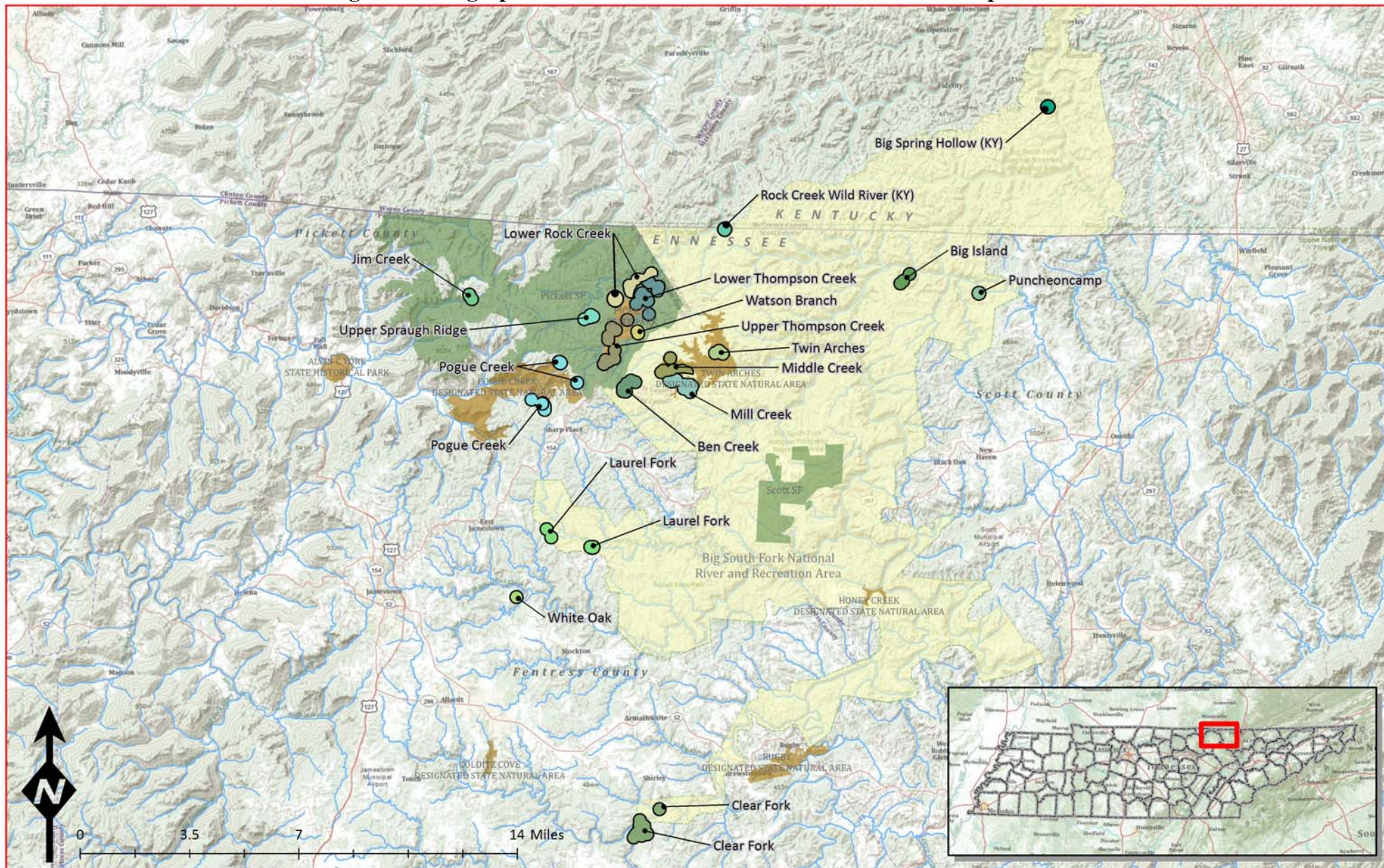


Table 1: Kentucky and Tennessee Occurrences (EO) and Populations

| EOID | EO | Population Name | SITE NAME | COUNTY | OWNER | EO Rank |
|------------------|---------------------|------------------------|---|---------------|--------------|----------------|
| Kentucky | 1 | Rock Creek | Rock Creek Wild River | McCreary | NPS | X |
| | 2 | Big Hollow Springs | Big Hollow Springs | McCreary | NPS | A |
| Tennessee | | | | | | |
| 13693 | 2 | Clear Fork | Peters Bridge Southeast | Morgan | NPS | F/H |
| 394 | 3 | Clear Fork | Peters Bridge North Side Cedar Creek | Fentress | NPS | D |
| 577 | 48(a,b,c,d,e,f) | Clear Fork | Peters Bridge East Facing Bluff | Fentress | PRIVATE | C |
| 8997 | 54(1,2,3,4,5,6,7,8) | Clear Fork | Peters Bridge South Facing Bluff | Fentress | PRIVATE | AB |
| 16297 | 73 | Clear Fork | Skull Cave Creek | Fentress | NPS | D |
| 4613 | 7 | White Oak | Jamestown Barrens | Fentress | PRIVATE | D |
| 12098 | 25 | Laurel Fork | Darrow Ridge Northern | Fentress | NPS | C |
| 15610 | 60(1,2a,2b) | Laurel Fork | Hippy Cave | Fentress | NPS | A |
| 16112 | 65 | Laurel Fork | Darrow Ridge Southern | Fentress | NPS | B |
| 15143 | 58 | Pogue Creek | Johnson Branch | Pickett | TDEC | BC |
| 16088 | 62 | Pogue Creek | Pogue Creek #6 | Fentress | TDEC | D |
| 16099 | 63(1,2,3,5) | Pogue Creek | Pogue Creek East Side Tributary | Fentress | PRIVATE | CD |
| 16296 | 72 | Pogue Creek | Pogue Creek Wasik Site | Fentress | TDEC | D |
| 16524 | 76 | Pogue Creek | Pogue Creek Rockhouse#4 | Fentress | PRIVATE | CD |
| 9557 | 27 | Ben Creek | Middle Creek Loop Trail Rockhouse3 | Fentress | NPS | D |
| 8983 | 29(1,2,3) | Ben Creek | Middle Creek Loop Trail/Head of Ben Creek | Pickett | NPS | B |
| 7952 | 31 | Ben Creek | Middle Creek Loop Trail Open Ledges | Fentress | NPS | D |
| 8984 | 61(1,2) | Ben Creek | Middle Creek Loop Trail | Fentress | NPS | BC |

| EOID | EO | Population Name | SITE NAME | COUNTY | OWNER | EO Rank |
|-------------|--------------|------------------------|-------------------------------------|---------------|--------------|----------------|
| 15229 | 59 | Puncheoncamp | Puncheon Camp Fork Bluff | Scott | NPS | D |
| 12693 | 1(a,b) | Big Island | Big Island Rockhouses | Scott | NPS | C |
| 4004 | 41 | Big Island | Rockhouse ESE of Big Island | Scott | NPS | D |
| 9052 | 42 | Twin Arches | Loop Trail South Facing Rockhouses | Scott | NPS | D |
| 3827 | 45(1,2,3) | Twin Arches | Loop Trail At Ladders | Scott | NPS | D |
| 7466 | 17 | Mill Creek | Slave Falls | Pickett | NPS | AB |
| 1940 | 43(a,b,c) | Mill Creek | Mill Creek Tributary Ravine#1 | Pickett | NPS | B |
| 11528 | 44(a,b,c,d) | Mill Creek | Mill Creek Tributary Ravine | Pickett | NPS | B |
| 13125 | 47(1, 2a,2b) | Mill Creek | Downstream of Slave Falls | Pickett | NPS | D |
| 16111 | 64 | Mill Creek | Rockhouse Benchmark | Fentress | NPS | D |
| 16536 | 79(a,b) | Mill Creek | Mill Creek Tributary Ravine#2 | Pickett | NPS | D |
| 14055 | 18(a,b,c,d) | Middle Creek | Middle Creek Ridgetop Cliffs North | Pickett | NPS | A |
| 6526 | 19 | Middle Creek | Middle Creek 2 | Pickett | NPS | F |
| 6525 | 20 | Middle Creek | Middle Creek 3 | Pickett | NPS | D |
| 14662 | 21 | Middle Creek | Middle Creek 4 | Pickett | NPS | C |
| 2902 | 22(1,2) | Middle Creek | Middle Creek 5 | Pickett | NPS | C |
| 16377 | 74(a,b) | Middle Creek | Middle Creek Ridgetop Cliffs South | Pickett | NPS | A |
| 2450 | 16(a,b) | Watson Branch | Watson Branch | Pickett | TSP | B |
| 7357 | 4(a,b) | Upper Thompson Creek | Hazard Cave and West Rockhouse | Pickett | TSP | AB |
| 3968 | 5 | Upper Thompson Creek | Hidden Passage Tunnel/Crystal Falls | Pickett | TSP | D |
| 6251 | 12 | Upper Thompson Creek | Swinging Bridge | Pickett | TSP | D |
| 9337 | 13 | Upper Thompson Creek | Ladder Trail | Pickett | TSP | AB |
| 1509 | 24 | Upper Thompson Creek | Indian Rockhouse | Pickett | TDF | C |
| 5290 | 26 | Upper Thompson Creek | Natural Bridge At Pickett Lake | Pickett | TSP | D |

| EOID | EO | Population Name | SITE NAME | COUNTY | OWNER | EO Rank |
|---|---------------|------------------------|--|---------------|--------------|----------------|
| 1671 | 33 | Upper Thompson Creek | Rockhouse SW of Hazard Cave | Fentress | TDF | C |
| 5608 | 34 | Upper Thompson Creek | Natural Bridge Trail | Pickett | TSP | D |
| 16113 | 66 | Upper Thompson Creek | Lake & Ridge Trail | Pickett | TSP | D |
| 10857 | 6 | Lower Thompson Creek | Double Falls Rockhouse | Pickett | TDF | BC |
| 16530 | 77 | Lower Thompson Creek | Trail to Rock Creek | Pickett | TDF | D |
| 16531 | 78 | Lower Thompson Creek | Trail From Thompson Overlook | Pickett | TDF | D |
| 5044 | 10 | Lower Thompson Creek | Hidden Passage 1 | Pickett | TDF | D |
| 12100 | 11 (1,2) | Lower Thompson Creek | Hidden Passage Rockhouses 1&2 | Pickett | TDF | B |
| 1439 | 14 | Lower Thompson Creek | Thompson Creek Ridgetop | Pickett | TDF | D |
| 4358 | 35 | Lower Thompson Creek | Double Falls Bluff | Pickett | TDF | A |
| 6867 | 36 | Lower Thompson Creek | Rockhouse Below The Hidden Passage Trail | Pickett | TDF | D |
| 16117 | 71 | Lower Thompson Creek | Hidden Passage Trail West of Powerline | Pickett | TSP | D |
| 16115 | 69(a,b,Uc,Lc) | Upper Sprauh Ridge | Sprauh Ridge Rockhouse D | Pickett | TDF | B |
| 16537 | 80 | Upper Sprauh Ridge | Sprauh Ridge Road | Pickett | TDF | D |
| 9774 | 8 | Lower Rock Creek | Powerline Rockhouse | Pickett | TDF | C |
| 9888 | 15 | Lower Rock Creek | Rock Creek Gorge | Pickett | TDF | D |
| 9546 | 37 | Lower Rock Creek | Bluffs AboveTunnel Trail | Pickett | TDF | CD |
| 6277 | 38(1,2a,2b) | Lower Rock Creek | North of Powerline | Pickett | TDF | A |
| 10367 | 39 | Lower Rock Creek | Hidden Passage/Tunnel Trail Intersection | Pickett | TDF | BC |
| 16116 | 70 | Lower Rock Creek | Group Camp Bluffs | Pickett | TDF | A |
| 17003 | 81(a,b,c) | Jim Creek | Rockhouses 4, 12, 13 | Fentress | TDF | BC |
| 17004 | 82 | Jim Creek | Rockhouse 3 | Fentress | TDF | D |
| TN TOTAL EOs: <u>64</u> TN TOTAL POPULATIONS: <u>16</u> | | | | | | |
| KY TOTAL EOs: <u>2</u> KY TOTAL POPULATIONS: <u>2</u> | | | | | | |

There has been no apparent change in the distribution of *A. cumberlandensis* within its historic range. The preferred habitat is extensive and intact (no recent disturbance) but located within a defined geographic area, the South Fork Cumberland Watershed and Obey Watershed. The habitat is fragmented and isolated by steep river gorges and eroded sandstone bluffs. Due to the vast amount of public land in a five county area of Kentucky and Tennessee, little effort has been given toward surveys on private land. Likewise, little effort has been given to surveys outside of the South Fork Cumberland watershed. It is not clear why *A. cumberlandensis* is absent in suitable habitat that is plentiful within its range. It could be due to past human disturbance, limited seed dispersal, or other factors. Ecological processes have been little studied, particularly the mechanisms of seed and pollen dispersal among sites which are critical for understanding population structure and genetic diversity (Winder 2004).

Delineation of Populations and Element Occurrences

The recovery plan indentified 28 occurrences of *A. cumberlandensis* in Tennessee and Kentucky and uses numbers of occurrences (EOs) for assessing recovery of *A. cumberlandensis*.

Arenaria cumberlandensis (Cumberland sandwort) will be considered for reclassification from endangered to threatened status when 30 geographically distinct, self-sustaining occurrences are protected in four counties in Tennessee and Kentucky and have maintained stable or increasing numbers for 5 consecutive years. The species will be considered for delisting when 40 geographically distinct, self-sustaining occurrences are protected and have maintained statistically stable or increasing numbers for 5 consecutive years. At least 12 of these occurrences must be in counties other than Pickett County, Tennessee.

Because Cumberland sandwort occurs in small isolated patches that are not contiguous throughout the habitat, it has proven difficult to delineate separate EOs. Unfortunately, the recovery plan does not clearly define what constitutes an EO and without a clear definition of “occurrence”, the accurate number of EOs that exists for recovery purposes cannot be determined. Past field surveys and EO mapping have been inconsistent because of biologists’ interpretations of what constitutes an EO. Monitoring efforts in one year might identify two adjacent patches of plants as separate EOs while the next year the same two patches might be considered a single EO by a different biologist. This confusion regarding the locations of EOs is further complicated because early (pre-2000) observers did not use GPS so EOs were imprecisely mapped on topographic maps. As result, these early observations were difficult to relocate in subsequent survey years. As GIS and GPS technologies evolved, mapping precision has increased and, in many cases, early observations have been combined with newer observations and remapped to create EOs. Heritage methodology has been used over the years to map Cumberland sandwort EOs and to enter data into the original Heritage BCD database and presently into the BIOTICS database. However, until 2008, the procedures for combining old and new observations and determining EO limits for *A. cumberlandensis* were not standardized, again, because of the lack of a definition for an EO in the recovery plan.

In 2008, in order to facilitate data comparisons and to consistently locate and monitor the same plants from year to year, TNHP developed custom specifications for delineating EOs. The specifications were created using the most current, best available knowledge of Cumberland sandwort habitat preferences as well as NatureServe Natural Heritage Methodology. After the field surveys were completed in 2009, it

was apparent that the NatureServe (2004) standard guidance for habitat-based delineation of EOs did not logically apply to *A. cumberlandensis*.

Since the recovery plan was published, more has been learned about the distribution of *A. cumberlandensis* within its preferred habitat. The plants grow in patches that are defined by the availability of habitat in and around the sandstone rockhouses and ledges on cliff-lines. The locations of these isolated patches appear to be based on topographic and micro-topographic factors. Patches often occur scattered horizontally along topographic contours where a series of rockhouses appear at the same elevation along a cliff-line. These rockhouses may be scattered a long distance along the cliff-line. Patches can also be distributed vertically across elevation contours associated with rockhouses connected by talus or rockfalls (stacked rockhouses at two different elevations), or along streams or ravines that possess consecutive, down-slope rockhouses. These rockhouses may not be separated by a long distance but rather more stacked on the landscape.

Anywhere within these rockhouses and associated cliff-lines, patches may be distributed based on micro-topographic factors such as the location of sand deposits on the rockhouse floor or on cliff-face ledges. The degree of exposure to the sun (or more xeric conditions) within rockhouses or on ledges also influences the distribution of patches. Aspect, shape or curvature of the cliff-line, and proximity to taller vegetation may affect the degree of exposure. Also, micro-drainage features such as waterfalls and seeps may determine the distribution of patches within rockhouses or on ledges as the plants do not tolerate too much water. All of these topographic and micro-topographic physical features may separate patches of *A. cumberlandensis* within a single EO.

The knowledge of these distribution factors has been used by TNHP to delineate EOs of *A. cumberlandensis*. The first step in developing the custom specifications involved separating Cumberland sandwort sites or locations where the plants occur from each other by watershed boundaries at the HUC-12 level¹ (Figure 2). The EOs grouped at this level were designated as populations (Table 2) although genetic studies for each EO have not been completed to determine true populations. Within each of these HUC-12 watersheds, or populations, each site was examined using GPS for factors that could create discontinuity and possible barriers to seed and/or pollen dispersal including slope aspect, stream connectivity, geologic connectivity (i.e. rockfalls), and elevation differences. The sites that do not have obvious topographic discontinuity among them are then combined into an EO. The locations for these EOs, collected with GPS, are precisely mapped as polygons and can now be revisited with certainty in subsequent monitoring years. By using this method one EO may consist of two or more noncontiguous rockhouses or series of ledges, either vertical or linear, that are monitored separately. Each of these monitoring locations or clusters within an EO is mapped using GPS as a “source point” in the BIOTICS database [e.g. EO 29(1), EO 29(2), or EO 48(a), EO 48(b)].

¹ Based on TDEC's work with National Hydrography Dataset http://nhd.usgs.gov/wbd_data_citation.html.

The following are the criteria used for delimiting an occurrence for *A. cumberlandensis*:

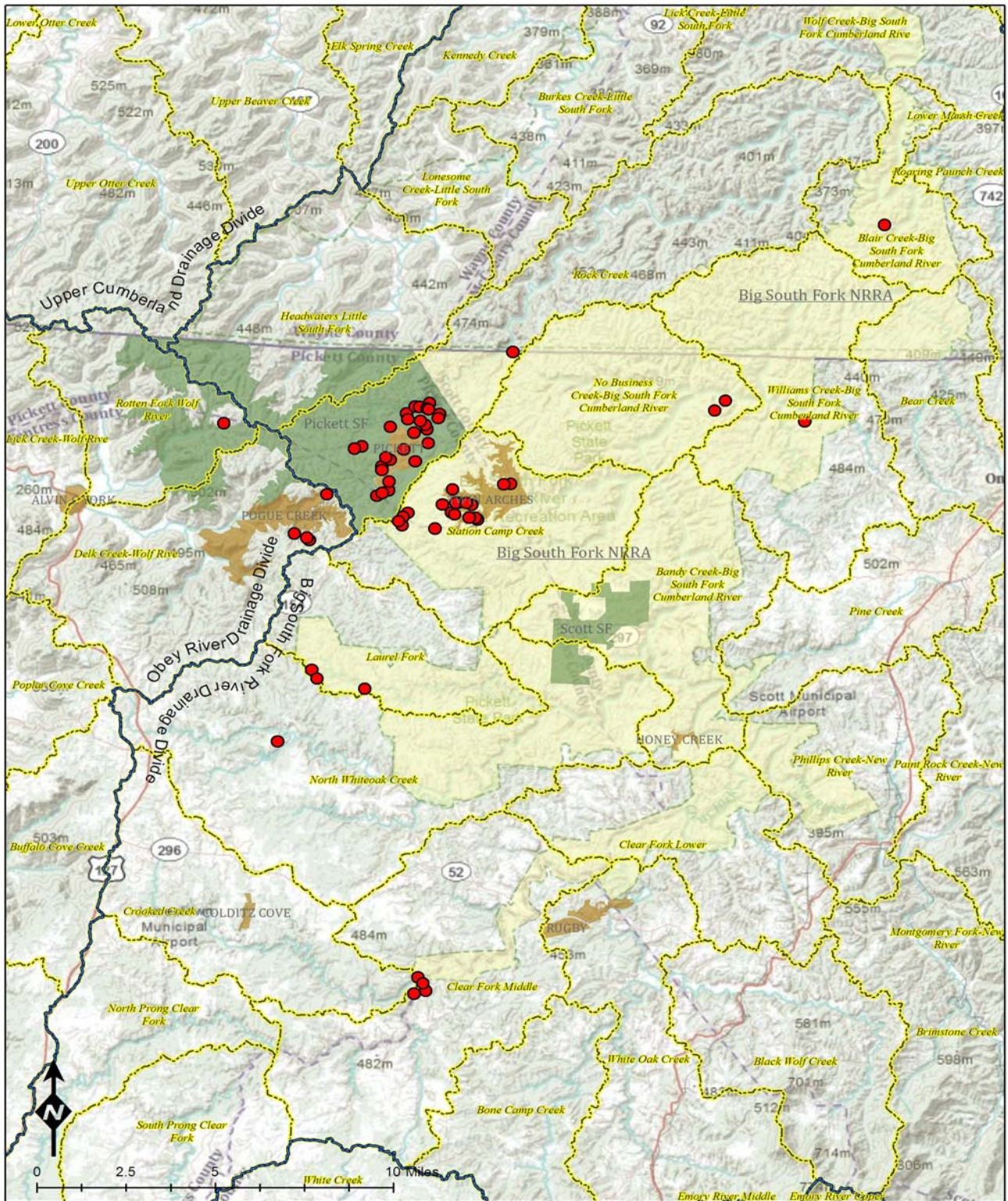
1. At a minimum, an EO is defined as a noncontiguous cluster or patch of plants that naturally occurs in suitable habitat.
2. An EO may consist of several noncontiguous patches that occur in one or more rockhouses or cliff-faces which are located in a linear or vertical pattern with no barriers present. Discontinuity and barriers to dispersal have been identified based on slope aspect, stream connectivity, geologic connectivity (i.e., rockfalls), and elevation differences. These patches can be monitored separately and mapped as individual source points in order to repeat data collection.
3. The EO is assigned to a population based on the HUC-12 watershed level.

In the absence of extensive genetic studies for each EO within a population, such EO delineation represents the best method for assessing Cumberland sandwort recovery.

Table 2: Populations and Number of Occurrences by Watershed (USGS HUC Level)

| HUC 8 | HUC 10 | HUC 12 | Populations | Number of Occurrences |
|-----------------------|--|--|--|-----------------------|
| KENTUCKY | | | | |
| South Fork Cumberland | Roaring Paunch Creek-Big South Fork Cumberland River | Blair Creek- Big South Fork Cumberland River | Big Spring Hollow | 1 |
| South Fork Cumberland | Roaring Paunch Creek-Big South Fork Cumberland River | Rock Creek | Rock Creek Wild River | 1 |
| TENNESSEE | | | | |
| South Fork Cumberland | Roaring Paunch Creek-Big South Fork Cumberland River | Rock Creek | Upper Spraugh Ridge, Lower Rock Creek, Upper Thompson Creek, Lower Thompson Creek, Watson Branch | 27 |
| South Fork Cumberland | Roaring Paunch Creek-Big South Fork Cumberland River | Station Camp Creek | Ben Creek, Twin Arches, Mill Creek, Middle Creek | 18 |
| South Fork Cumberland | Roaring Paunch Creek-Big South Fork Cumberland River | No Business Creek- Big South Fork Cumberland River | Big Island | 2 |
| South Fork Cumberland | Roaring Paunch Creek-Big South Fork Cumberland River | Williams Creek- Big South Fork Cumberland River | Puncheon Camp | 1 |
| South Fork Cumberland | North White Oak Creek | North White Oak Creek | White Oak | 1 |
| South Fork Cumberland | North White Oak Creek | Laurel Fork | Laurel Fork | 3 |
| South Fork Cumberland | Clear Fork | Clear Fork Middle | Clear Fork | 5 |
| Obey | Wolf River | Rotten Fork River | Jim Creek | 2 |
| Obey | Wolf River | Delk Creek -Wolf River | Pogue Creek | 5 |

Figure 2. Distribution of Cumberland Sandwort Occurrences by HUC-12 Watersheds



Population Monitoring Data

Population monitoring of *A. cumberlandensis* was conducted in 2000 and again in 2006-2008 at the majority of the EOs. Only eight locations (6 EOs) were not visited or were not located in 2006-2008. Monitoring data for the 2000 survey and the 2006-2008 surveys are presented in Table 3. The column titled “Old EO” is the original EO number that was assigned to the database record prior to the 2008 remapping and the application of the custom EO delineation. The monitoring data, occurrence reports, and maps for each of the 66 EOs and 18 populations (including Jim Creek found in 2010) in Tennessee and Kentucky are provided in Appendix I.

In 2000, TNHP established a monitoring protocol for *A. cumberlandensis* and conducted the baseline monitoring at 30 EOs (34 locations) in Tennessee (Bailey and Shea 2000). In 2004-2005, two EOs were monitored and the number of plants estimated. In 2006-2008, monitoring was conducted for the second time at 34 of the year-2000 sites and for the first time at 39 additional locations for a total of 57 EOs (73 locations) monitored (TDEC 2008). Long-term monitoring is necessary for assessing recovery goals and determining threats to the populations of *Arenaria cumberlandensis*. Long-term monitoring should include collection of demographic data to determine whether populations are self-sustaining. The population data collection since 2000 occurred in the winter and spring months when all stage classes are not observable. If demographic data are to be collected in the future, then monitoring may need to be done during both the winter and summer at all or a sample of the EOs.

Monitoring Protocol

The protocol for the baseline monitoring was developed in 2000. The **estimated** number of plants and the **estimated** spatial extent (in square meters) of area occupied by the plants were to be recorded for each occurrence. This method was used instead of typical monitoring methods that involve counting the number of individuals through either census or sampling. Both the *A. cumberlandensis* plants and the habitat (sand substrate) are very sensitive to trampling and counting individual fragile plants would cause significant disturbance and damage. The plants that occupy the higher ledges on the cliff overhangs cannot be accessed in most cases so the area occupied cannot be measured. Some higher ledges can be viewed with binoculars. The monitoring has been done in the spring and winter months when the associated plants have died back. The *A. cumberlandensis* over-winters and is readily visible as the rosettes, or tufts, remain green to brown and in most cases the remains of longer stems and capsules are present. As mentioned above, if demographic data are to be obtained then the sites will need to be visited in additional months of the year. In this case permanent monitoring plots may need to be established to determine if reproduction and recruitment are occurring.

In 2000, as part of the monitoring protocol, detailed hand-drawn maps were made and photos taken for each monitoring location to provide a basis for comparing distribution of plants at an occurrence over time. However, in 2000 the area occupied was not recorded for most of the occurrences, but, the estimated number of plants was recorded. This protocol was used by TNHP in 2006-2008 for collecting data to track changes in the status of *A. cumberlandensis* occurrences which included the estimated number of plants and the area covered (Table 3). The year-2000 maps were edited and new maps drawn for new EOs and photographs taken at each site. The current monitoring methods will need to be evaluated periodically to determine whether they are providing an effective basis for evaluating trends in *A. cumberlandensis* populations throughout the species' range.

As stated in the recovery plan, delisting will be considered when 40 geographically distinct, self-sustaining occurrences are protected and have maintained statistically stable or increasing numbers for 5 consecutive years. A monitoring schedule for the next 10 years has been proposed to help provide data for assessing threats and evaluating whether occurrences are self-sustaining. The Cumberland sandwort sites within the EOs have

been assigned priority monitoring rankings based on threats, ownership, and accessibility. The sites with the higher threats of disturbance, especially ones along heavily used trails on public lands, will be monitored more frequently. The sites on private lands and those on public lands that are more remote and not along trails will be monitored less frequently. The three monitoring intervals or tiers are 1-3 years, 3-6 years, and 6-10 years (Table 3). Starting in 2011, a total of 80 extant sites (61 EOs) will be monitored using the following schedule: 1-3 years monitoring at 24 sites (18 EOs), 3-6 years at 27 sites (27 EOs), and, 6-10 years at 29 locations (18 EOs). Three locations were not found during the survey and will not be monitored. TNHNP plans to coordinate with NPS Appalachian Highlands Inventory and Monitoring Network and the USFWS to establish a monitoring program for EOs at BSFNRRRA.

Table 3: Population Monitoring 2000-2008.

| ID | EO | COUNTY | OWNER | SITE NAME | Old EO | Pop# | Population Name | Monitor Schedule 1-3 Yrs | Monitor Schedule 3- 6 Yrs | Monitor Schedule 6-10 Yrs | First Observed | Last Observed | Monitoring 2006-2007-2008 Est# Plants | Area Covered | 2006-2008 Comments | Monitoring 2000 Est# Plants | 2000 Area covered | 2000 Comments |
|----|---------|----------|---------|--------------------------------------|---------|------|-----------------|--------------------------|---------------------------|---------------------------|----------------|---------------|---------------------------------------|---------------------|--------------------|-----------------------------|-------------------|---------------|
| 93 | 2 | Morgan | NPS | Peters Bridge Southeast | 2 | 1 | Clear Fork | | | | 1968-12-11 | 1980-10-14 | 0 | | no plants found | | | |
| 4 | 3 | Fentress | NPS | Peters Bridge North Side Cedar Creek | 3 | 1 | Clear Fork | X | | | 1977-08-29 | 2007-04-17 | 127 | | | | | |
| 97 | 73 | Fentress | NPS | Skull Cave Creek | 73 | 1 | Clear Fork | | X | | 1999-04-17 | 1999-04-17 | | | not visited | 1999=1,000 | <5.0 m | |
| 7 | 48a | Fentress | PRIVATE | Peters Bridge East Facing Bluff | 48 | 1 | Clear Fork | | | X | 1996-10-30 | 2007-04-17 | 80 | 0.5 M ² | | | | |
| 7 | 48b | Fentress | PRIVATE | Peters Bridge East Facing Bluff | 49 | 1 | Clear Fork | | | X | 1996-10-30 | 2007-04-17 | 123 | 2.75 M ² | | | | |
| 7 | 48c | Fentress | PRIVATE | Peters Bridge East Facing Bluff | 50 | 1 | Clear Fork | | | X | 1996-10-30 | 2007-04-17 | 31 | <0.5 M ² | | | | |
| 7 | 48d | Fentress | PRIVATE | Peters Bridge East Facing Bluff | 51 | 1 | Clear Fork | | | X | 1996-10-30 | 2007-04-17 | 50 | 0.5 M ² | | | | |
| 7 | 48e & f | Fentress | PRIVATE | Peters Bridge East Facing Bluff | 52 & 53 | 1 | Clear Fork | | | X | 1996-10-30 | 2007-04-17 | 620 | 3.25 M ² | | 1996=600 | | |

| ID | EO | COUNTY | OWNER | SITE NAME | Old EO | Pop# | Population Name | Monitor Schedule 1-3 Yrs | Monitor Schedule 3- 6 Yrs | Monitor Schedule 6-10 Yrs | First Observed | Last Observed | Monitoring 2006-2007-2008 Est# Plants | Area Covered | 2006-2008 Comments | Monitoring 2000 Est# Plants | 2000 Area covered | 2000 Comments |
|----|-------------|----------|---------|----------------------------------|--------|------|-----------------|--------------------------|---------------------------|---------------------------|----------------|---------------|---------------------------------------|----------------------|--------------------|-----------------------------|--------------------------|-----------------------------|
| 97 | 54(1-2-3) | Fentress | PRIVATE | Peters Bridge South Facing Bluff | 54 | 1 | Clear Fork | | | X | 1996-10-30 | 2007-04-17 | 650 | 10.5 M ² | | | | |
| 97 | 54(4) | Fentress | PRIVATE | Peters Bridge South Facing Bluff | 55 | 1 | Clear Fork | | | X | 1996-10-30 | 1996-10-30 | | | not visited | 1996=15 | | |
| 97 | 54(5-6-7-8) | Fentress | PRIVATE | Peters Bridge South Facing Bluff | 56 | 1 | Clear Fork | | | X | 1996-10-30 | 2007-04-17 | 1,250 | 39.25 M ² | | | | |
| 3 | 7 | Fentress | PRIVATE | Jamestown Barrens | 7 | 2 | White Oak | | | X | 1979-06-16 | 2007-11-06 | 450 | 4 M ² | | 200 | | |
| 98 | 25 | Fentress | NPS | Darrow Ridge Northern | 25 | 3 | Laurel Fork | | X | | 1995-08-03 | 2006-12-20 | 1500 | 24M ² | floor & ledges | | | |
| 12 | 65 | Fentress | NPS | Darrow Ridge Southern | 65 | 3 | Laurel Fork | X | | | 2006-12-20 | 2006-12-20 | 1760 | 30 M ² | scattered | | | |
| 10 | 60(1) | Fentress | NPS | Hippy Cave | 60 | 3 | Laurel Fork | X | | | 2006-12-20 | 2006-12-20 | 2,250 | 30 M ² | | | | |
| 10 | 60(2) | Fentress | NPS | Hippy Cave | 60 | 3 | Laurel Fork | X | | | 2004-07-21 | 2006-12-20 | 6130 | 40 M ² | | (2004) 250 | | Monitored in 2004 |
| 43 | 58 | Pickett | TDEC | Johnson Branch | 58 | 4 | Pogue Creek | X | | | 2005-10-11 | 2005-10-11 | | | | (2005) 500 | (2005) 10 M ² | Visited 2005, not monitored |

| ID | EOR | COUNTY | OWNER | SITE NAME | Old EO | Pop# | Population Name | Monitor Schedule 1-3 Yrs | Monitor Schedule 3- 6 Yrs | Monitor Schedule 6-10 Yrs | First Observed | Last Observed | Monitoring 2006-2007-2008 Est# Plants | Area Covered | 2006-2008 Comments | Monitoring 2000 Est# Plants | 2000 Area covered | 2000 Comments |
|----|-------|----------|---------|---|--------|------|-----------------|--------------------------|---------------------------|---------------------------|----------------|---------------|---------------------------------------|--------------------|--------------------|-----------------------------|-------------------|------------------------|
| 88 | 62 | Fentress | TDEC | Pogue Creek #6 | 62 | 4 | Pogue Creek | | X | | 2007-08-11 | 2007-08-11 | 50-100 | | | | | Visited not monitored |
| 89 | 63 | Fentress | PRIVATE | Pogue Creek East Side Tributary | 63 | 4 | Pogue Creek | | X | | 2007-08-11 | 2007-08-11 | 400+ | | | | | Visited not monitored |
| 96 | 72 | Fentress | TDEC | Pogue Creek Wasik Site | 72 | 4 | Pogue Creek | | X | | 2007-12-21 | 2007-12-21 | 2 plants | <0.1 | floor | | | |
| 24 | 76 | Fentress | PRIVATE | Pogue Creek Rockhouse#4 | 63 | 4 | Pogue Creek | | X | | 2007-08-11 | 2007-08-11 | 200+ | 1 M ² | | | | Visited not monitored |
| 7 | 27 | Fentress | NPS | Middle Creek Loop Trail Rockhouse3 | 27 | 5 | Ben Creek | X | | | 2000-02-08 | 2007-01-10 | 62 | 1 M ² | floor | 8 | | |
| 2 | 31 | Fentress | NPS | Middle Creek Loop Trail Open Ledges | 31 | 5 | Ben Creek | X | | | 2000-02-08 | 2007-01-10 | 500-1000 | 5 M ² | ledges | 200 | | |
| 3 | 29(1) | Pickett | NPS | Middle Creek Loop Trail/Head of Ben Creek | 29 | 5 | Ben Creek | X | | | 2000-02-02 | 2007-01-10 | 95 | 0.5 M ² | ledge | 100 | | dense and 100 on ledge |
| 3 | 29(2) | Pickett | NPS | Middle Creek Loop Trail/Head of Ben Creek | 29 | 5 | Ben Creek | X | | | 2000-02-02 | 2007-01-10 | 1000+ | 35 M ² | floor | 100 | | |
| 3 | 29(3) | Pickett | NPS | Middle Creek Loop Trail/Head of Ben Creek | 28 | 5 | Ben Creek | X | | | 2000-02-02 | 2007-01-10 | 200+ | 1 M ² | ledges | 100 | | |

| ID | EOR | COUNTY | OWNER | SITE NAME | Old EO | Pop# | Population Name | Monitor Schedule 1-3 Yrs | Monitor Schedule 3- 6 Yrs | Monitor Schedule 6-10 Yrs | First Observed | Last Observed | Monitoring 2006-2007-2008 Est# Plants | Area Covered | 2006-2008 Comments | Monitoring 2000 Est# Plants | 2000 Area covered | 2000 Comments |
|----|-----------|----------|-------|------------------------------------|--------|------|-----------------|--------------------------|---------------------------|---------------------------|----------------|---------------|---------------------------------------|--------------------|-------------------------|-----------------------------|-------------------|---------------|
| 56 | 61(1) | Fentress | NPS | Middle Creek Loop Trail | 61 | 5 | Ben Creek | X | | | 2002-06-02 | 2007-01-10 | 250 | 1 M ² | floor & ledges | | | |
| 4 | 61(2) | Fentress | NPS | Middle Creek Loop Trail | 30 | 5 | Ben Creek | X | | | 2000-02-08 | 2007-01-10 | 1000+ | 20+ M ² | floor & ledges | 250 | | |
| 29 | 59 | Scott | NPS | Puncheon Camp Fork Bluff | 59 | 6 | Puncheoncamp | | X | | 1990 | 2008-01-23 | 110 | 2 M ² | | | | |
| 4 | 41 | Scott | NPS | Rockhouse ESE of Big Island | 41 | 7 | Big Island | | | X | 2000-03-15 | 2000-03-15 | | | No plants found at site | 50 | | |
| 93 | 1a | Scott | NPS | Big Island Rockhouses | 1 | 7 | Big Island | X | | | 1980-07-18 | 2006-11-01 | 250-500 | 2.0 M ² | floor & ledges | 500 | 0.5 m2 | |
| 93 | 1b | Scott | NPS | Big Island Rockhouses | 40 | 7 | Big Island | | X | | 1980-07-18 | 2006-11-01 | 2100+ | 8.0 M ² | ledges | 2000 | | |
| 2 | 42 | Scott | NPS | Loop Trail South Facing Rockhouses | 42 | 8 | Twin Arches | X | | | 2000-03-15 | 2006-12-06 | 500-1000 | 3.5 M ² | floor | 200 | | |
| 7 | 45(1,2,3) | Scott | NPS | Loop Trail At Ladders | 45 | 8 | Twin Arches | X | | | 2000-02-07 | 2006-12-06 | 552+ | 2.5 M ² | floor & ledges | 120 | | |
| 6 | 17 | Pickett | NPS | Slave Falls | 17 | 9 | Mill Creek | X | | | 1992-09-13 | 2006-12-14 | 3200 | 60 M ² | | 100'S | | |

| ID | EOR | COUNTY | OWNER | SITE NAME | Old EO | Pop# | Population Name | Monitor Schedule 1-3 Yrs | Monitor Schedule 3- 6 Yrs | Monitor Schedule 6-10 Yrs | First Observed | Last Observed | Monitoring 2006-2007-2008 Est# Plants | Area Covered | 2006-2008 Comments | Monitoring 2000 Est# Plants | 2000 Area covered | 2000 Comments |
|----|-------------|----------|-------|------------------------------------|--------|------|-----------------|--------------------------|---------------------------|---------------------------|----------------|---------------|---------------------------------------|----------------------|-----------------------|-----------------------------|-------------------|---------------|
| 25 | 47 | Pickett | NPS | Downstream of Slave Falls | 47 | 9 | Mill Creek | X | | | 2000-02-22 | 2006-12-14 | 800 | 7.5 M ² | floor & ledges | 20 | | |
| 11 | 64 | Fentress | NPS | Rockhouse Benchmark | 64 | 9 | Mill Creek | | X | | 2006-12-14 | 2006-12-14 | 425 | 3.25 M ² | | | | |
| 0 | 43(a,b,c) | Pickett | NPS | Mill Creek Tributary Ravine#1 | 43 | 9 | Mill Creek | | X | | 2000-04-19 | 2007-03-13 | 1,750+ | 37 M ² | upper slopes of drain | 500 | | |
| 28 | 44(a,b,c,d) | Pickett | NPS | Mill Creek Tributary Ravine | 44 | 9 | Mill Creek | | X | | 2000-04-19 | 2007-03-13 | 3325 | 34.5 M ² | ledge | 1000 | | |
| 36 | 79(1,2) | Pickett | NPS | Mill Creek Tributary Ravine#2 | 44 | 9 | Mill Creek | | X | | 2000-04-19 | 2007-03-13 | 525 | 3.25 M ² | | part of 44 | | |
| 6 | 19 | Pickett | NPS | Middle Creek 2 | 19 | 10 | Middle Creek | | | | 1992-07-29 | 1992-07-29 | | | not found | | | |
| 5 | 20 | Pickett | NPS | Middle Creek 3 | 20 | 10 | Middle Creek | | | X | 1992-07-20 | 2006-12-06 | <10 | <0.25 M ² | ledges | | | |
| 62 | 21 | Pickett | NPS | Middle Creek 4 | 21 | 10 | Middle Creek | | | X | 1992-07-29 | 2008-03-12 | 1,250 | 10.5 M ² | floor & ledges | | | |
| 55 | 18a | Pickett | NPS | Middle Creek Ridgetop Cliffs North | 18 | 10 | Middle Creek | | | X | 1992 | 2008-02-07 | 30-40 | 1 M ² | ledges on cliff | | | |

| ID | EOR | COUNTY | OWNER | SITE NAME | Old EO | Pop# | Population Name | Monitor Schedule 1-3 Yrs | Monitor Schedule 3- 6 Yrs | Monitor Schedule 6-10 Yrs | First Observed | Last Observed | Monitoring 2006-2007-2008 Est# Plants | Area Covered | 2006-2008 Comments | Monitoring 2000 Est# Plants | 2000 Area covered | 2000 Comments |
|----|---------|---------|-------|-------------------------------------|--------|------|----------------------|--------------------------|---------------------------|---------------------------|----------------|---------------|---------------------------------------|--------------------|-----------------------|-----------------------------|-------------------|---------------|
| 55 | 18b | Pickett | NPS | Middle Creek Ridgetop Cliffs North | 18 | 10 | Middle Creek | | | X | 1992 | 2008-02-07 | 12 | 0.5 M ² | muddy gravel | | | |
| 55 | 18c | Pickett | NPS | Middle Creek Ridgetop Cliffs North | 18 | 10 | Middle Creek | | | X | 1992 | 2008-02-07 | 2,500-6,000 | 40 M ² | wet floor | | | |
| 55 | 18d | Pickett | NPS | Middle Creek Ridgetop Cliffs North | 23 | 10 | Middle Creek | | | | 1992 | 1992 | | | not found, mismapped? | | | |
| 2 | 22(1,2) | Pickett | NPS | Middle Creek 5 | 22 | 10 | Middle Creek | | | X | 1992-07-22 | 2008-03-12 | 1500 | 9.5 M ² | | | | |
| 77 | 74a | Pickett | NPS | Middle Creek Ridgetop Cliffs South | 74 | 10 | Middle Creek | | | X | 1992 | 2008-02-07 | 1,600 | 70 M ² | | | | |
| 77 | 74b | Pickett | NPS | Middle Creek Ridgetop Cliffs South | 75 | 10 | Middle Creek | | | X | 1992 | 2008-02-07 | 11,400 | 600 M ² | | | | |
| 0 | 16(a,b) | Pickett | TSP | Watson Branch | 16 | 11 | Watson Branch | | | X | 1993-03-29 | 2007-04-19 | 2050 | 30 M ² | floor & ledges | | | |
| 8 | 5 | Pickett | TSP | Hidden Passage Tunnel/Crystal Falls | 5 | 12 | Upper Thompson Creek | X | | | 1978-09-17 | 2007-03-13 | 300-500 | 3 M ² | | | | |
| 1 | 12 | Pickett | TSP | Swinging Bridge | 12 | 12 | Upper Thompson Creek | | X | | 1980 | 2007-04-19 | 34 | >1m ² | scattered on ledges | 100 | | |

| ID | EOR | COUNTY | OWNER | SITE NAME | Old EO | Pop# | Population Name | Monitor Schedule 1-3 Yrs | Monitor Schedule 3- 6 Yrs | Monitor Schedule 6-10 Yrs | First Observed | Last Observed | Monitoring 2006-2007-2008 Est# Plants | Area Covered | 2006-2008 Comments | Monitoring 2000 Est# Plants | 2000 Area covered | 2000 Comments |
|----|-----|----------|-------|--------------------------------|--------|------|----------------------|--------------------------|---------------------------|---------------------------|----------------|---------------|---------------------------------------|---------------------|---------------------|-----------------------------|-------------------|---------------|
| 7 | 13 | Pickett | TSP | Ladder Trail | 13 | 12 | Upper Thompson Creek | X | | | 1980 | 2007-03-13 | 4150 | 40 M ² | floor & ledges | 1000 | | |
| 9 | 24 | Pickett | TDF | Indian Rockhouse | 24 | 12 | Upper Thompson Creek | X | | | 1973-06-11 | 2007-02-14 | 1000+ | 7.5 M ² | 2 rockhouses, floor | 600 | 4X2 FT | |
| 0 | 26 | Pickett | TSP | Natural Bridge At Pickett Lake | 26, 57 | 12 | Upper Thompson Creek | X | | | 2000-02-03 | 2007-04-19 | 70-100 | 1 M ² | | <100 | | |
| 1 | 33 | Fentress | TDF | Rockhouse SW of Hazard Cave | 33 | 12 | Upper Thompson Creek | | X | | 2000-02-23 | 2007-02-14 | 2000 | 25 M ² | floor | 1000 | | |
| 8 | 34 | Pickett | TSP | Natural Bridge Trail | 34 | 12 | Upper Thompson Creek | | X | | 2000-02-23 | 2007-02-14 | 90 | 0.5 M ² | floor | 100 | 5X3 M | 60-100 |
| 13 | 66 | Pickett | TSP | Lake & Ridge Trail | 66 | 12 | Upper Thompson Creek | | X | | 2007-04-19 | 2007-04-19 | 500 | 3 M ² | ledges | | | |
| 7 | 4a | Pickett | TSP | Hazard Cave and West Rockhouse | 4 | 12 | Upper Thompson Creek | X | | | 1979-07-13 | 2007-02-17 | 3000 | 25 M ² + | floor & ledges | 1,000+ | | not counted |
| 1 | 4b | Pickett | TDF | Hazard Cave and West Rockhouse | 32 | 12 | Upper Thompson Creek | | X | | 2000-02-23 | 2007-02-17 | 750 | 14 M ² | floor | 300 | | |
| 57 | 6 | Pickett | TDF | Double Falls Rockhouse | 6 | 13 | Lower Thompson Creek | | X | | 1978-05-22 | 2007-02-27 | 1500 | 10 M ² | ledges mostly | 1000 | | |

| ID | EOR | COUNTY | OWNER | SITE NAME | Old EO | Pop# | Population Name | Monitor Schedule 1-3 Yrs | Monitor Schedule 3- 6 Yrs | Monitor Schedule 6-10 Yrs | First Observed | Last Observed | Monitoring 2006-2007-2008 Est# Plants | Area Covered | 2006-2008 Comments | Monitoring 2000 Est# Plants | 2000 Area covered | 2000 Comments |
|----|--------|---------|-------|--|--------|------|----------------------|--------------------------|---------------------------|---------------------------|----------------|---------------|---------------------------------------|---------------------|---------------------|-----------------------------|-------------------|---------------|
| 4 | 10 | Pickett | TDF | Hidden Passage 1 | 10 | 13 | Lower Thompson Creek | | | X | 1984-10-13 | 1984-10-13 | | | not visited | | | |
| 9 | 14 | Pickett | TDF | Thompson Creek Ridgetop | 14 | 13 | Lower Thompson Creek | | X | | 1980 | 2007-03-13 | 100 | 1 M ² | floor & ledges | | | |
| 8 | 35 | Pickett | TDF | Double Falls Bluff | 35 | 13 | Lower Thompson Creek | | | X | 2000-03-01 | 2007-02-27 | 5000 | 50 M ² | ledges inaccessible | 1000'S MAYBE 10,000 | | |
| 7 | 36 | Pickett | TDF | Rockhouse Below The Hidden Passage Trail | 36 | 13 | Lower Thompson Creek | | | X | 2000-03-02 | 2000-03-02 | | | site not found | 600+ | | seepy floor |
| 17 | 71 | Pickett | TSP | Hidden Passage Trail West of Powerline | 71 | 13 | Lower Thompson Creek | | X | | 2007-03-13 | 2007-03-13 | 300+ | 10.5 M ² | ledges | | | |
| 30 | 77 | Pickett | TDF | Trail to Rock Creek | 9 | 13 | Lower Thompson Creek | | X | | 2007-01-19 | 2007-01-19 | 100 | 1 M ² | rockhouse on ledges | | | |
| 31 | 78 | Pickett | TDF | Trail From Thompson Overlook | 9 | 13 | Lower Thompson Creek | | X | | 1979-12-11 | 2007-01-19 | 300 | 3 M ² | rockhouse on ledges | | | |
| 00 | 11 (1) | Pickett | TDF | Hidden Passage Rockhouses 1&2 | 11 | 13 | Lower Thompson Creek | X | | | 1984-10-13 | 2007-02-27 | 1500 | 16 M ² | floor | 1000 | | |
| 00 | 11 (2) | Pickett | TDF | Hidden Passage Rockhouses 1&2 | 11 | 13 | Lower Thompson Creek | X | | | 1984-10-13 | 2007-02-27 | 1500 | 17.5 M2 | floor | 500-1000 | | |

| ID | EOR | COUNTY | OWNER | SITE NAME | Old EO | Pop# | Population Name | Monitor Schedule 1-3 Yrs | Monitor Schedule 3- 6 Yrs | Monitor Schedule 6-10 Yrs | First Observed | Last Observed | Monitoring 2006-2007-2008 Est# Plants | Area Covered | 2006-2008 Comments | Monitoring 2000 Est# Plants | 2000 Area covered | 2000 Comments |
|----|-----|----------|-------|--|---------|------|---------------------|--------------------------|---------------------------|---------------------------|----------------|---------------|---------------------------------------|--------------------------------|--------------------|-----------------------------|-------------------|------------------|
| 15 | 69 | Pickett | TDF | Spraugh Ridge Rockhouse D | 69 | 14 | Upper Spraugh Ridge | | X | | 2007-03-06 | 2007-03-06 | 2800+ | 27.5 M ² | 3 rockhouses | | | |
| 37 | 80 | Pickett | TDF | Spraugh Ridge Road | 69d | 14 | Upper Spraugh Ridge | | X | | 2007-03-06 | 2007-03-06 | 500 | 10 M ² | 1 rockhouse | | | |
| 4 | 8 | Pickett | TDF | Powerline Rockhouse | 8 | 15 | Lower Rock Creek | | X | | 1979-12-11 | 2007-01-19 | 1,000 | 10 M ² | floor & ledges | 250 | | |
| 8 | 15 | Pickett | TDF | Rock Creek Gorge | 15 & 67 | 15 | Lower Rock Creek | | | X | 1980 | 2007-01-19 | 500 | 5 M ² | floor & ledges | | | |
| 6 | 37 | Pickett | TDF | Bluffs AboveTunnel Trail | 37 | 15 | Lower Rock Creek | | | X | 2000-03-09 | 2007-01-18 | 500+ | 3 M ² | ledges | 100? | | uncertain number |
| 7 | 38 | Pickett | TDF | North of Powerline | 38 | 15 | Lower Rock Creek | | | X | 2000-03-09 | 2008-03-11 | 2900+ | 36 M ² | floor | 3000 | | |
| 57 | 39 | Pickett | TDF | Hidden Passage/Tunnel Trail Intersection | 39 | 15 | Lower Rock Creek | | X | | 2000-03-10 | 2007-01-18 | 1550 | 9 M ² | floor & ledges | 300 | | |
| 16 | 70 | Pickett | TDF | Group Camp Bluffs | 70 | 15 | Lower Rock Creek | | X | | 2007-03-07 | 2007-03-07 | 10,000 | 30M ² +50M (scatt.) | 2 bluff series | | | |
| 04 | 82 | Fentress | TDF | Rockhouse 3 | 82 | 16 | Jim Creek | | | X | 2010-03-18 | 2010-03-18 | 218 (YR 2010) | | | | | |

| ID | EOR | COUNTY | OWNER | SITE NAME | Old EO | Pop# | Population Name | Monitor Schedule 1-3 Yrs | Monitor Schedule 3- 6 Yrs | Monitor Schedule 6-10 Yrs | First Observed | Last Observed | Monitoring 2006-2007-2008 Est# Plants | Area Covered | 2006-2008 Comments | Monitoring 2000 Est# Plants | 2000 Area covered | 2000 Comments |
|----|-------|----------|---------|---------------|--------|------|-----------------|--------------------------|---------------------------|---------------------------|----------------|---------------|---------------------------------------|--------------|--------------------|-----------------------------|-------------------|---------------|
| 03 | 81(a) | Fentress | TDF | Rockhouses 4 | 81 | 16 | Jim Creek | | | X | 2010-03-15 | 2010-03-17 | 230 (YR 2010) | | | | | |
| 03 | 81(b) | Fentress | TDF | Rockhouses 12 | 81 | 16 | Jim Creek | | | X | 2010-03-15 | 2010-03-17 | 2,025 (YR 2010) | | | | | |
| 03 | 81(c) | Fentress | PRIVATE | Rockhouses 13 | 81 | 16 | Jim Creek | | | X | 2010-03-15 | 2010-03-17 | 200 (YR 2010) | | | | | |

Monitoring Results

In general, the extant occurrences of *A. cumberlandensis* do not appear to have declined overall in the last decade, with individuals numbering in the hundreds and thousands (Table 4). The estimated number of plants at each EO has slightly increased in general and it appears that the majority are stable. More time was spent at each site and more detailed notes were recorded in the 2006-2008 field seasons than in the 2000 field season. Nine of the 16 populations (30 EOs) have been monitored more than one year. Seven populations have only been monitored or visited one time. Two of the tasks identified in the recovery plan are to establish the criteria for determining a self-sustaining EO and to refine the definition of a geographically distinct, self-sustaining EO. Data are not currently sufficient to evaluate population trends, long-term monitoring of each EO or each population is needed. In general, self-sustaining is usually defined as reproducing successfully and stable or increasing in size. The monitoring studies will help determine what factors are necessary for occurrences/populations to be self-sustaining.

Based on monitoring data gathered from 2000 to 2010, there are an estimated 104,000 Cumberland sandwort plants located in an estimated 1564 M² area that occur within the species' range in Tennessee and Kentucky (Table 4). NatureServe (2010a) provides the Population/Occurrence Viability Ranks for *A. cumberlandensis* based on custom EO specifications written for the species by KYNPC in 2005. TNHP and KYNPC have ranked the occurrences using the following specifications:

A Rank-Excellent Viability: Population/occurrence inhabits an area of about 40 m or more, occurring as scattered dense groups of plants and these the dominant vegetation. Few if any weedy plants present or other evidence of disturbance. Population reproductive. The rockhouse or overhang is part of a good quality mesophytic forest with trees of varying size classes and the largest over 20 dbh. The forested portion of the habitat is about 40 acres or more in size and provides buffer to the rock outcropping where the population occurs.

B Rank-Good Viability: Population/occurrence inhabits an area of about 40-25 m with scattered dense groups of plants. Population reproductive. Few of any weedy plants present or other evidence of disturbance. The rockhouse/overhang is part of a good quality mesophytic forest as defined above.

C Rank-Fair Viability: Population/occurrence inhabits an area of 25-10 m in area, plants may be sparse and individuals scattered in this area or groups not particularly dense. Habitat may have been disturbed in the recent past and the forest structure altered.

D Rank-Poor Viability: Population/occurrence of scattered individual plants or very small groups, the size of the habitat less than 10 m area.

X Rank: Extirpated

H Rank: Historic, not seen in 25 years

F Rank: Failed to find

E Rank: Extant but no data available, habitat exists at site.

The custom ranking factors are based on quantitative and qualitative measures including habitat size and/or occupied area, and to some degree, habitat quality and landscape context. Ongoing events such as successional changes, threats, or unfavorable management that result in degradation of occurrence quality and quantity should be considered. The 66 EOs for *A. cumberlandensis* were assigned viability ranks based on the conditions when monitored in 2006-2008. If a site was not found or not visited in

2006-2008, the rank was based on the date it was last visited. As discussed earlier, an EO may consist of several rockhouses or a series of ledges and cliffs. The ranks have been assigned to the EO as a whole not the individual rockhouse or site (Table 4). In summary, of the 66 EOs, 11 EOs are ranked A (A or AB); 12 EOs ranked B (B or BC), 12 EOs ranked C (C or CD), 29 EOs ranked D, one ranked H/F, and 2 ranked F (Figures 3a,b,c). The CD-ranked EOs are considered to have uncertain viability and an additional survey would be needed to determine whether the EOs are viable or nonviable. Many of the CD-ranked occurrences were not monitored by TNHP but reported by persons conducting other surveys. Forty-six percent of the EOs is D-ranked. The A-, B- and C-ranked occurrences are considered viable and are distributed fairly equally among the EOs (Figure 3b).

Figure 3a: Range of Occurrence Viability Ranks

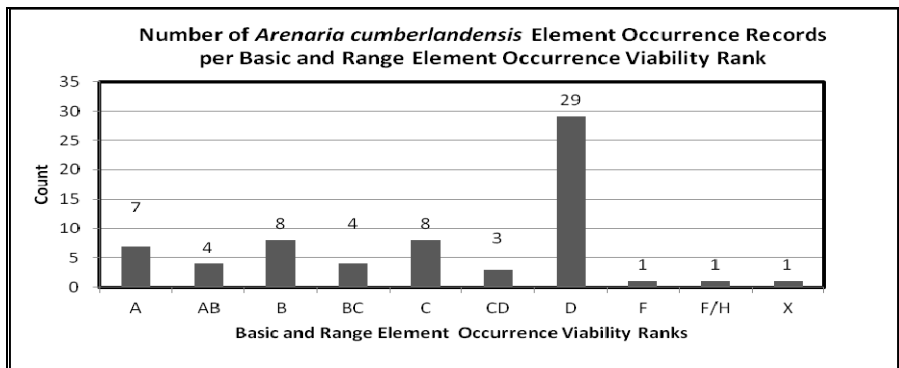


Figure 3b: Range of Occurrence Viability Ranks

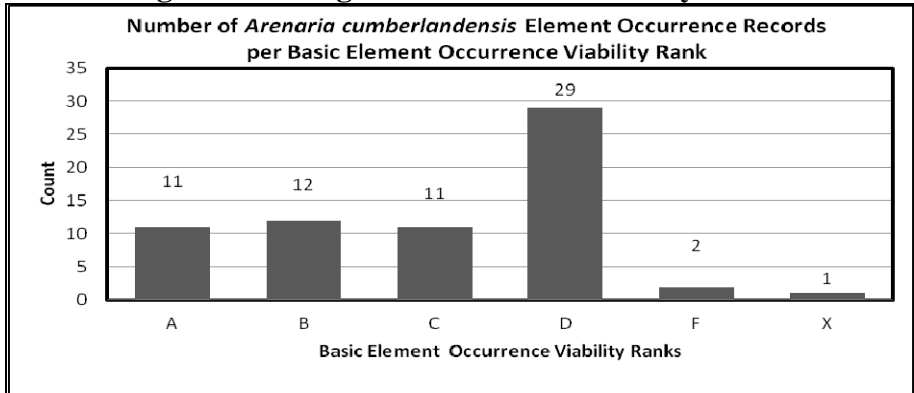
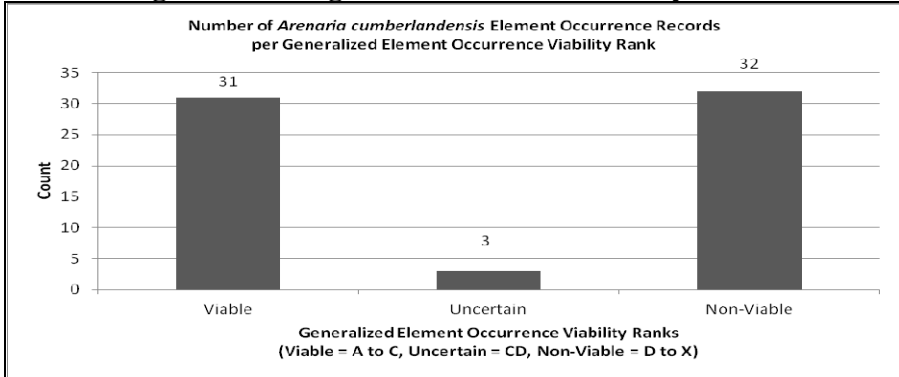


Figure 3c: Range of Occurrence Viability Ranks



Discussion of Populations

The highest density of populations is located in Pickett County. The largest population is the Middle Creek Population in the BSFNRRRA with EO 74 and EO 18 consisting of six very large rockhouses with deep overhangs, moist sandy floors, waterfalls, springs and seeps. For this population, the estimated area occupied by *A. cumberlandensis* is 733 m² with an estimated 21,800 plants (Table 4). Although the Middle Creek EOs were surveyed in the winter, it appears that competition from other vegetation is minimal in these large rockhouses. These EOs are very remote with no trails in the vicinity and little disturbance by human activities. Some of the other rockhouses within this population have evidence of past and present relic digging.

Figure 4: Middle Creek EO 18



Figure 5: Middle Creek EO 74



Six populations have A-ranked EOs - Big Hollow Springs, Laurel Fork, Middle Creek, Upper Thompson Creek, Lower Thompson Creek and Lower Rock Creek. Lower Rock Creek and Middle Creek populations have two A-ranked EOs and the other four populations have one A-ranked EO.

Three populations have AB-ranked EOs – Clear Fork (Peters Bridge South facing bluff), Upper Thompson Creek (Ladder Trail and Hazard Cave), and Mill Creek (Slave Falls). The Upper Thompson Creek EOs are ranked AB because of the degradation of habitat due to disturbance from foot traffic in the rockhouses. TNHP and PSP have built boardwalks and fences to minimize impacts resulting in improved conditions. Slave Falls, located in the BSFNRRRA, is a heavily visited site with significant trampling although the number of plants is large. TNHP and NPS staff will be working on a site protection project in 2012. The Peters Bridge South Facing Bluff occurrence needs to be revisited to determine if the area was calculated correctly. There are a relatively small number of plants, only 1,900, in an estimated area of almost 50 m².

Three populations with A- or AB-ranked EOs, Upper Thompson Creek, Lower Rock Creek and Mill Creek, are all comparable in area and number of plants for *A. cumberlandensis*. The estimated area of the Upper Thompson Creek population is 120 m² with an estimated 1200 plants; the Lower Rock Creek population estimated area is 143 m² with an estimated 1350 plants; and, the Mill Creek population estimated area is 145 m² with an estimated 10,000 plants. The smallest population with an AB-ranked

EO is the Clear Fork population with an estimated 62.52 m² area and 3900 plants. However, most of the sandwort plants were found in one rockhouse in an estimated 36 m² area with an estimated 1000 plants.

Some of the smallest populations (C- and D-ranked) are on the periphery of the range, Puncheon Camp population, Big Island population, White Oak population, part of the Pogue Creek population, and Jim Creek population. Surveys for new populations have not been systematically conducted in these areas, but are needed.

Table 4: Estimated Number and Area of *Arenaria cumberlandensis* Plants for Each Occurrence (EOR)

| E OID | E OR | COUNTY | OWNER | SITE NAME | Pop# | Population Name | EO Rank | First Observed | Last Observed | 1999-2010 Est# Plants | Area Covered | |
|----------------------|---------------------|---------------|--------------|--------------------------------------|-------------|------------------------|----------------|-----------------------|----------------------|---|----------------------|--|
| Kentucky | | | | | | | | | | | | |
| 5864 | 1 | McCreary | NPS | Rock Creek Wild River | 1 | Rock Creek | X | 1984 | 1984-06-24 | | 3x5 ft. | |
| 7700 | 2 | McCreary | NPS | Big Hollow Springs | 2 | Big Hollow Springs | A | 1991-00-00 | 2002-06-20 | 1000+ | | |
| KY TOTAL EORS | 2 | | | | | | | | | KY TOTAL ESTIMATED NUMBER PLANTS | 1000+ | |
| Tennessee | | | | | | | | | | | | |
| 13693 | 2 | Morgan | NPS | Peters Bridge Southeast | 1 | Clear Fork | F/H | 1968-12-11 | 1980-10-14 | | | |
| 394 | 3 | Fentress | NPS | Peters Bridge North Side Cedar Creek | 1 | Clear Fork | D | 1977-08-29 | 2007-04-17 | 127 | | |
| 577 | 48(a,b,c,d,e,f) | Fentress | PRIVATE | Peters Bridge East Facing Bluff | 1 | Clear Fork | C | 1996-10-30 | 2007-04-17 | 904 | 7.5 m ² | |
| 8997 | 54(1,2,3,4,5,6,7,8) | Fentress | PRIVATE | Peters Bridge South Facing Bluff | 1 | Clear Fork | AB | 1996-10-30 | 2007-04-17 | 1,900 | 49.75 m ² | |
| 16297 | 73 | Fentress | NPS | Skull Cave Creek | 1 | Clear Fork | D | 1999-04-17 | 1999-04-17 | 1,000 | 5.0 m ² | |
| 4613 | 7 | Fentress | PRIVATE | Jamestown Barrens | 2 | White Oak | D | 1979-06-16 | 2007-11-06 | 450 | 4 m ² | |
| 12098 | 25 | Fentress | NPS | Darrow Ridge Northern | 3 | Laurel Fork | C | 1995-08-03 | 2006-12-20 | 1500 | 24m ² | |
| 15610 | 60(1,2a,2b) | Fentress | NPS | Hippy Cave | 3 | Laurel Fork | A | 2004-07-21 | 2006-12-20 | 8380 | 70 m ² | |
| 16112 | 65 | Fentress | NPS | Darrow Ridge Southern | 3 | Laurel Fork | B | 2006-12-20 | 2006-12-20 | 1760 | 30 m ² | |
| 15143 | 58 | Pickett | TDEC | Johnson Branch | 4 | Pogue Creek | BC | 2005-10-11 | 2005-10-11 | 500 | 10 m ² | |

| E OID | E OR | COUNTY | OWNER | SITE NAME | Pop# | Population Name | EO Rank | First Observed | Last Observed | 1999-2010 Est# Plants | Area Covered |
|--------------|-------------|---------------|--------------|--|-------------|------------------------|----------------|-----------------------|----------------------|------------------------------|---------------------|
| 16088 | 62 | Fentress | TDEC | Pogue Creek #6 | 4 | Pogue Creek | D | 2007-08-11 | 2007-08-11 | 100 | |
| 16089 | 63(1,2,3,5) | Fentress | PRIVATE | Pogue Creek East Side Tributary | 4 | Pogue Creek | CD | 2007-08-11 | 2007-08-11 | 400 | |
| 16296 | 72 | Fentress | TDEC | Pogue Creek Wasik Site | 4 | Pogue Creek | D | 2007-12-21 | 2007-12-21 | 2 | >0.1 m ² |
| 16524 | 76 | Fentress | PRIVATE | Pogue Creek Rockhouse#4 | 4 | Pogue Creek | CD | 2007-08-11 | 2007-08-11 | 200 | 1 m ² |
| 9557 | 27 | Fentress | NPS | Middle Creek Loop Trail Rockhouse3 | 5 | Ben Creek | D | 2000-02-08 | 2007-01-10 | 62 | 1 m ² |
| 8983 | 29(1,2,3) | Pickett | NPS | Middle Creek Loop Trail/Head of Ben Creek | 5 | Ben Creek | B | 2000-02-02 | 2007-01-10 | 1295 | 36.5 m ² |
| 7952 | 31 | Fentress | NPS | Middle Creek Loop Trail Open Ledges | 5 | Ben Creek | D | 2000-02-08 | 2007-01-10 | 1000 | 5 m ² |
| 8984 | 61(1,2) | Fentress | NPS | Middle Creek Loop Trail | 5 | Ben Creek | BC | 2000-02-08 | 2007-01-10 | 1250 | 21 m ² |
| 15229 | 59 | Scott | NPS | Puncheon Camp Fork Bluff | 6 | Puncheoncamp | D | 1990 | 2008-01-23 | 110 | 2 m ² |
| 12693 | 1(a,b) | Scott | NPS | Big Island Rockhouses | 7 | Big Island | C | 1980-07-18 | 2006-11-01 | 2600 | 10 m ² |
| 4004 | 41 | Scott | NPS | Rockhouse ESE of Big Island | 7 | Big Island | D | 2000-03-15 | 2000-03-15 | 50 | |
| 9052 | 42 | Scott | NPS | Loop Trail South Facing Rockhouses | 8 | Twin Arches | D | 2000-03-15 | 2006-12-06 | 500-1000 | 3.5 m ² |
| 3827 | 45(1,2,3) | Scott | NPS | Loop Trail At Ladders | 8 | Twin Arches | D | 2000-02-07 | 2006-12-06 | 552 | 2.5 m ² |
| 7466 | 17 | Pickett | NPS | Slave Falls | 9 | Mill Creek | AB | 1992-09-13 | 2006-12-14 | 3200 | 60 m ² |
| 1940 | 43(a,b,c) | Pickett | NPS | Mill Creek Tributary Ravine#1 | 9 | Mill Creek | B | 2000-04-19 | 2007-03-13 | 1,750 | 37 m ² |
| 11528 | 44(a,b,c,d) | Pickett | NPS | Mill Creek Tributary Ravine | 9 | Mill Creek | B | 2000-04-19 | 2007-03-13 | 3325 | 34.5 m ² |
| 16536 | 79(a,b) | Pickett | NPS | Mill Creek Tributary Ravine#2 | 9 | Mill Creek | D | 2000-04-19 | 2007-03-13 | 525 | 3.25 m ² |

| E OID | E OR | COUNTY | OWNER | SITE NAME | Pop# | Population Name | EO Rank | First Observed | Last Observed | 1999-2010 Est# Plants | Area Covered |
|--------------|--------------|---------------|--------------|-------------------------------------|-------------|------------------------|----------------|-----------------------|----------------------|------------------------------|---------------------|
| 13125 | 47(1, 2a,2b) | Pickett | NPS | Downstream of Slave Falls | 9 | Mill Creek | D | 2000-02-22 | 2006-12-14 | 800 | 7.5 m ² |
| 16111 | 64 | Fentress | NPS | Rockhouse Benchmark | 9 | Mill Creek | D | 2006-12-14 | 2006-12-14 | 425 | 3.25 m ² |
| 14055 | 18(a,b,c,d) | Pickett | NPS | Middle Creek Ridgetop Cliffs North | 10 | Middle Creek | A | 1992 | 2008-02-07 | 6042 | 42.5 m ² |
| 6526 | 19 | Pickett | NPS | Middle Creek 2 | 10 | Middle Creek | F | 1992-07-29 | 1992-07-29 | | |
| 6525 | 20 | Pickett | NPS | Middle Creek 3 | 10 | Middle Creek | D | 1992-07-20 | 2006-12-06 | 10 | 0.25 m ² |
| 14662 | 21 | Pickett | NPS | Middle Creek 4 | 10 | Middle Creek | C | 1992-07-29 | 2008-03-12 | 1,250 | 10.5 m ² |
| 2902 | 22(1,2) | Pickett | NPS | Middle Creek 5 | 10 | Middle Creek | C | 1992-07-22 | 2008-03-12 | 1500 | 9.5 m ² |
| 16377 | 74(a,b) | Pickett | NPS | Middle Creek Ridgetop Cliffs South | 10 | Middle Creek | A | 1992 | 2008-02-07 | 13,000 | 670 m ² |
| 2450 | 16(a,b) | Pickett | TSP | Watson Branch | 11 | Watson Branch | B | 1993-03-29 | 2007-04-19 | 2050 | 30 m ² |
| 7357 | 4(a,b) | Pickett | TSP | Hazard Cave and West Rockhouse | 12 | Upper Thompson Creek | AB | 1979-07-13 | 2007-02-17 | 3,750 | 39 m ² |
| 3968 | 5 | Pickett | TSP | Hidden Passage Tunnel/Crystal Falls | 12 | Upper Thompson Creek | D | 1978-09-17 | 2007-03-13 | 300-500 | 3 m ² |
| 6251 | 12 | Pickett | TSP | Swinging Bridge | 12 | Upper Thompson Creek | D | 1980 | 2007-04-19 | 34 | 1.0 m ² |
| 9337 | 13 | Pickett | TSP | Ladder Trail | 12 | Upper Thompson Creek | AB | 1980 | 2007-03-13 | 4150 | 40 m ² |
| 1509 | 24 | Pickett | TDF | Indian Rockhouse | 12 | Upper Thompson Creek | C | 1973-06-11 | 2007-02-14 | 1000+ | 7.5 m ² |
| 5290 | 26 | Pickett | TSP | Natural Bridge At Pickett Lake | 12 | Upper Thompson Creek | D | 2000-02-03 | 2007-04-19 | 70-100 | 1 m ² |
| 1671 | 33 | Fentress | TDF | Rockhouse SW of Hazard Cave | 12 | Upper Thompson Creek | C | 2000-02-23 | 2007-02-14 | 2000 | 25 m ² |
| 5608 | 34 | Pickett | TSP | Natural Bridge Trail | 12 | Upper Thompson Creek | D | 2000-02-23 | 2007-02-14 | 90 | 0.5 m ² |

| EOID | EOR | COUNTY | OWNER | SITE NAME | Pop# | Population Name | EO Rank | First Observed | Last Observed | 1999-2010 Est# Plants | Area Covered |
|-------------|--------------|---------------|--------------|--|-------------|------------------------|----------------|-----------------------|----------------------|------------------------------|---------------------|
| 16113 | 66 | Pickett | TSP | Lake & Ridge Trail | 12 | Upper Thompson Creek | D | 2007-04-19 | 2007-04-19 | 500 | 3 m ² |
| 10857 | 6 | Pickett | TDF | Double Falls Rockhouse | 13 | Lower Thompson Creek | BC | 1978-05-22 | 2007-02-27 | 1500 | 10 m ² |
| 16530 | 77 | Pickett | TDF | Trail to Rock Creek | 13 | Lower Thompson Creek | D | 2007-01-19 | 2007-01-19 | 100 | 1 m ² |
| 16531 | 78 | Pickett | TDF | Trail From Thompson Overlook | 13 | Lower Thompson Creek | D | 1979-12-11 | 2007-01-19 | 300 | 3 m ² |
| 5044 | 10 | Pickett | TDF | Hidden Passage 1 | 13 | Lower Thompson Creek | D | 1984-10-13 | 1984-10-13 | | |
| 12100 | 11 (1,2) | Pickett | TDF | Hidden Passage Rockhouses 1&2 | 13 | Lower Thompson Creek | B | 1984-10-13 | 2007-02-27 | 3,000 | 33.5 m ² |
| 1439 | 14 | Pickett | TDF | Thompson Creek Ridgetop | 13 | Lower Thompson Creek | D | 1980 | 2007-03-13 | 100 | 1 m ² |
| 4358 | 35 | Pickett | TDF | Double Falls Bluff | 13 | Lower Thompson Creek | A | 2000-03-01 | 2007-02-27 | 5000 | 50 m ² |
| 6867 | 36 | Pickett | TDF | Rockhouse Below The Hidden Passage Trail | 13 | Lower Thompson Creek | D | 2000-03-02 | 2000-03-02 | 600 | |
| 16117 | 71 | Pickett | TSP | Hidden Passage Trail West of Powerline | 13 | Lower Thompson Creek | D | 2007-03-13 | 2007-03-13 | 300 | 10.5 m ² |
| 16115 | 69a,b,Uc,Lc | Pickett | TDF | Spraugh Ridge Rockhouse D | 14 | Upper Spraugh Ridge | B | 2007-03-06 | 2007-03-06 | 2800 | 27.5 m ² |
| 16537 | 80 | Pickett | TDF | Spraugh Ridge Road | 14 | Upper Spraugh Ridge | D | 2007-03-06 | 2007-03-06 | 500 | 10 m ² |
| 9774 | 8 | Pickett | TDF | Powerline Rockhouse | 15 | Lower Rock Creek | C | 1979-12-11 | 2007-01-19 | 1,000 | 10 m ² |
| 9888 | 15 | Pickett | TDF | Rock Creek Gorge | 15 | Lower Rock Creek | D | 1980 | 2007-01-19 | 500 | 5 m ² |
| 9546 | 37 | Pickett | TDF | Bluffs AboveTunnel Trail | 15 | Lower Rock Creek | CD | 2000-03-09 | 2007-01-18 | 500 | 3m ² |
| 6277 | 38(1, 2a,2b) | Pickett | TDF | North of Powerline | 15 | Lower Rock Creek | A | 2000-03-09 | 2008-03-11 | 2900+ | 36 m ² |
| 10367 | 39 | Pickett | TDF | Hidden Passage/Tunnel Trail Intersection | 15 | Lower Rock Creek | BC | 2000-03-10 | 2007-01-18 | 1550 | 9 m ² |

| EOID | EOR | COUNTY | OWNER | SITE NAME | Pop# | Population Name | EO Rank | First Observed | Last Observed | 1999-2010 Est# Plants | Area Covered |
|------------------------------|------------|---------------|--------------|----------------------|-------------|------------------------|----------------|-----------------------|----------------------|---|---------------------------|
| 16116 | 70 | Pickett | TDF | Group Camp Bluffs | 15 | Lower Rock Creek | A | 2007-03-07 | 2007-03-07 | 10,000 | 80 m ² |
| 17003 | 81(a,b,c) | Fentress | TDF/Private | Rockhouses 4, 12, 13 | 16 | Jim Creek | BC | 2010-03-15 | 2010-03-17 | 2,265 | |
| 17004 | 82 | Fentress | TDF | Rockhouse 3 | 16 | Jim Creek | D | 2010-03-18 | 2010-03-18 | 218 | |
| TN TOTAL EORS | 64 | | | | | | | | | TN TOTAL ESTIMATED NUMBER PLANTS 102,766 | 1564 m² |

Reproductive Biology and Genetics

Systematic studies of the life history of *A. cumberlandensis* have not been done. Breeding system studies are needed to identify biological, demographic, and reproductive traits that could constrain population sizes or influence observed levels and patterns of genetic variation. Winder (2004) studied the levels of patterns of genetic diversity within the species range in Tennessee. Although these studies are preliminary, he made many observations about the ecology and biology of the species and suggested that finer-scale sampling of genetic variation within populations could add to our understanding of mechanisms of gene flow within the species.

As discussed by Winder, the vectors of seed dispersal and pollinators have not been determined but have been surmised based on observations of the pollen mechanisms of this species in the flower structure. The small white flowers are suited to a strategy of generalist insect pollination. The floral morphology and development suggest outcrossing, but pollination studies are needed to determine what degree of selfing occurs. Winder observed abundant viable seed production and frequent growth of seedlings in most populations. The seeds appear to drop from the parent plant directly onto the sandy substrate and are likely dispersed by water flow, animal activity, or human activities such as hiking, camping and relic digging.

Winder sampled 10 populations which are designated as EOs by TNHP. It is important that the distinction between Winder's populations and TNHP's EOs be considered throughout this discussion. The following are the populations (EOs) that were sampled: Ladder Trail (EO 13), Hazard Cave (EO 4), Pickett Dam (EO 26); Slave Falls (EO 17), Middle Creek (EO 20), Big Island rockhouse A and rockhouse B (EO 1), Puncheon Camp (EO 59), Laurel Fork (EO 60-1), Jamestown Reservoir (EO 7), and Peters Bridge (EO 54). Winder's 10 sampled "populations" are located within 8 populations defined by TNHP.

| Winder's Populations | TNHP Populations |
|---|----------------------|
| Ladder Trail (EO 13) | Upper Thompson Creek |
| Hazard Cave (EO 4) | Upper Thompson Creek |
| Pickett Dam (EO 26) | Upper Thompson Creek |
| Slave Falls (EO 17) | Mill Creek |
| Middle Creek (EO 20) | Middle Creek |
| Big Island rockhouse A and rockhouse B (EO 1) | Big Island |
| Puncheon Camp (EO 59), | Puncheon Camp |
| Laurel Fork (EO 60-1) | Laurel Fork |
| Jamestown Reservoir (EO 7) | White Oak |
| Peters Bridge (EO 54) | Clear Fork |

Winder's genetic studies found that because of extremely reduced gene flow among "populations" and the influence of genetic drift within small "populations," *A. cumberlandensis* shows a significant structuring of overall genetic variation with "populations" carrying only a small non-representative subset of the overall variation found in the species. About 63 percent of the total variation in *A. cumberlandensis* is distributed among "populations" rather than contained within them, a pattern that is consistent with long-term limited gene flow among isolated populations and/or recent establishment of

populations from a heterogeneous source population. This pattern suggests that the populations contain only a small, non-representative subset of the overall phylogenetic variation that exists in the species. He found that a few geographically outlying populations contain a significant amount of the species' overall variation, despite current genetic isolation from the main cluster of populations in Pickett County. This supports the conclusion that populations in general are essentially independent of one another genetically and have been for a significant period of time with the possible exception of densely clustered "populations" in Pickett County that have little geographic separation.

Winder noted reduced levels of heterozygosity in *A. cumberlandensis* populations despite having high haplotype diversity. This is consistent with the effects of inbreeding which characteristically occurs in smaller populations. He suggested that studies are needed for the two factors that could influence breeding patterns in *A. cumberlandensis*, (1) to determine whether movement of pollen and seeds is highly restricted, potentially even within a single rockshelter population, and (2) to conduct breeding system studies to determine whether there could be high rates of self-fertilization in populations of *A. cumberlandensis* (Winder 2004).

Overall Assessment of Reproductive Success

Seeds from *A. cumberlandensis* have been collected for long-term storage by the Missouri Botanical Gardens (MBG), Center for Plant Conservation. The accessions from Tennessee were collected in 1990, 1991, 1994 and 2005 and the report from MBG is on file at TNHP (Albrecht 2011). The seeds accessioned by MBG are sent to the USDA in Fort Collins where they are stored and tested for viability. Of the 2005 seeds tested for viability, only 1% germinated (Albrecht 2011). Tests from previous years showed germination rates ranging from 2-3%; the seeds that did germinate did not survive to reproductive maturity. Dr. Valerie Pence, at Center for Conservation and Research of Endangered Wildlife at Cincinnati Zoo and Botanical Garden (CZBG), has collected seed for reintroduction experiments and has tested germination rates. Five tests showed rates from 10% to 76% (Pence 2011). Winder (2004) observed prolific seed production and seedling recruitment for most populations during his investigations although he did not study the seed viability.

Cultivation: Status and Location of Presently Cultivated Material

A historical occurrence (KY EO 1) in the Rock Creek drainage on Daniel Boone National Forest (DBNF) in McCreary County, Kentucky, has not been relocated since 1984 despite repeated attempts (KYSNP 2010, USFWS 1996) and is considered extirpated. The US Forest Service (USFS) and the CZBG have collaborated on attempts to establish a new population of *A. cumberlandensis* at DBNF at another location. Dr. Valerie Pence has cultured multiple genotypes of this species *in vitro*. DBNF staff planted 77 individuals in one rockhouse in September 2005. These were placed in seven locations within the rockhouse with differing microclimate. As of May 2009, approximately one-third of these plants had survived and 40 new seedlings were counted (Taylor 2009).

Threats and Site Management

The present or threatened destruction or modification of habitat is the greatest threat to *A. cumberlandensis* due to the heavy recreational uses of its habitat on public lands and the digging for

Native American artifacts in rockhouses. The floors of the Plateau rockhouses consist primarily of damp loose sand, which can easily be disturbed or compacted from trampling by human activities such as hiking, horseback riding, rappelling, relic hunting, logging practices, and trampling and rooting by wild hogs and other animals. During the 2006-2008 monitoring at least 30 EOs were immediately threatened and 16 EOs potentially threatened from human activities (Table 5). TDEC, in cooperation with all of the owners and USFWS, are conducting management activities to minimize anthropogenic impacts.



Natural phenomena, such as the southern pine bark beetle and the hemlock wooly adelgid infestations and loss of trees from catastrophic weather events, can indirectly affect *A. cumberlandensis* by changing the light intensity and hydrology of the rockhouse habitat. The monitoring projects have helped to identify these threats and to analyze what is needed to minimize impacts to the plants. Another potential threat includes habitat modification from timber harvesting that could occur on private lands or on state forest lands. The monitoring projects could help identify these threats and to analyze what is needed to minimize impacts to the plants.

Trampling of the sandy floors of rockhouses is of urgent concern due to the rapid degradation of habitat. The shallow root system and small stature of the Cumberland sandwort plants are sensitive to any physical disturbance. Hiking trails built through the rockhouses or in close proximity are the primary source of trampling. Hikers and/or horseback riders stray from the trails and unknowingly trample habitat and plants. Unapproved camping in the rockhouses is a severe threat; many of the rockhouses observed have long-established campfire pits. Climbing on the ledges and cliff faces can damage the plants and could cause rockfall or collapse of the ledges increasing light levels and drying the habitat.

No impact to the rockhouse ecology and to the rare plants is more destructive than the digging for Native American artifacts. Rockhouses have provided shelter for man for thousands of years and the artifacts are buried in the sandy substrate of the floors. Illegal digging has been occurring on BSNRRA and PSP and PSF for decades. These agencies try to deter this activity but enforcement of is difficult since most of the sites are remote and not easily accessed. During the monitoring, 25 locations of *A. cumberlandensis* were found to have been looted in the distant and recent past. In some cases the tools and screens used for excavating were left at the site along with large mounds of sifted dirt remain and deeply excavated pits up to 3 feet deep.

At present, there are no timber removal projects near the EOs at PSP, PSF and BSNRRA, but logging practices could have detrimental effects on the rockhouse habitats. Trees from around the opening of rockhouses and the bluffs supporting *A. cumberlandensis* populations should not be removed. Increased sunlight and exposure to drying winds can dry the site and change the floristic composition of rockhouses. Logging can also change the hydrology of the rockhouses by increasing runoff and erosion and alteration of downslope habitat. Other destructive aspects of logging are the construction of logging roads, herbicide use, and mechanical damage all of which negatively impact Cumberland sandwort. Consequently, timber management should be carefully monitored in the immediate vicinity of suitable habitats for this taxon.

Forest fires have been controlled for many years throughout the range. This management activity could have changed the natural successional sequence of native plant communities and may have long term effects on species associations within those communities.

Forest health is an issue that will continually need to be addressed by TDF. The infestation of the Southern pine beetle in the late 1990's and early 2000's has affected the forest composition and canopy cover on the Plateau. The introduced hemlock wooly adelgid now occurs on the Cumberland Plateau and long-term effects on forests are unknown. It has not been determined what effect the potential changes in forest composition are having or will have in the future on the *A. cumberlandensis* populations. Long-term monitoring of rockhouses is critical to detecting the changes.

The natural threats to *A. cumberlandensis* are the restricted geographic range and the small population sizes; the loss of even a few individuals in a population could cause its extirpation. The genetic study by Winder (2004) concluded that gene flow among and within populations is not completely understood. The highest density of populations is in Pickett County, but most of the other populations are geographically isolated from each other and genetically independent. The bulk of the genetic diversity is maintained within the Pickett County populations, whereas, the outlying populations have relatively low portions of the overall diversity. The reduced levels of heterozygosity are consistent with the effects of inbreeding and the risk of inbreeding depression. Until studies of the breeding patterns of the species are conducted, the low heterozygosity levels remain a threat.

As for the effects of climate change, Winder (2004) suggests that *A. cumberlandensis* has persisted in its current location through cyclical climate changes during the Pleistocene, and if protected from habitat destruction and population losses, it should be resilient to future climate change.

Table 5: Threats and Management Activities

| EOR | Site Name | Population Name | Population Number | Immediate Threats 2006-2008 | Potential Threats 2006-2008 | Management completed | Management planned or recommended |
|-------------|--------------------------------------|------------------------|--------------------------|---|-------------------------------------|-----------------------------|--|
| 3 | Peters Bridge North Side Cedar Creek | Clear Fork | 1 | Trampling in rockhouse and overhang | | | 2011:signs |
| 48a | Peters Bridge East Facing Bluff | Clear Fork | 1 | | Private - dry site conditions | | |
| 48b | Peters Bridge East Facing Bluff | Clear Fork | 1 | | Private - dry site conditions | | |
| 48c | Peters Bridge East Facing Bluff | Clear Fork | 1 | | Private - dry site conditions | | |
| 48d | Peters Bridge East Facing Bluff | Clear Fork | 1 | | Private - dry site conditions | | |
| 48e & f | Peters Bridge East Facing Bluff | Clear Fork | 1 | | Private - dry site conditions | | |
| 54(1-2-3) | Peters Bridge South Facing Bluff | Clear Fork | 1 | | Private-Past relic digging | | |
| 54(5-6-7-8) | Peters Bridge South Facing Bluff | Clear Fork | 1 | | Private-Past relic digging | | |
| 7 | Jamestown Barrens | White Oak | 2 | Recent relic digging, trampling, soil erosion | | | |
| 25 | Darrow Ridge Northern | Laurel Fork | 3 | | Old fire pit, relic digging in past | | |
| 65 | Darrow Ridge Southern | Laurel Fork | 3 | | Relic digging in past | | |
| 60(1) | Hippy Cave | Laurel Fork | 3 | | Relic digging, trampling | | |
| 60(2) | Hippy Cave | Laurel Fork | 3 | Trampling in spite of fence | Relic digging | 2004: fencing | Sign needed |
| 72 | Pogue Creek Wasik Site | Pogue Creek | 4 | | Trampling | | |
| 27 | Middle Creek Loop Trail Rockhouse3 | Ben Creek | 5 | Trampling, hogs, active fire pit | | | Signs needed; remove campfire pit |

| EOR | Site Name | Population Name | Population Number | Immediate Threats 2006-2008 | Potential Threats 2006-2008 | Management completed | Management planned or recommended |
|-------------|---|------------------------|--------------------------|---|--------------------------------------|-----------------------------|--|
| 31 | Middle Creek Loop Trail Open Ledges | Ben Creek | 5 | | Trampling | | |
| 29(1) | Middle Creek Loop Trail/Head of Ben Creek | Ben Creek | 5 | Ledges accessible | Trampling | | |
| 29(2) | Middle Creek Loop Trail/Head of Ben Creek | Ben Creek | 5 | Ledges accessible | Trampling | | 2011: fencing |
| 29(3) | Middle Creek Loop Trail/Head of Ben Creek | Ben Creek | 5 | Relic digging, hogs, trampling | | | |
| 61(1) | Middle Creek Loop Trail | Ben Creek | 5 | Hogs | Minimal trampling inspite of fence | 2003: fencing, boardwalk | Signs needed |
| 1a | Big Island Rockhouses | Big Island | 7 | | Past relic digging, old campfire pit | | |
| 1b | Big Island Rockhouses | Big Island | 7 | Past & recent relic digging | | | |
| 42 | Loop Trail South Facing Rockhouses | Twin Arches | 8 | Heavy trampling | | | Sign needed |
| 45(1,2,3) | Loop Trail At Ladders | Twin Arches | 8 | Trampling | | | Sign needed |
| 17 | Slave Falls | Mill Creek | 9 | Severe trampling, soil erosion | | | 2011: fencing or barricade, signs |
| 64 | Rockhouse Benchmark | Mill Creek | 9 | | Relic digging | | |
| 43(a,b,c) | Mill Creek Tributary Ravine#1 | Mill Creek | 9 | | | | Sign needed |
| 44(a,b,c,d) | Mill Creek Tributary Ravine | Mill Creek | 9 | Recent and past relic digging, trampling, | Dry site condtions | | |
| 47(a,b) | Downstream of Slave Falls | Mill Creek | 9 | Trampling, fresh firewood pile | Past relic digging | | Sign needed |
| 79(1,2) | Mill Creek Tributary Ravine#2 | Mill Creek | 9 | Trampling | Dry site conditions | | |

| EOR | Site Name | Population Name | Population Number | Immediate Threats 2006-2008 | Potential Threats 2006-2008 | Management completed | Management planned or recommended |
|---------|-------------------------------------|----------------------|-------------------|--|--------------------------------|--|---|
| 21 | Middle Creek 4 | Middle Creek | 10 | | Dry site conditions | | |
| 22(1,2) | Middle Creek 5 | Middle Creek | 10 | Past relic digging, old fire pit in "area 1" | | | |
| 16 | Watson Branch | Watson Branch | 11 | Relic digging, flooding | Trampling | | |
| 5 | Hidden Passage Tunnel/Crystal Falls | Upper Thompson Creek | 12 | Trampling, climbing on rocks | | 2008: signs installed | |
| 12 | Swinging Bridge | Upper Thompson Creek | 12 | Dry site conditions, dead pine trees | | | |
| 13 | Ladder Trail | Upper Thompson Creek | 12 | Trampling, trail runs thru rockhouse, climbing on ledges | | 2008: Trail cribbing, signs, rock barricades, trail blazing. 2003: signs | |
| 24 | Indian Rockhouse | Upper Thompson Creek | 12 | Trampling, recent digging | | 2000:Fencing, 2003 & 2008: signs | 2011: additional fencing |
| 26 | Natural Bridge At Pickett Lake | Upper Thompson Creek | 12 | Trampling, climbing on rocks | | 2008:Sign installed | |
| 33 | Rockhouse SW of Hazard Cave | Upper Thompson Creek | 12 | | Past relic digging, trampling | | Block social trail to rockhouse |
| 34 | Natural Bridge Trail | Upper Thompson Creek | 12 | Severe trampling | | | Recommend boardwalk or reroute trail |
| 66 | Lake & Ridge Trail | Upper Thompson Creek | 12 | | Creek flooding | | |
| 4a | Hazard Cave and West Rockhouse | Upper Thompson Creek | 12 | Trampling, competing vegetation | Relic digging | 1990s & 2002:Fencing, boardwalk; 2003: signs | 2011:additional fencing; vegetation thinning needed |
| 4b | Hazard Cave and West Rockhouse | Upper Thompson Creek | 12 | Trampling, trail thru rockhouse | Relic digging | 2000 & 2008:blocked volunteer trail | 2011:permanent blocking of trail, fencing, signs |
| 14 | Thompson Creek Ridgetop | Lower Thompson Creek | 13 | Trampling, trail thru sandwort patches | Full sun - dry site conditions | | |

| EOR | Site Name | Population Name | Population Number | Immediate Threats 2006-2008 | Potential Threats 2006-2008 | Management completed | Management planned or recommended |
|------------|--|------------------------|--------------------------|---|--------------------------------------|--|--|
| 35 | Double Falls Bluff | Lower Thompson Creek | 13 | | Climbing on falls | | |
| 71 | Hidden Passage Trail West of Powerline | Lower Thompson Creek | 13 | | Trampling; trail goes thru rockhouse | | 2011: fence or cribbing |
| 77 | Trail to Rock Creek | Lower Thompson Creek | 13 | | Trail adjacent to rockhouse | | |
| 78 | Trail From Thompson Overlook | Lower Thompson Creek | 13 | Trampling, old firepit | | | Sign needed |
| 11 (1) | Hidden Passage Rockhouses 1&2 | Lower Thompson Creek | 13 | Trampling, trail thru rockhouse | | 2008:cribbing, trail blazed, signs, rerouted trail, bridge built | |
| 11 (2) | Hidden Passage Rockhouses 1&2 | Lower Thompson Creek | 13 | Trampling, trail thru rockhouse | | 2008:cribbing, trail blazed, signs, rerouted trail, bridge built | |
| 69 | Sprough Ridge Rockhouse D | Upper Sprough Ridge | 14 | Trampling, recent relic digging, old fire pit | | | Sign needed |
| 80 | Sprough Ridge Road | Upper Sprough Ridge | 14 | Recent relic digging, trampling | | | Sign needed |
| 8 | Powerline Rockhouse | Lower Rock Creek | 15 | Intensive recent relic digging and trampling | Powerline maintenance | | |
| 38 | North of Powerline | Lower Rock Creek | 15 | Past relic digging | | | |
| 39 | Hidden Passage/Tunnel Trail Intersection | Lower Rock Creek | 15 | Trampling, trail thru part of site | | | Signs needed |
| 70 | Group Camp Bluffs | Lower Rock Creek | 15 | Past relic digging | | | |

| EOR | Site Name | Population Name | Population Number | Immediate Threats 2006-2008 | Potential Threats 2006-2008 | Management completed | Management planned or recommended |
|------------|------------------|------------------------|--------------------------|------------------------------------|------------------------------------|-----------------------------|--|
| 81(a) | Rockhouse 4 | Jim Creek | 16 | Past relic digging | | | |

Management and Protection

In Tennessee, all but six EOs are located on state and federal lands. There are 27 EOs in BSFNRRRA, three EOs in Pogue Creek State Natural Area (TDEC), nine EOs in PSP and 21 EOs in PSF. As a result a number of these populations have recently been afforded a good deal of protection. However, additional management is needed and will be ongoing. Threats to the populations on public lands are caused by the hundreds to thousands of visitors that come to the public lands for outdoor recreational activities. The hiking and horseback trail systems are extensive in PSP and BSFNRRRA. Many of these trails are within or near the habitat of Cumberland sandwort. Two of the private sites are owned by a conservation-minded person.

The numerous threats to *A. cumberlandensis* must be minimized for recovery purposes. About 30 EOs have immediate threats and 16 EOS have potential threats (see Table 5). Habitat protection measures have been implemented, but more is needed especially at areas associated with recreational activities on public lands. Wooded fences, boardwalks, and trail cribbing have been constructed to prevent trampling by limiting access to the plants at 10 locations in PSP, PSF, and BSFNRRRA. In some cases the trails have been rerouted. Interpretive signs have also been installed to educate the public about *A. cumberlandensis*.



Figure 6: Interpretive signs.



Figure 7: Boardwalk and cribbing along trail.

At PSP and PSF, proper site protection was urgently needed at Hazard Cave, the Ladder Trail, and along the Hidden Passage Trail. Human alteration of the natural habitat has greatly limited the number of plants occurring at these areas and improved management was needed. Between 2000 and 2004, fencing and boardwalks were constructed at Hazard Cave and Indian Rockhouse, two popular destinations for visitors, and at one rockhouse on the Middle Creek Loop Trail (EO 61). In addition, fences were built inside the rockhouse in 2004 at Hippy Cave (EO 60) in BSFNRRRA. The site is recovering as there has been a significant increase in the number of plants within the area protected by the fence.

In 2008, site management, including construction of fences, boardwalks, trail cribbing and interpretive signs, was conducted at PSP and PSF by TDEC and the Youth Conservation Corps. Site protection activities were conducted at six locations: Hazard Cave (EO 4), Ladder Trail (EO 13), Island Trail Natural Bridge (EO 57), Hidden Passage Trail (EO 11), Hidden Passage Trail at Hidden Passage (EO 5), and Indian Rockhouse (EO 24) (TDEC 2008). The first three sites are on PSP, while the last three sites are on PSF. Additional site management will be conducted by TDEC at five locations (4 EOs) in 2011.

Current Management Policies and Actions

A management meeting was held in 1998 with all public agencies that have *A. cumberlandensis* on their lands (TDEC, BSFRRA, PSP, and PSF) to discuss the need for a cooperative management agreement. A management agreement was drafted by TDEC and reviewed by the agencies but was never finalized. This cooperative agreement for protection measures should be revisited and commitments made by all of the appropriate agencies. All of the agencies have been actively involved in management; PSP staff has participated in the fencing projects and are monitoring one population on a yearly basis, and, BSFRRA has cooperated with management activities at several of their sites including fencing at two sites.

Conservation and Recovery Recommendations

Winder (2004) suggests that the knowledge of genetic variation can be used to influence conservation management decisions. The ultimate goal would be to mitigate the effects of present and future human environmental impacts on the continued existence and viability of plant lineages of narrowly restricted endemic plant species such as *A. cumberlandensis*, whose “histories are obscure and whose futures seem equally uncertain.” Protection of large populations is important to adequately protect the species due to the scattered and somewhat isolated distribution patterns. Suitable habitat should be protected for new colonization. The populations should be protected by management agreements on public lands and on private lands by acquisition, cooperative management agreements, or donated conservation easements.

Assessment of the Recovery Criteria

Arenaria cumberlandensis (Cumberland sandwort) will be considered for reclassification from endangered to threatened status when 30 geographically distinct, self-sustaining occurrences are protected in four counties in Tennessee and Kentucky and have maintained stable or increasing numbers for 5 consecutive years. The species will be considered for delisting when 40 geographically distinct, self-sustaining occurrences are protected and have maintained statistically stable or increasing numbers for 5 consecutive years. At least 12 of these occurrences must be in counties other than Pickett County, Tennessee.

Based on the currently known range of *A. cumberlandensis*, it appears that the recovery criterion for reclassification to threatened may be partially met. There are 63 extant EOs and one historic (or failed to find) occurrence currently reported from Tennessee. With one extant occurrence in Kentucky, the total number of extant occurrences is 64. Of the total 66 occurrences reported in the two states, 24 occur outside Pickett County. The ongoing monitoring project started in 2000 will help to determine if the populations are stable and increasing for 5 consecutive years. At least 34 sites (30 EOs) have been monitored for two years and 39 monitored for one year with a total of 73 sites (57 EOs). Although the

monitoring has not been consecutive since 2000, an increase in numbers has been shown at most EOs. There are at least 102,000 *A. cumberlandensis* plants at the 62 extant occurrences, the lowest number is 2 plants and the highest number is 13,000, an average of 1,612 plants. Additional monitoring is needed before this evaluation can be made. Collecting and analyzing demographic data is needed to determine which EOs are self-sustaining.

Evaluation of Recovery Tasks

1. Protect existing occurrences and essential habitat. A total of 60 occurrences (91% of the total) occur on public lands in TN and KY and are afforded some level of protection. Five occurrences within the Clear Fork Population (Peters Bridge sites) are found on private land that is adjacent to the southern boundary of BSFNRRRA. These sites are owned by one landowner, who has expressed an interest in protecting the plants. The EOs have low numbers of plants and the habitat for *A. cumberlandensis* is marginal. There are no trails although human impacts were observed. Protection of these sites is a low priority. Many of the EOS on public lands have threats from recreational activities and management is being done to mitigate these threats.
 - 1.1 Develop interim research and management plans and develop cooperative management agreements with landowners or land managers. Draft management plans were written in 1998 but were not finalized. These cooperative agreements must include TDEC, TDA, USFWS and NPS (BSFNRRRA). Populations are currently being monitored and include evaluations of threats and management needs.
 - 1.2 Search for additional occurrences and characterize all known occurrences. Several searches have been conducted in Tennessee and Kentucky. The suitable habitat is extensive in the South Fork Cumberland watershed, much of which has not been searched. TDEC has found that surveys in the winter and early spring are better for estimating numbers of plants because the other competing plants are dormant and the sandwort is visible.
 - 1.3 Determine habitat protection priorities and develop landowner or land manager agreements. The EOs with the highest threats are the ones adjacent to hiking trails. Management is ongoing at these sites to lessen the impacts. The landowners are cooperating to help protect the sites and agreements will be developed.
 - 1.4 Evaluate habitat protection alternatives. Cooperative agreements need to be signed by all of the public landowners. The five private sites are on one tract of land and a conservation easement would be appropriate. There are no sites that are impacted by highways. There is a TVA power line that goes through PSP and PSF and maintenance activities associated with it could impact three EOs: EO 8, EO 38, and EO 10. TVA will need to be contacted about potential impacts.
 - 1.4.1 Protect the species from recreational overuse of the habitat. The sites on public land with the greatest threats are being addressed and management is taking place. Monitoring will determine if the management is successful.
 - 1.4.2 Protect the species' habitat from adverse timber management. This should be addressed in the cooperative agreement. No timbering projects should be done on slopes above or adjacent to rockhouses with sandwort unless there are emergency situations or if it will benefit the habitat for sandwort. Timbering has not occurred in the vicinity of the known occurrences at PSP or PSF.

2. Determine and implement the management necessary for long-term reproduction, establishment, maintenance, and vigor. Little is known about the species requirements. There has been only one genetic study and no ecological or micro-environmental studies on the species' habitat. Based on preliminary monitoring the EOs appear to be stable.
 - 2.1 Determine occurrence size and stage-class distribution for all occurrences. One of the goals of the ongoing monitoring is to determine the size of the EOs. Stage class has not been determined at each EO but flower and fruit production is prolific at most sites. Reproduction is by seed although low seed viability has been reported by germination studies by CZBG. Based on field observations by TDEC, there appears to be all stage classes at most of the sites. Demographic data needs to be collected during the monitoring to determine if occurrences are self-sustaining.
 - 2.2 Study abiotic and biotic features of the species habitat. These types of studies have not been done. There are no known extirpated occurrences in TN and two EOs are considered historic (or failed to find). One of the two occurrences in KY has been extirpated by unknown circumstances. Vectors of seed dispersal are unknown and pollinators have not been studied.
 - 2.3 Conduct long-term demographic studies and determine genetic variability between occurrences. Monitoring protocol includes an estimate of numbers of plants and area covered. An initial genetic study has been completed and comparative information for the sampled EOs provided. Not all EOs within the range were sampled for genetic material.
 - 2.4 Determine effects of past and ongoing habitat disturbance. This will be done through monitoring where management has been conducted. It may not be possible to determine effects of past disturbance such as relic digging in the rockhouses since a lot of the damage occurred in the early to mid-20th century.
 - 2.5 Define criteria for self-sustaining occurrences and determine the size of the area needed to protect each occurrence. Demographic data will need to be collected at the EOs. Criteria have not been developed to determine self-sustaining occurrences. Since many of the EOs contain one or more groups of sandwort plants in separate rockhouses or microsites, adequate sampling is necessary.
 - 2.6 Implement appropriate management techniques as they are developed from previous tasks. Management has been implemented at the most threatened sites on public lands and is ongoing.
 - 2.7 Develop techniques and reestablish populations in suitable habitat within the species' historic range. At this point reintroduction is not essential to the survival of the species. One site was extirpated in KY at DBNF and a new site has been established at a different location within the National Forest. The population is small but maintaining good reproduction.
3. Maintain a cultivated source of plants and provide for long-term seed storage. A long-term seed storage project is ongoing at the MBG. Seed germination studies are ongoing at MBG and CZBG and plants are being propagated by tissue culture at CZBG.
4. Enforce laws protecting the species and/or its habitat. No commercial trade is known for this species. Populations located on the public lands are protected by state and federal laws.

5. Develop materials to inform the public about the status of the species and the recovery objectives completed. Interpretive signs for *A. cumberlandensis* have been placed along hiking trails and in places that have the greatest impacts from human trampling in PSP and PSF.
 - 5.1 Prepare and distribute news releases and informational brochures.
 - 5.2 Prepare articles about research and reintroductions, etc. for popular and scientific publications. See *References*.

6. Annually assess the success of recovery efforts for the species. The USFWS conducts an annual recovery data call for listed species with updates obtained from the various agencies with populations of the *A. cumberlandensis*.

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