

*Geocarpon minimum*  
(Geocarpon)



Photo by: Brent Baker / Arkansas Natural Heritage Commission

**5-Year Review:  
Summary and Evaluation**

**U.S. Fish and Wildlife Service  
Southeast Region  
Arkansas Ecological Services Field Office  
Conway, Arkansas**

**5-YEAR REVIEW**  
*Geocarpon minimum* (Geocarpon)

**I. GENERAL INFORMATION**

**A. Methodology used to complete review**

We announced initiation of this review and requested information in a published *Federal Register* notice with a 60-day comment period on September 23, 2014 (79 FR 56821). During the comment period, we received additional information about *Geocarpon minimum* from botanical experts. This review was completed by the lead recovery biologist in the U. S. Fish and Wildlife Service's (Service) Arkansas Field Office. All literature and documents used for this review are on file at the Arkansas Field Office.

A draft of this 5-year review was circulated to eleven persons for peer review. Comments and suggestions regarding the review were received and incorporated as appropriate (see Appendix A). No part of the review was contracted to an outside party. Recommendations are a result of thoroughly reviewing the best available information on *Geocarpon minimum*.

**B. Reviewers**

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

**Lead Field Office:** Arkansas Ecological Services Field Office - Jason W. Phillips, 870-503-1101

**Cooperating Field Office(s):** Missouri Field Office - Paul McKenzie, 573-234-2181; Louisiana Field Office - Monica Sikes, 337-291-3118; Arlington Texas Field Office - Rob Allen, 936-569-7981.

**Cooperating Regional Office(s):** Brady McGee, Southwest Region, (505-248-6657) and Jessica Hogrefe, Midwest Region, 612-713-5102

**C. Background**

1. **Federal Register Notice announcing initiation of this review:** September 23, 2014 (79 FR 56821).
2. **Species Status:** Stable. No comprehensive range-wide surveys have been conducted for the species. Personnel from the Missouri Department of Conservation (MDC) periodically survey some of the 25 documented sites in Missouri, but this occurs irregularly. The species is considered stable in Missouri.

In Arkansas, personnel from the Arkansas Natural Heritage Commission (ANHC) also periodically survey the known populations of *Geocarpon*. The larger populations (Warren Prairie and Kingsland Prairie) have been surveyed on a frequent basis since the mid-1980s. The number of individual plants in these populations fluctuates greatly between years, but overall these populations are classified as stable. Other sites in south Arkansas and the Arkansas River Valley are monitored less frequently and appear less stable. Additionally, a new population was discovered in 2014 near the Oklahoma border at Ft. Chaffee in Sebastian County. The historic sites in Louisiana continue to persist. Texas Parks and Wildlife Department (TPWD) recently discovered a new site in Gregg County. They plan to continue surveying known and potential sites within Texas.

**3. Associated Rulemakings:** None

**4. Listing History**

**Original Listing**

FR notice: 52 FR 22930

Date listed: July 16, 1987

Entity listed: species

Classification: threatened

**5. Review History**

5-Year Reviews

5-year review November 6, 1991 (56 FR 56882) - In this review, different species were simultaneously evaluated with no in-depth assessment of the five factors, threats, etc. as they pertained to the different species' recovery. In particular, no changes in status were proposed for this plant.

U.S. Fish and Wildlife Service. 2009. *Geocarpon minimum* 5-Year review: summary and evaluation. Conway, AR. 33 pp. No change in status was recommended for this plant.

Final Recovery Plan - 1993

Recovery Data Call – 2014-1998

**6. Species' Recovery Priority Number at start of review (48 FR 43098):** 13. This number indicates the species represents a monotypic genus with a low degree of threat and high recovery potential.

**7. Recovery Plan:**

Name of plan: Recovery Plan for *Geocarpon minimum* Mackenzie

Date issued: July 26, 1993

## II. REVIEW ANALYSIS

**A. Application of the 1996 Distinct Population Segment (DPS) policy:** *Geocarpon minimum* is a plant and, therefore, not covered by the DPS policy. The other DPS questions will not be addressed further in this review.

### **B. Recovery Plan and Criteria**

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

#### **2. Adequacy of recovery criteria.**

**a. Do the recovery criteria reflect the best available and most up-to-date information on the biology of the species and its habitat?** Yes. The primary threat to the species appears to be competition from other vegetation due to lack of disturbance/soil development. Researchers suspect that some level of disturbance is necessary to maintain the preferred habitats for this species. There is also preliminary data that suggests over-disturbance in the form of feral hog rooting may be a significant threat to some populations. Research is currently ongoing to help clarify the role of disturbance in the maintenance of *Geocarpon* populations. The recovery criteria state that at least 15 populations should be protected as necessary to ensure their continued existence. These protections may include land acquisition, management agreements, land management, feral hog management, or other actions as necessary to ensure the long-term protection of viable populations. Ongoing research should help fill the in the gaps regarding specific measures that are necessary to reach this goal.

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

#### **3. List the recovery criteria and discuss how each has or has not been achieved?**

The *Geocarpon minimum* recovery plan was approved in 1993.

The objective of this recovery plan is to delist *Geocarpon minimum*. Delisting can be considered when:

1. A total of 15 viable populations, representing the diversity of habitats and geographic range of the species, are protected as necessary to ensure their continued existence;
2. Populations include the wide spectrum of current genetic variation found in the species; and

3. Population viability is confirmed through periodic monitoring for at least a 15-year period.

Populations are protected if they are secure from any present or foreseeable threats. Although publicly owned sites should be protected from immediate destruction by most anthropogenic agents, long-term survival of these populations may require active measures to abate less acute threats.

A viable population is one which is reproducing and stable or increasing in size.

The term “population” has never been formally defined for this species. Some states or individuals may refer to each “patch” as a population while others may refer to multiple patches at a site as “sub-populations” within a site. Arkansas has some of the most robust populations in the Gulf Coastal Plain and tends to describe multiple patches within a saline barrens complex as one population. Many sites elsewhere in Arkansas and other states are smaller in size and occur as distinct populations rather than part of a complex. This may be due to unique circumstances in geography or soils, or a lack of detailed study at these sites. For the purposes of this review, the use of the term “population” henceforth adopts the current opinions of individuals or agencies that have provided data.

A summary of achievement toward delisting criteria is presented here. First, a breakdown by state is provided of populations and their protective status (Table 1). Sites are considered protected if they are owned by a state or federal agency, private conservation group, or other private entities enrolled in conservation agreements. This is assumed to be adequate protection to ensure that occupied sites are not developed or converted to other uses. Most of the populations included in the protected category are not managed according to a specific plan that addresses the habitat requirements of *Geocarpon*. As more information is gathered regarding the habitat requirements of this species, the incorporation of a management plan may be necessary at some sites to ensure long-term viability.

## **Missouri**

The Missouri Department of Conservation (MDC) currently recognizes 22 extant naturally occurring *Geocarpon* populations and three plantings (Briggler in litt. 2015) (Figure 1 and Table 2). The plantings on public lands were an attempt to establish protected populations using seed sources from nearby unprotected populations on private land. Two of these populations have been documented to persist after monitoring periods of eight and 11 years, respectively. The one planting on private property was conducted by a private landowner wishing to expand *Geocarpon* to uninhabited suitable habitat near existing sites. This site was only observed once. All or a significant portion of the populations at 11 of the 22 naturally occurring sites are protected on public lands or lands belonging to private conservation groups. The remaining 11 sites occur on private property and have no formal protective agreements.

## **Arkansas**

The Arkansas Natural Heritage Commission (ANHC) recognizes five Geocarpon populations containing dozens of subpopulations (Baker and Witsell 2015) (Figure 1 and Table 2). The site containing the largest known population (Warren Prairie) is owned and managed by the ANHC. A population at the Kingsland

Prairie site is also owned and managed by the ANHC. In 2010, the ANHC purchased the remaining site within the Gulf Coastal Plain and designated it Hall Creek Barrens Natural Area (formally referred to as New Edinburg Prairie). The other two sites are located within the Arkansas River valley near the border with Oklahoma. One population on private property is currently unmanaged for Geocarpon and the site has been used as a cattle pasture in the past. The other site was recently discovered and is located on Ft. Chaffee (Department of Defense). This population appears rather small, although investigations at this site are limited so far. The vast majority of populations and subpopulations in Arkansas are on public land. There is some recent speculation that feral hog activity may have an effect on the viability of some populations, especially those occurring in the Gulf Coastal Plain. The ANHC is currently studying the role of disturbance on the maintenance and viability of populations and has incorporated monitoring of areas damaged by feral hogs (Witsell pers. comm. 2015).

## **Louisiana**

The Louisiana Natural Heritage Program (LNHP) recognizes six Geocarpon populations (Reid in litt. 2015) (Figure 1 and Table 2). All populations occur on private property. Two are owned by a large timber company and are managed cooperatively with the LNHP as registered natural areas. The other four are owned by individuals or timber companies and currently have no protective agreements. Portions of these sites are heavily impacted by all-terrain vehicle (ATV) traffic and use of dirt-moving equipment. However, several of these unprotected tracts are described as having vigorous populations. Feral hog activity has been noted at many sites in the past, but in recent years the amount of activity has declined due to control measures or disease (Reid in litt. 2015).

## **Texas**

The Texas Parks and Wildlife Department (TPWD) recognizes four populations of Geocarpon. Three occur on private property, although one of these is within the acquisition boundary of the Neches River National Wildlife Refuge (Singhurst in litt. 2015). There was recent unsuccessful litigation to prevent the establishment of this refuge in favor of river impoundment to provide water supplies. In 2010, the U.S. Supreme Court refused to hear an appeal and the lower court decision stood. The acquisition phase of the refuge is currently underway and this site will be a priority for purchase if funding becomes available (Mueller in litt. 2015). The fourth site occurs mostly on private property but also

extends into the Caddo Lake State Park. This site is near Caddo Lake National Wildlife Refuge, but recent surveys of potential sites there yielded no populations (Singhurst in litt. 2015).

### **Range-wide**

This review indicates that *Geocarpon* is close to meeting all of the criteria required for delisting. The minimum number of viable populations with protective status (15) is exceeded ( $n = 17$ ) and in the near future at least 15 of these will have been monitored for a period spanning at least 15 years (Table 1). Twenty “populations” representing both sandstone glades and saline prairies/barrens and at least one site from each state occur on protected properties. Many of the sites that are not officially protected appear to be stable and in no immediate danger of conversion. The largest unresolved issue preventing delisting criteria one and three from being met is need for a consensus regarding the definition of a “population” (see pp. 4-5).

Range-wide at least 17 viable (Element Occurrence (EO) rank of C or higher; see Table 2 for explanation) protected populations have been monitored for a minimum of 1 year and as long as 55 years ( $\bar{x}=24$ ). Thirteen of these viable populations have been monitored for a period of at least 15 years and several others for nearly 10 years. On average, the protected populations in Missouri have been monitored for a period of 22 years with EO ranks ranging from “A” to “D” (A=3, B=2, C=4, D=2). Two unprotected sites also have EO ranks of “A”, indicating that they are large, vigorous populations with few threats. The only protected sites with ranks of “D” are those planted by the MDC. They were ranked low due to their small initial size and the uncertainty of long-term success. The protected populations in Arkansas (4) have been monitored for an average of 30 years and have EO ranks ranging from “A” to “CD” (A=2, C=1, CD=1). The remaining unprotected population ranks “D”. In Louisiana the two officially protected sites have been monitored for an average of 24 years and have ranks of “BC” and “B”. The remaining sites in Louisiana range in rank from “A” to “D” (A=2; AB=1; D=1). All sites in Texas are recently discovered and the state of Texas does not assign EO ranks. However, researchers note that several of these new populations appear to be vigorous. For the purposes of this analysis, we assumed the one protected population is viable.

Although delisting criteria one and three have been met or nearly met, criteria two states that we should gather information regarding the genetic variability of geographically isolated populations and populations that occur in differing habitats (sandstone glades vs. saline prairies/barrens). In 2013, Albrecht *et al.* completed a genetic analysis of *Geocarpon* from throughout the range. This effort was ultimately unsuccessful due to two factors. First, the investigators had difficulty extracting DNA from older stored samples as well as fresh samples. Two independent labs attempted several different extraction protocols but were ultimately unsuccessful for most individual plant samples. Secondly, due to the

difficulty with DNA extraction from individual plants, the investigators were forced to “bulk” samples from several plants within a population. This was attempted as a last resort in order to generate genetic data for each population sampled. Investigators were unable to amplify enough DNA for analysis even from these bulk samples from sites in Texas and the two largest populations in Arkansas. For those sites where DNA was extracted, the analysis of inter-population and intra-population variation was difficult due to the batching of samples. Most reviewers of the final report cited these factors as reasons why the study was inadequate to describe the genetic variation throughout the geographic range (Albrecht in litt. 2013; Crabill in litt. 2013; McKenzie in litt. 2013; Singhurst in litt. 2013; Witsell in litt. 2013).

Recently, staff from the Missouri Botanical Garden (MOBOT) indicated that their continued efforts to work on extraction and amplification of DNA from *Geocarpon* were successful (Yatskievych in litt. 2015). Preliminary extraction trials were all successful and the investigators are confident that they can obtain enough high-quality DNA to get a good estimate of range-wide patterns of genetic structure and levels of genetic diversity (Edwards in litt. 2015). MOBOT submitted a research proposal to the Service and it was funded in 2015. Results are expected in 2017.

## **C. Updated Information and Current Species Status**

### **1. Biology and Habitat**

#### **a. Spatial distribution, abundance and population trends**

At the time of the recovery plan publishing, 27 *Geocarpon* populations (many with subpopulations) were known to occur within 12 counties/parishes in three states (USFWS 1993). Populations are currently documented to occur at a total of 40 sites (including three plantings in Missouri) within 19 counties in four states (Baker in litt. 2015; Baker and Witsell 2015; Briggler in litt. 2015; Reid in litt. 2015; Singhurst in litt. 2015). In Missouri, it occurs only on Pennsylvanian-age sandstone glades or outcrops in upland prairies. Elsewhere it occurs in habitats known as “slick spots” which are sparsely vegetated soils with high concentrations of magnesium and sodium (USFWS 1993). The latter habitats are often referred to as “saline prairies” or “barrens”.

The number and location of subpopulations and individual plants within each population varies widely between years due to variations in winter and spring rainfall as well as competition with native and/or invasive plants (Baker and Witsell 2015; McInnis and Large 1997). Some sites have no plants during dry years and may contain hundreds or thousands of

individuals during wetter years. Some subpopulations have disappeared over the years apparently due to succession of lichens, non-native grasses, and other salt tolerant plants into slick spots (Baker and Witsell 2015). In recent years some subpopulations have been degraded due to heavy rooting by feral hogs. In at least one case, a sub-population may have been severely reduced due to this activity (Baker in litt. 2015). Previously unknown subpopulations within known populations have also been noted. Population changes associated with weather tend to be dramatic and temporary while those associated with succession of competitors tend to occur at a slower rate and may be more permanent (Witsell 2004; Smith and Ely 2006).

Long-term monitoring of known sites indicates that aside from annual variations due to weather, populations appear resilient if the appropriate microhabitats (shallow, sandy soil within sandstone glades or the margins of slick spots within saline prairies) are maintained at the site. The only extirpation of an entire population at a known site involved intensive disturbance of a sandstone glade (Smith in litt. 2006a). Some subpopulations have been extirpated or migrated around a known site due to natural shifts in the location of shallow soils within sandstone glades (Smith and Ely 2006), competition with other plants due presumably to a lack of periodic disturbance (Witsell 2004), and anthropogenic changes in microhydrology (TNC 2004; Witsell pers. comm. 2006). It is unclear how rooting activity from feral hogs will affect the long-term viability of populations. AHNC is currently conducting experiments regarding the role of disturbance in the maintenance of populations and also is monitoring sites impacted by hogs (Baker and Witsell 2015; Witsell pers. comm. 2015).

**b. Demographic characteristics**

Geocarpon is an annual usually easily visible for only three to six weeks during the spring. The flowering and fruiting period when the plant is usually most visible ranges from late February to early June (Bates 1994; McInnis and Larke 1997; Smith in litt. 1998; MDC 2000; TNC 2004, 2005). The flowering date appears to be earlier in the southern range presumably due to milder temperatures. March and April are the most common survey dates reported throughout the range and this likely corresponds to the peak flowering period.

The factors affecting the timing and success of germination are not fully understood, although many researchers suggest that temperature and weather conditions are the two primary factors (Bates 1994; Logan 1998; TNC 2004; Witsell 2003; Singhurst in litt. 2006). During dry years, the number of observed plants often plummets to few or none only to return to previous numbers in subsequent wet years. This indicates that seeds

remain viable for several years or more. The factor that appears to most affect the long-term reproductive success and persistence of *Geocarpon* populations is competition with and shading by other native or invasive plants (Baker and Witsell 2015). This is attributed by some researchers to a lack of slick spot or sandstone glade disturbance by fire, large mammals, or other erosive forces (Baker and Witsell 2015; Thurman and Hickey 1990; Logan 1998; TNC 2002; Witsell 2002, 2003, 2004a). The amount of disturbance required to maintain suitable *Geocarpon* habitat without negatively impacting the long-term viability of populations is unclear.

**c. Taxonomy and Genetics**

*Geocarpon* MacKenzie is a monotypic genus originally described by K.K. MacKenzie (1914). It is placed in the family Caryophyllaceae (USFWS 1993). Recently, an article was published based on molecular analysis suggesting that *Geocarpon* should be placed in the genus *Mononeuria* and assigned the name *Mononeuria minima* (Dillenberger and Kadereit 2014). It is unclear if the general botanical community will accept this taxonomic change. If this is ultimately accepted *Geocarpon* would no longer be placed within a monotypic genus. For now *Mononeuria minima* will be considered synonymous with *Geocarpon minimum*, although the latter will be used for the purposes of this review. If it occurs, reassignment to a different genus would have no effects on the conservation and recovery of *Geocarpon*.

No studies adequately describe the genetic variability among geographically isolated populations and populations that occur in differing habitats (sandstone glades vs. saline prairies/barrens). Researchers at MOBOT attempted to fill this data gap, but difficulty in extracting high quality DNA prevented conclusive analysis of genetic diversity (Albrecht *et al.* 2013). Recent advances in the extraction of DNA from *Geocarpon* should allow future studies to draw more certain conclusions (Edwards in litt. 2015; Yatskievych in litt. 2015).

**d. Habitat**

The range of *Geocarpon* has been extended farther west within the Arkansas River Valley and the habitat at this site appears similar to that described for the other known site within this region (Baker and Witsell 2015). All populations outside Missouri are associated with “slick spots” within saline soil barrens (Baker and Witsell 2015; Keith *et al.* 2004; Singhurst in litt. 2015). In Missouri sandstone glades, it colonizes shallow depressions within rocks that provide poor habitat for most other herbaceous species (USFWS 1993, Smith and Ely 2006). No populations have been found in sandstone glades outside of Missouri (Baker and Witsell 2015).

## 2. Five Factor Analysis

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

Specific threats to habitats for known populations are detailed in Table 2. The primary threat continues to be soil development on suitable sites within saline prairies (slick spots) and sandstone glades (shallow sandy soils) (Baker and Witsell 2015; Logan 1998; Singhurst in litt. 2015; Smith and Ely 2006). Geocarpon thrives in these harsh conditions that exclude competing plant species. Accumulation of more suitable soils quickly leads to an invasion of other plants that shade Geocarpon. Such soil development may be facilitated by lack of disturbances such as fire and use by large mammals (Witsell 2004; Smith and Ely 2006).

Excessive soil development and subsequent colonization by competitive plants may also occur when excessive soil movement occurs due to dense cattle use, ATV use, or other factors. Movement of dirt can also alter the microhydrology of sites which may lead to localized extirpation of subpopulations (TNC 2004; Witsell pers. comm. 2006). Although ATV and other off-road vehicle damage has been cited at some sites (TNC 2004; Reid in litt. 2006), some authors have suggested that limited erosion from ATV traffic or other anthropogenic disturbances may play a role in maintaining slick spots that are otherwise susceptible to rapid succession (TNC 2004; Witsell 2004; Smith pers. comm. 2006). Witsell (2003) suggested with intensive cattle grazing the Geocarpon population at the Branch Saline Barrens site was able to thrive among grasses that normally outcompete it. When cattle were removed from the site, Geocarpon was restricted to areas only along the margins of the remaining slicks. Alternatively, some activity by large animals (feral hog rooting) may rise to the level of over-disturbance and has been linked to the possible loss of portions of some Geocarpon subpopulations (Baker and Witsell 2015; Witsell pers. comm. 2015).

There is an incomplete understanding of the role of disturbance in the maintenance of Geocarpon populations. It is likely that some level of disturbance is required to maintain the required microhabitat. It is also likely that intensive use by livestock, feral hogs, or off road vehicles may be detrimental. The impact of such activities may be better assessed on a case-by-case basis depending on the amount of natural disturbance at the site. The ANHC is currently conducting experiments on their properties to determine the appropriate level of disturbance to maintain Geocarpon patches. In conjunction with the monitoring of experimental disturbance plots, patches disturbed by feral hog rooting are being monitored to assess

the response of both Geocarpon and other vegetation (Baker and Witsell 2015; Witsell pers. comm. 2015).

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

Taking for these purposes could pose a risk to Geocarpon due to the ease of access at many sites and its desirability due to its taxonomic uniqueness (monotypic genus). However, at this time there is no indication that this is a likely threat.

**c. Disease or predation:**

There is no evidence to suggest that this factor is a threat. There could be some incidental ingestion by feral hogs in search of tubers from nearby associated plants, but it is unlikely that they are targeting Geocarpon. It is more likely that their search for other food items may result in excessive soil disturbance and development of competing plant communities (Witsell pers. comm. 2015).

**d. Inadequacy of existing regulatory mechanisms:**

Thirteen of the 25 known populations in the Ozark and Osage Plains region of Missouri are partially or fully owned by the MDC, U.S. Army Corps of Engineers (USCOE), Missouri Department of Transportation (MODOT), or private conservation organizations (Briggler in litt. 2015). The three populations in the West Gulf Coastal Plain of Arkansas are owned by the ANHC aside from a few adjacent subpopulations on private property. One of the two populations in the Arkansas River Valley is located at Ft. Chaffee on property owned and managed by the Department of Defense (Baker and Witsell 2015). Two of the Louisiana populations are owned by a timber products company. The owners have worked with the LNHP to develop protective measures and have registered the sites as natural areas. The remaining four populations occur on private lands in the northwestern section of the state near the Texas border. The four populations in Texas occur mostly on private land, although one site is within the acquisition boundary of a proposed national wildlife refuge and is currently under management by the owner to limit impacts from off-road vehicles and silvicultural activities (Mueller in litt. 2015). One of the sites occurs partially on Caddo Lake State Park (Singhurst in litt. 2015).

Under chapter four of the Missouri Wildlife Code “the exportation, transportation, or sale of any endangered species of plant or parts thereof, or the sale of or possession with intent to sale any product in whole or in part from any parts of any endangered species of plant is prohibited” (3 CSR 10-4.111 Endangered Species, p.4). In the state of Missouri, Geocarpon is considered an endangered species under the Wildlife Code.

None of the other inhabited states have laws that protect Geocarpon habitat within private property. A permit is required for individuals wishing to survey or collect Geocarpon or modify habitat within federal or state lands. Enforcement of these regulations is difficult, but there are no indications that illegal activities have occurred at any of these sites. The listing of Geocarpon as threatened provides some protection through section 7 (requires interagency consultation on federally funded or permitted activities) and section 9 (prohibits removal and reduction to possession from federal lands and restricts interstate commercial activity) of the ESA.

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

Geocarpon is vulnerable to local extirpations because it occurs in isolated populations and depends on the presence of specific microhabitats in order to compete with other plants. Although extirpations of subpopulations due to encroachment of other vegetation have been observed (Witsell 2004), no known populations have disappeared due to this factor. Loss of microhabitats such as thin soils within sandstone glades and the margins of slick spots within saline prairies appear to be the biggest threat to the long-term survival of Geocarpon. The presence of natural disturbances such as fire, movement of sheet water, and periodic use by large mammals may play a key factor in the maintenance of these microhabitats (Smith and Ely 2006; Witsell pers. comm. 2006). Fire suppression, alteration of microhydrology, and extirpation of large mammals such as elk and bison may result in the long-term loss of microhabitats that support Geocarpon. The rooting activity of feral hogs has recently been identified as a potential threat and may be responsible for the partial loss of a subpopulation in Arkansas (Witsell pers. comm. 2015). Active management even within protected sites may be necessary to ensure the long-term viability of this species. This could include management activities such as burning and light soil disturbance or could include management of feral hog populations to prevent over-disturbance.

Climate change may affect Geocarpon, although the exact mechanisms and whether these effects will be negative or positive is unknown. Some authors have suggested that plant diversity, species phenology and distribution, and increases in extinction risk are all potential outcomes of climate change (Iverson and Prasad 2002; Bertin 2008; and Maclean and Wilson 2011). Changes in localized weather patterns associated with climate change may lead to more frequent and long-lasting droughts (Rind *et al.* 1990; Seager *et al.* 2007; and Rahel and Olden 2008). Climate warming may also increase the spread of non-native species (Rahel and Olden 2008). Changes in drought cycles and increases in air and soil temperatures could have effects on seed set, germination, and general fitness of Geocarpon.

### 3. Conservation Measures

In 1997, the MDC and the Service worked with the MODOT to develop a plan for the relocation of a *Geocarpon* population in the path of a proposed highway expansion project (Smith and Gardner 1999). In the late summers of 1997-1999, researchers removed sandy soil containing seeds from the impacted site to a total of nine protected glade sites on the opposite side of the road. Soil was disturbed at each site in an attempt to allow the development of suitable microhabitat. All of the plots, including the source location, continue to support *Geocarpon* (MDC 2005; Smith 2003; Smith in litt. 2008).

In 2003 and 2004, the MDC removed soil from a *Geocarpon* population on private property and placed it within plots in the nearby Bluff Springs Conservation Area in Cedar County (MDC 2005). *Geocarpon* has been observed in all of four plots, although not all in the same year. The population has ranged from a high of 135 plants in 2008 to a low of 3 plants in 2006 (Smith in litt. 2008; Briggler in litt. 2015). The low numbers in 2006 were likely due to dry weather. In 2005, soil from a site on private property in Greene County was moved to suitable habitat at the nearby Bois D'Arc Conservation Area. A survey of this site in March of 2006 revealed 72 plants (Smith in litt. 2006c). A more recent survey revealed the population still persisting with low numbers (Briggler in litt. 2015). The purpose of these projects was to establish protected populations on public property. No eminent threat was noted at either of the seed sources.

In 2005, the MDC initiated a survey funded through section 6 of the ESA of *Geocarpon* throughout the assumed range in Missouri (MDC 2005). Searchers visited 28 known and potential sites and observed 20 populations, including one new subpopulation of 200 plants.

MDC monitored permanent plots established at Flint Hill Glades in Dade County from 1994-2003 (MDC 2005). These plots were monitored in an attempt to assess the role that succession and competition plays in the distribution and success of *Geocarpon* and to better define the distribution of the plant in relation to soil depth (Smith and Ely 2006). This study revealed that plants were found in shallow sandy soil (mean of 19 mm) and increased in density as depth increased to about 20 mm with declines thereafter. An examination of bare rock distribution in the glade revealed that the distribution of shallow soils moved dynamically within the glade due to water transport. Researchers observed a negative association between cryptograms (combined category including bryophytes and lichens) and *Geocarpon* numbers. This suggests the possibility that these plants and lichens may depress *Geocarpon* numbers in sandstone glades. However, the population of *Geocarpon* within the glade was highly variable and may have been more affected by weather patterns and the shifting distribution of shallow sandy soils. The last year of surveying revealed a larger population of plants than observed in any of the previous nine years. In recent years, surveys in Missouri have been more opportunistic and many sites have not

been assessed in ten years or more (Briggler in litt. 2015). More frequent monitoring may be needed for some protected sites in order to meet the recovery criteria.

The ANHC monitors most known Geocarpon sites and searches for new sites in areas containing appropriate habitat and associate plant species (Baker and Witsell 2015). Warren Prairie Natural Area contains the largest population in Arkansas and long-term monitoring has taken place at this site since 1986. This monitoring has been an important aid to begin understanding the plant succession and disturbance factors that influence the distribution and success of Geocarpon. Based on observations at this site, researchers currently theorize that some level of disturbance is necessary to maintain optimum habitat along the edge of slick spots (Witsell 2004). Some of the subpopulations noted in the 1980s are now dominated by lichens, bryophytes, and other competitive plants. Since 2012, ANHC has conducted experiments involving habitat modification at Warren Prairie Natural Area (Baker and Witsell 2015). This study involves monitoring the effects of various levels of disturbance in plots at sites formally occupied by subpopulations of Geocarpon. Monitoring of nearby areas affected by heavy feral hog rooting has been incorporated into the effort (Witsell pers. comm. 2015).

The ANHC has actively targeted land acquisition at the three known populations in the West Gulf Coastal Plain. In addition to the Warren Prairie Natural Area, since 2010 they have partnered with TNC and used funds from USFWS Recovery Land Acquisition grants to acquire most of the Geocarpon patches at Kingsland Prairie and Hall Creek Barrens Natural Areas (Baker and Witsell 2015). The ANHC also opportunistically surveys for new populations of Geocarpon near known populations and in other sites containing appropriate habitat. These efforts led to the 2014 discovery of a new population at Ft. Chaffee in the Arkansas River Valley (Baker and Witsell 2015).

The populations in Winn Parish, Louisiana are owned by a private timber products company. The LNHP has worked with the company to monitor and protect the sites. The saline prairies that include the populations are now registered natural areas with the LNHP and the landowners are actively protecting the sites (Reid in litt. 2006; Reid in litt. 2015). LNHP has been less successful in securing protective agreements with other landowners in Caddo and DeSoto Parishes.

The Geocarpon population in Anderson County, Texas is on property owned by a private timber products company. Botanists from the TPWD have cooperated with the company to monitor and protect the site (Singhurst in litt. 2006). Although no formal agreements are in place, the company considers the area a unique conservation site and has taken steps to exclude the primary threat which was overuse by ATVs. Additionally, the site is within the acquisition boundary of the Neches River National Wildlife Refuge (Neal in litt. 2006). It is considered an ideal tract for purchase contingent on funding availability and the willingness

of the landowner (Mueller in litt. 2015). Researchers in Texas have also discovered sites in Harrison, Panola, and Gregg Counties (Singhurst in litt. 2015). They are also hopeful that future surveys will document additional populations in nearby counties containing similar habitats as identified by aerial photography.

### 3. Synthesis

When the recovery plan was published for *Geocarpon minimum* in 1993, 27 populations (many with subpopulations) were known within 12 counties in three states. Today, 40 populations (including 3 plantings in Missouri) are recognized within 19 counties in four states (see discussion regarding “populations” on pages 4-5). Twenty of the 40 populations are at least partially on public land (n = 15), owned by private conservation groups such as TNC (n = 2), or are recognized in a private conservation plan (n = 3). The remaining 20 sites are not protected by any official measures (Baker in litt. 2015; Baker and Witsell 2015; Briggler in litt. 2015; Reid in litt. 2015; Singhurst in litt. 2015). The status of sites on private land ranges from stable with no immediate threats (n = 16) to degraded sites heavily impacted by off-road traffic, livestock, and silvicultural activities (n = 4; Table 2). Some private sites with human disturbance appear to be stable and some may even depend on occasional disturbance from off-road use and cattle grazing to maintain suitable habitats (Witsell 2004; Smith pers. comm. 2006). The status of the species is variable even in protected areas. Many subpopulations that were noted in the 1980s have succumbed to competition with competitive native or invasive plant species. Additionally, some impacts such as those resulting from feral hog rooting are difficult and expensive to control even on publicly managed lands (Witsell pers. comm. 2015). The number of individual plants in a population varies widely on an annual basis primarily due to the amount of spring and winter rainfall.

Both government and privately funded monitoring programs of varying intensity and scope are in place in all states where *Geocarpon* occurs. Most of these efforts are focused on documenting occurrence and density. Some efforts in Missouri, Arkansas, and Louisiana have focused on establishing permanent survey plots to identify the role of vegetative succession and disturbance on the distribution, movement, and success of *Geocarpon* populations. Preliminary hypotheses indicate that some level of disturbance in the form of fire or erosion is necessary to maintain the thin and/or highly saline soils where *Geocarpon* thrives and to suppress competitive plant growth. The exact role of erosion in maintenance of populations is unknown. Grazing and trampling by cattle has been listed as both a negative impact and a mechanism for maintenance of slick spots. Excessive erosion from off-road vehicle use has been cited as a risk to several populations. Rooting by feral hogs has recently been identified as a potentially significant risk

to the three populations in south Arkansas (Witsell pers. comm. 2015). Ongoing research should help define the appropriate level of disturbance for long-term habitat management. The differentiation between beneficial and detrimental disturbance may depend on the extent, frequency, and timing of events.

Although several new populations have been discovered since 1993, the delisting criteria required for *Geocarpon* have yet to be fully accomplished. The recovery plan states that 15 populations representing the full geographic and genetic variability should be protected and that population viability at these sites should be demonstrated by 15 years of monitoring. Although monitoring throughout the geographic range indicates that the species appears viable, currently there is an incomplete understanding of the genetic variability of the species. There is also a need to develop a consensus regarding the delimitation of populations. At this time, *Geocarpon minimum* should remain listed as threatened and efforts to accomplish the delisting criteria regarding genetics and population delimitation should continue.

### **III. RESULTS**

#### **A. Recommended Classification:**

*Geocarpon* should remain listed as threatened. No change in status is recommended.

#### **B. New Recovery Priority Number: 7**

We recommend a change in the Recovery Priority Number from 13 to 7. This number is assigned to species within a monotypic genus with moderate threats and high recovery potential. In the previous review, the degree of threat to *Geocarpon* was considered low because about half of the known populations, including many with the largest populations, are protected by public ownership or private protective agreements. However, the security of these protected populations may be lower than reported in the last five year review. Botanists at the ANHC have noted a marked increase in the amount of feral hog activity at some of the larger populations in the Gulf Coastal Plain. It is currently unclear what the long-term implications of this threat may be, but they are currently incorporating sites with damage into their monitoring efforts. Despite this potential threat and an incomplete understanding of its biology and ecology, the recovery potential is high. Researchers have identified the preferred microhabitats at known locations and the species appears to thrive in such sites. There are active efforts to determine what actions may be necessary to maintain these microhabitats. Preliminary results indicate that a light level of disturbance may be important for maintenance of thin, sandy soils characteristic of the sandstone glade sites in Missouri and the slick spots within saline prairies

elsewhere in the range. Work conducted by the MDC has shown that relocation and augmentation of threatened populations is possible without intensive effort, although the long-term success of these efforts has yet to be proven.

#### **IV. RECOMMENDATIONS FOR FUTURE ACTIONS**

1. Complete the investigation into the genetic variability of *Geocarpon* throughout the plant's range (funded in 2015 with completion expected in 2017) to get a better understanding on possible completion of recovery criteria #2.
2. Continue to investigate the role of disturbance in the distribution and success of *Geocarpon* in sandstone glades and saline prairies. The impacts of extreme disturbance due to feral hogs should be incorporated into these studies. As an understanding develops regarding the role of disturbance, a threats assessment should be conducted to determine which threats should be addressed first.
3. Develop standardized monitoring protocols and reach consensus among states regarding the delimitation of populations and sub-populations.
4. Continue to search for new populations in suitable sandstone glade habitats in Missouri and Arkansas and saline prairie habitats in the Arkansas River Valley of Arkansas and Oklahoma and other saline prairie sites in Arkansas, Louisiana, and Texas.
5. Select sites throughout the range to be demographically monitored. Where it is already occurring this should continue and it should be instituted at other representative sites throughout the range that are currently only monitored opportunistically for presence/absence or rough estimations of population.
6. Develop a long-term management plan based on the results of studies on genetics, the role of disturbance, and other life history studies. Specific recovery criteria that address the long-term protection and viability of *Geocarpon* should be developed as new information becomes available.
7. Work cooperatively with landowners to conserve privately owned sites through fee title or easement purchases or development of management agreements.

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*All references and documents pertaining to this five year review can be obtained from the U. S. Fish and Wildlife Service's Arkansas Ecological Services Field Office.*

**U.S. FISH AND WILDLIFE SERVICE  
5-YEAR REVIEW  
*Geocarpon minimum* (Geocarpon)**

Current Classification Threatened

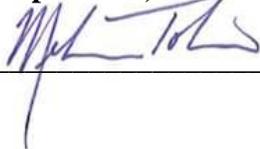
Recommendation resulting from the 5-Year Review

**X** **No change is needed**

Review Conducted By Jason W. Phillips, U.S. Fish and Wildlife Service Arkansas Field Office, Delta Sub-office

FIELD OFFICE APPROVAL:

**Lead Field Supervisor, Fish and Wildlife Service**

Approve  Date 8/25/2015

OTHER REGION OFFICE APPROVAL:

**Cooperating Assistant Regional Director, Fish and Wildlife Service**

Southwest Region

Approve \_\_\_\_\_ Date \_\_\_\_\_

**Cooperating Assistant Regional Director, Ecological Services, Fish and Wildlife Service**

Midwest Region

Approve  Date 7/20/16

OTHER REGION OFFICE APPROVAL:

**Cooperating Assistant Regional Director, Fish and Wildlife Service**

Southwest Region

Approve *John* **ACTING** Date *Jan 12, 2016*

**Cooperating Assistant Regional Director, Ecological Services, Fish and Wildlife Service**

Midwest Region

Approve \_\_\_\_\_ Date \_\_\_\_\_

## Appendix A

### Summary of peer review for the 5-year review of *Geocarpion minimum* (Geocarpon)

A. Peer Review Method: The Service conducted peer review. We selected at least one reviewer from each state within the range (Arkansas, Missouri, Louisiana, and Texas). These individuals represented state agencies, Service field offices, or other entities with responsibilities for the management and/or monitoring of Geocarpon. Eight individuals responded with comments on the completed draft, although others provided input and data during the early development of the review. Service personnel helped us conduct internal peer review. We also have independent peer review from 3 outside experts as well.

B. Peer Review Charge: Reviewers were asked to provide comments on the draft as they pertained to Geocarpon in both their respective state and range wide.

C. Summary of Peer Review Comments/Reports: Our response to each reviewer comment is in bold font within parenthesis.

- Robert Allen  
Wildlife Biologist  
USFWS, Arlington, Texas FO

I have reviewed the Texas portions and have no comments other than changing the "Cooperating Field Supervisor" office to the Arlington, Texas Field Office instead of "Texas Field Office, East Texas Sub-Office."

**(This change was incorporated into the review.)**

- Monica Sikes  
Biologist  
USFWS, Louisiana FO

I read the document and find it very informative and well-prepared! To my knowledge, the information you have included for Geocarpon in Louisiana is complete and accurate. I have no substantial comments. I only have some minor grammatical edits if you want them - - if not disregard. Thanks!

**(Minor grammatical changes were incorporated.)**

- Trisha Crabill  
Biologist  
USFWS, Missouri FO

Thanks for the opportunity to comment on the review. I do not have much in the way of comments beyond what we provided in 2013 - I agree with your recommendations to keep Geocarpon listed as threatened, to change the RPN from 13 to 7, and the recommendations for future actions. As a future action, however, you might also include

determining how populations are defined. There was discussion about that on one of the last calls and I believe the states were going to discuss further?

**(Recommendation was incorporated into the review.)**

- Paul McKenzie  
Biologist  
USFWS, Missouri FO

Jason: I have some general comments and Trisha thought it would be best if I provide those rather than her take the time to capture my thoughts without missing something and given my history with the species.

1. There has been a lot of emphasis in recent years on the importance of having recovery criteria that address the threats that were identified at the time of listing. This emphasis stems from 3 perspectives: a) a law suit in *Defenders of Wildlife vs. Babbitt* in 2001, b) our new interim NMFS/FWS recovery planning guidance, and c) multiple manuscripts or books (e.g., Lawler, Joshua J., Steven P. Campbell, Anne D. Guerry, Mary Beth Kolozsvary, Raymond J. O'Connor, Lindsay C. N. Seward, 2002. *The scope and treatment of threats in Endangered Species Recovery Plans. Ecological Applications* V. 12, No.3, pp. 663-667) that reiterate the importance of threats-based criteria. Consequently, I would suggest that the proper answer to question 2a is the same as 2b: no- the recovery criteria are not adequate because they do not address the threats to the species.
2. In our interim recovery planning guidance, it is recommended that a threats assessment be considered as a way to prioritize what threats should be first addressed. This may be a perfect tool in the case of *Geocarpon* where there is a question on how much disturbance is necessary, as you pointed out, is contradictory- this could be a recommended item for the next 5 years; a revision to the recovery plan would be better but such an endeavor is not likely to be given a high priority given workload issues. Additionally, your recommendation of a higher recovery priority number is due to the perception of an increased level of threats.
3. Given the number of populations and subpopulations, one recommendation would be to establish a best representative example of sites to be demographically monitored- not just inventoried with simple presence/absence or rough estimates but something we can assess trends over time. I am not sure what the number of sites for monitoring would be (e.g., so many per state; habitat type, etc.). This is something you could get input from botanists in the 4 states where it occurs.
4. I think everyone is in agreement on the need to do a comprehensive range-wide genetics study.
5. Another advantage of a threats assessment is that it could lead to some rough management recommendations- it could be an output of an analysis on how much disturbance is necessary for the long term viability and persistence of the species, how to address exotics, etc.
6. Under factor e, there is no mention of the potential impact of climate change on this species. While this is a threat that we would probably have no suggestions to address it,

it should be discussed and it was my understanding that we need to address this threat in listing rules, species status assessments, recovery plans, and 5-year reviews?

I hope these comments are helpful.

**(Recommendations 2-6 were incorporated into the review. Recommendation 1 was not adopted. The current recovery criteria state among other things that, “populations should be protected as necessary to ensure their continued existence.” Protections could include land acquisition, land protection agreements, land management, feral hog management, and other actions as needed. While the development of more specific protective criteria based on new research may be appropriate, the recovery criteria as currently stated address the overall need to protect a minimum number of sites.**

- Malissa Briggler  
Botanist  
Missouri Department of Conservation  
Missouri Natural Heritage Program

Thank you for the opportunity to review your draft of the 5-year Review for Geocarpon. I found only one error and that is on page 6, 3<sup>rd</sup> paragraph where you mention the protected populations in Missouri and their EO ranks. It should state: “On average, the protected populations in Missouri have been monitored for a period of 22 years with EO ranks ranging from “A” to “D” (A=3, B=2, C=4, D=2)”. I think you might have counted a few private property sites.

I have no other suggestions. It is obvious this took a lot of work to put together and you did a fine job. Thank you!

Oh, and I did check the heritage records with aerial photos and did not find any that indicate the habitat had been destroyed (i.e. parking lot, road, etc.)  
**(Changes were incorporated into the review.)**

- Dr. Matthew Albrecht  
Botanist  
The Missouri Botanical Garden

Thanks for the opportunity to comment on the 5-year review. I read over the review and the conclusion drawn seems to be based on the best available data. I have a few comments:

p. 16, Section A: “Work conducted by the MDC has shown that relocation and augmentation of threatened populations is possible without intensive effort.” This seems like an overstatement because, while it is easy to translocate soil that contains dormant seeds, it remains unclear whether the relocated populations are sustainable over the longer-term. The first introduction site contains 60 plants (but previously had more), the

second introduction site has only been observed once (10 years ago) and contained 31 plants, and the third site contained only 4 plants in 2014.

p. 16: “Initiate studies to determine the mode of seed dispersal. Promising hypotheses include movement by water, insects, and large mammals.” This is going to be a difficult avenue of research to pursue and I am not sure how useful it will be for future conservation and management efforts. There does not appear to be a mechanism for directed seed dispersal to other glades/sites by animals or wind, unless some unknown insect is moving seeds around. Sure, migrating birds and large animals might periodically disperse seed stuck in their hooves/feet. And, undoubtedly, sheet/water flow following precipitation events can move seeds around within a site, but is probably not involved in longer-distance dispersal among sites. The new genetics study should provide insights into the frequency of gene flow among populations which might help provide clues to rates of pollen and seed dispersal among sites and across geographic distances.

p. 16: A more important priority for future actions should be the development of a sound management plan that could be disseminated to land managers. Based on previous work, succession appears to be a long-term threat at most sites. Once the delisting recovery criteria are met, sites will still need to be monitored for threats and succession will need to be managed in some cases. Developing a management plan based on the results of ongoing investigations of the role of disturbance on population dynamics should be a high priority future action.

Please let me know if you have any questions or would like to discuss further any of my comments.

**(All recommendations were incorporated into the review.)**

- Theo Witsell  
Botanist/Ecologist  
Arkansas Natural Heritage Commission

Brent Baker  
Botanist  
Arkansas Natural Heritage Commission

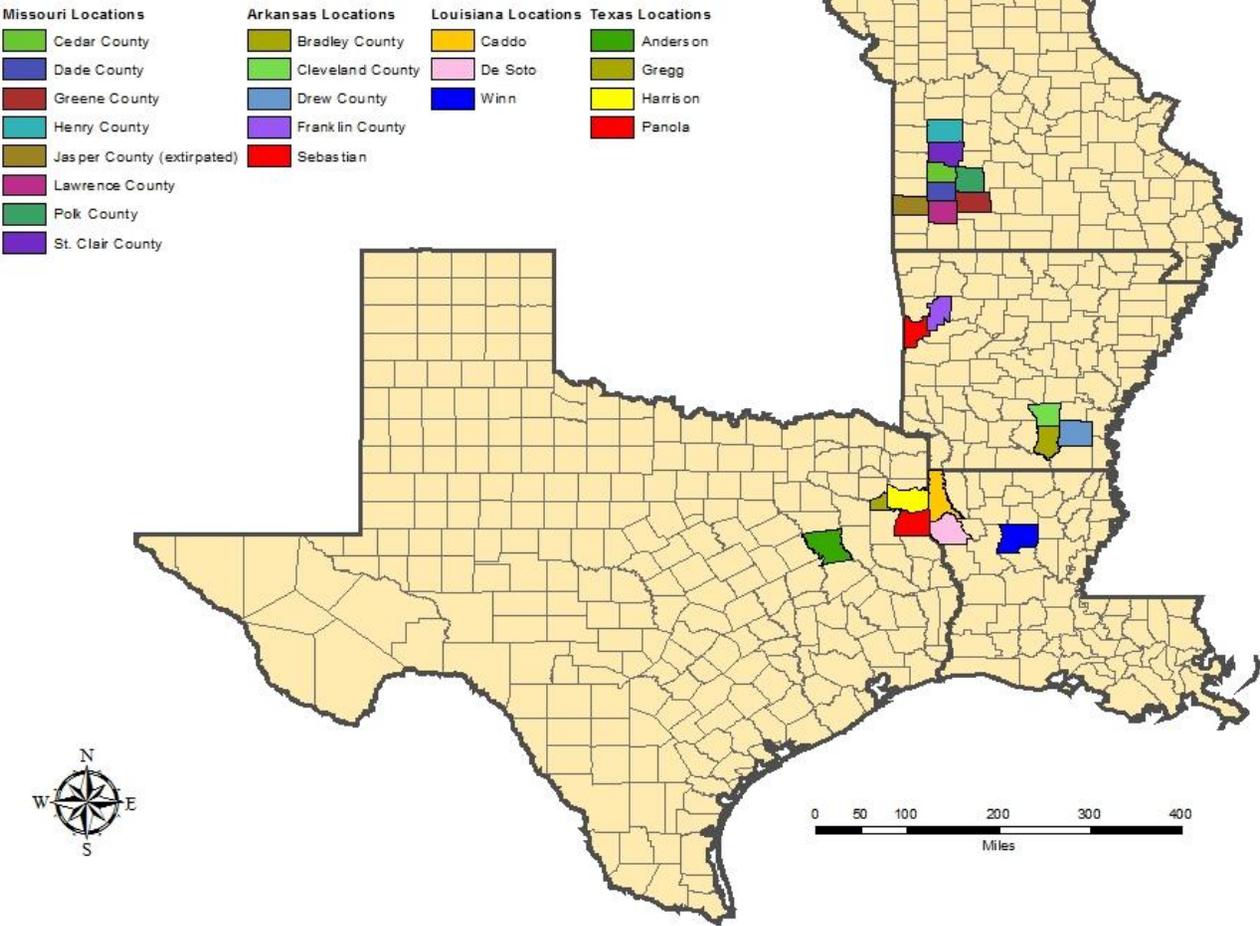
Please see attached for the ANHC comments on the draft of the 5 year review. Our main concern is the assertion that recovery criterion 1 has been met when there is still no range-wide consensus or standardized definition of what defines a population. It was our understanding from the conference call that until we had an accepted standardized definition of a population this criterion could not be considered met. We had a number of other more minor comments as well.

Let us know if you have any questions. Thanks for the opportunity for review.

**(The primary concern was addressed as well as all comments provided in an edited version of the draft document.)**

D. Response to Peer Review: Each comment provided by reviewers was taken into consideration when revising the draft.

**Figure 1. County/Parish distribution of *Geocarpon minimum***



**Table 1. Range wide protective status of *Geocarpon minimum*.**

<b>State</b>	<b>Protected Sites*</b>	<b>Viable Protected Sites (avg. years monitored)**</b>	<b>Viable Protected Sites Monitored at least 15 years</b>	<b>No Protection</b>	<b>Protected Population***</b>	<b>Unprotected Population**</b>	<b>TOTAL</b>
<b>Missouri</b>	13	11 (24)	9	12	22,130	8,462	30,592
<b>Arkansas</b>	4	3 (29)	2	1	9,392	0	9,392
<b>Louisiana</b>	2	2 (24)	2	4	190	1,500	1,690
<b>Texas</b>	1	1 (1)	0	3	1,806	4,560	6,366
<b>TOTAL</b>	20	17	13	20	33,518	14,522	48,040

\*Protected sites are those sites owned by a government agency, private conservation organization, or other private sites governed by a conservation agreement. Some populations included in this category may also extend onto adjacent unprotected property (see Table 2). Additionally, although typically managed to avoid development or other conversions, many of these sites are not managed specifically for *Geocarpon*.

\*\*Viability is determined based primarily on state EO ranks. Sites with an EO rank of “C” or higher are considered viable based on current expert opinions (see Table 2 for definition of EO rank).

\*\*\*These figures use the most recent survey data available. In many cases this was within the last few years. Other sites may not have been visited and/or had populations quantified for over 10 years (See Table 2). These figures do not account for the extreme annual population variability that characterizes this species.

**Table 2. Site records of *Geocarpon minimum***

<b>Missouri</b>				
<b>County</b>	<b>Site Name/Quad</b>	<b>Natural Division</b>	<b>Collection/Observation Data</b>	<b>Ownership/Comments</b>
Cedar	Bluff Springs CA / Caplinger Mills	Ozark	First observed in 2004 Last observed in April 2015 60 plants	MDC / Soil containing seeds from nearby Coal Bank Hills was moved to suitable habitat within the conservation area to secure a protected population. Occurs in four plots. Surveys in 2008 revealed 135 plants. Additional surveys are needed to determine long-term viability. EO rank = D*
Cedar	Cave Branch Glades / Roscoe	Ozark	First observed in 1984 Last observed in April 1995 12 plants	Private / Not protected. Earlier observations indicated large populations up to 4,000 plants, although numbers show great annual variation. Last observation was well past flowering. Lacked permission to survey in 2005. Owner historically recognized population and protected, but unwilling to sell or register with conservation organizations. EO rank = A
Cedar	Coal Bank Hills / Caplinger Mills	Ozark	First observed in 1989 Last observed in April 2005 1,107 plants	Private / Not protected. Contains an “east” and “west” population. Both populations surveyed in 2005. Large annual variation in number of plants. Served as source of seeds for Bluff Springs CA. EO rank = C

Cedar	Leila Store Glade / Caplinger Mills	Ozark	First and last observed in February 1984 230 plants	Private / Not protected. Occurred in two “patches” of 30 and 200 plants. Lacked permission to survey in 2005. EO rank = C
Cedar	Tara Glade / Bona	Ozark	First observed in 1989 Last observed in April 2005 1,700 plants	USCOE / Occurred at two rock outcroppings with 850 plants each. EO rank = C
Dade	Bona Glade NA / Bona	Ozark	First observed in 1973 Last observed in April 2015 1,369 plants	USCOE / Widely distributed throughout the northern and western portions of the area. EO rank = B
Dade	Carmack Branch Glade / Bona	Ozark	First observed in 1984 Last observed in April 2005 903 plants	Private / Not protected. Past surveys showed large populations estimated at 10,000 plants. Cedars were noted as encroaching on portions of the glade. EO rank = A
Dade	Corry Flatrocks / Dadeville	Ozark	First observed in 1984 Last observed in April 2005 Estimated over 1,000 plants	TNC / Private. TNC owns the northern half of glade and owner of south portion has registered the site with TNC. Last population estimate was in 1997. EO rank = A
Dade	Corry Flatrocks – Mayer Introduction Site / Dadeville	Ozark	First and last observed in April 2005 31 plants	Private / Not protected. Soil containing seeds from a nearby glade was placed in suitable habitat here by a private landowner. EO rank = D

Dade	Flint Hill Glades / Bona	Ozark	First observed in 1989 Last observed in April 2015 4,410 plants	USCOE & Private / Site of long-term monitoring to observe effects of succession on <i>Geocarpon</i> distribution and density. Majority of plants occur on Corps property. Significant population on adjacent private property not surveyed in 2015. EO rank = A
Dade	Maze Creek / Bona	Ozark	First observed in 1988 Last observed in April 2015 2,675 plants	USCOE / Plants primarily in two sites. Rocky outcrops to the south support most plants. Northern sites have fewer plants and suffer from cedar encroachment. EO rank = A
Dade	Maze Creek Outcrops / Dadeville	Ozark	First observed in 1984 Last visited in April 2005 No plants	Private / No protection. Several hundred plants historically occurred within small rock outcrops north and south of a road at this site. It is a heavily grazed pasture. Only the north site was surveyed in 2005. The site should be revisited in future wet years favorable to germination in order to determine the status of this site. EO rank = unknown
Dade	Rice Glade / Dadeville	Ozark	First and last observed in 1989 1,000 or less plants	Private / Not protected. Lacked permission to survey in 2005. EO rank = B
Dade	Stockton Lake – Corry Branch Glade / Greenfield	Ozark	First observed in 1978 Last observed in April 2015 687 plants	USCOE / Plants scattered throughout four subpopulations around east arm and west side of lake. EO rank = B

Greene	Bois D'Arc CA/ Ash Grove	Ozark	First observed in 2006 Last observed in April 2014 4 plants	MDC / In October 2005 soil containing viable seeds was removed from Pearl Glade and placed within six sandstone outcroppings. Surveys in 2005 revealed 72 plants. Additional surveys are needed to determine if more recent observations represent a long-term decline or poor germination due to climatic conditions. EO rank = D
Greene	Pearl Glade / Willard	Ozark	First observed in 2000 Last observed in March 2005 750 plants	Private / No protection. Site used as a source for soil/seed for introduction at Bois D'Arc CA. EO rank = C
Henry	Otter Creek Glade / Lowry City	Osage Plains	First observed in 2000 Last observed in April 2005 5,118 plants	USCOE & Private / Found scattered in 4-5 subpopulations throughout glade. Approximately half of population occurs on Corps property. Portion on private land not protected. EO rank = B
Henry	Truman Lake / Lowry City	Osage Plains	First observed in 1997 Last observed in April 2006 3,265 plants (2005)	USCOE / Last comprehensive survey was in April 2005. Over 3,000 plants observed scattered widely throughout the glade. Observers in 2006 noted "hundreds" of plants but did not conduct a thorough quantitative survey. EO rank = C
Lawrence	Halltown Glade / Halltown	Ozark	First observed in 1980 Last observed in April 2005 2,215 plants	Private / Not protected. Plants scattered on south side of road. EO rank = C

Polk	Eudora Glades / Walnut Grove	Ozark	First observed in 1970 Last observed in 1984 1,000 plants or less	Private / Registered by TNC in 1980s but no enforceable protection. May have changed owners since registration. Lacked permission to survey in 2005. EO rank = B
Polk	Graydon Springs Glade / Walnut Grove	Ozark	First observed in 1958 Last observed in April 2005 750 plants	Private / Not protected. Plants located in three subpopulations. EO rank = C
St. Clair	Buzzard's Bluff / Vista	Ozark	First observed in 1957 Last observed in April 2005 355 plants	Private / Not protected. EO rank = BC
St. Clair	Collins Glade / Vista	Ozark	First observed in 1986 Last observed in April 2015 1,270 plants	Missouri Department of Transportation (MODOT) / This site was impacted by a road expansion project. Soil containing seeds from the impacted portion were transferred to suitable habitat across the highway and have successfully germinated since 1997. The majority of plants in 2015 were found in a few concentrated areas. EO rank = C
St. Clair	Schwarz Prairie / Roscoe	Ozark	First observed in 1990 Last surveyed in April 2015 568 plants	Private / Area is owned by the Missouri Prairie Foundation and is managed to maintain native plants. EO rank = C

St. Clair	Taberville Prairie NA and vicinity	Osage Plains	First observed in 1985 Last observed in April 2014 4 plants	MDC & Private / Approximately half of population occurs on Natural Area. Remainder is on unprotected private property. Surveys in 2005 revealed 500-1,000 plants. Additional surveys needed to determine if more recent observations represent a long-term decline or poor germination due to climatic conditions. EO rank = C
<b>Arkansas</b>				
<b>County</b>	<b>Site Name/Quad</b>	<b>Natural Division</b>	<b>Collection/Observation Data</b>	<b>Ownership/Comments</b>
Bradley & Drew	Warren Prairie Natural Area / Wilmar South	West Gulf Coastal Plain	First observed in 1958 Observed March 2012 Comprehensive survey revealed an estimate of between 7,567-8,767 plants Limited surveys in 2013 revealed two potentially new patches containing nearly 200 plants total	ANHC / The Warren Prairie Natural Area represents the largest population in both number and area. The majority of the population is on protected land, although five patches occur on adjacent private property. The biggest threats are lack of appropriate disturbance and associated vegetation succession, and severe disturbance by feral hogs. EO rank = A

Cleveland	Kingsland Prairie / New Edinburg	West Gulf Coastal Plain	First observed in 1982 Eastern cluster last observed in March 2012 900+ plants Western cluster last observed in March 2013 925 plants Limited surveys in 2014 revealed two new patches containing 250-300 plants total	ANHC / The Kingsland Prairie Natural Area contains a relatively large population but covers much less area than Warren Prairie NA. The majority of the population is on protected land, although one historic patch occurs on adjacent private property. The biggest threats are lack of appropriate disturbance and associated vegetation succession, and severe disturbance by feral hogs. EO rank = A.
Cleveland	Hall Creek Barrens (formally New Edinburg Prairie / New Edinburg)	West Gulf Coastal Plain	First observed in 1984 Last observed in 2012 80+ plants Last surveyed in 2013 Zero plants	ANHC / Acquired recently by ANHC and designated as Hall Creek Barrens Natural Area. Several historic and likely sites were surveyed in 2013 with no plants observed. One small site is still extant. Much of the habitat at this site is marginal and may benefit from management to favor Geocarpon. EO rank = CD.
<u>Franklin</u>	Branch Saline Barrens / Branch	Arkansas River Valley	First observed in 1986 Last observed in March 2012 74 plants Last surveyed in spring 2014 Zero plants	Private / Used as a cattle pasture. The most recent survey revealed no plants at the site. It had been altered significantly by efforts to improve pasture in the area (fertilization and disturbance from adjacent tree removals). ANHC noted that these activities and declines had been noted in the past and in subsequent years Geocarpon was again observed. Continued surveys are needed to determine if this is a normal decline or a long-term trend. Only one population occurs at this site and it has an EO rank of D.

<u>Sebastian</u>	Ft. Chaffee / Fort Smith	Arkansas River Valley	First and last observed in April 2014 450-500 plants	DOD / This site was discovered within wing soils on a small, cedar-encroached saline slick area just inside the permanent plowed fireline. Other potentially suitable sites nearby were surveyed with no plants observed. EO rank = C.
<b>Louisiana</b>				
<b>Parish</b>	<b>Site Name/Quad</b>	<b>Natural Division</b>	<b>Collection/Observation Data</b>	<b>Ownership/Comments</b>
Winn	Saline Creek Prairie / Tullos	West Gulf Coastal Plain	First observed in 1990 Last observed in 2014 Plants casually observed in good numbers	Private / Recognized by owner as “unique site” and registered as a natural area with LNHP. During better years (1991) over 300 plants observed. EO rank = BC
Winn	Castor Creek Saline Prairie / Tullos	West Gulf Coastal Plain	First observed in 1991 Last observed in 2014 Plants casually observed in good numbers	Private / Recognized by owner as “unique site” and registered as a natural area with LNHP. During better years (1991) over 600 plants observed. EO rank = B
Caddo	Barren Road Prairie / Stonewall	West Gulf Coastal Plain	First observed in March 2006 Last observed in 2008 zero plants	Private / Impacts from ATV use and dirt moving activities, although it is unclear if these activities are affecting Geocarpon. Landowner has shown little interest in modifying these activities and recent access is questionable. EO rank = D
De Soto	Rambin Bayou Saline Prairie / Holly	West Gulf Coastal Plain	First observed in March 2007 Last observed in 2015 Plants casually observed in good numbers	Private / Some rutting from vehicle and ATV use but otherwise in good condition. No special protection by landowner. EO rank = AB

DeSoto	Dalton Prairie / Stonewall	West Gulf Coastal Plain	First and last observed in 2007 418 plants	Private / Some damage by ATV use. No special protection in place. EO rank = A
DeSoto	Dickson Prairie / Stonewall	West Gulf Coastal Plain	First observed in 2007 Last observed in 2015 Plants casually observed in good numbers	Private / Characterized as the “best quality” saline prairie (similar to Castor Creek) surveyed. No special protection in place. EO rank = A
<b>Texas</b>				
<b>County</b>	<b>Site Name/Quad</b>	<b>Natural Division</b>	<b>Collection/Observation Data</b>	<b>Ownership/Comments</b>
Anderson	Neches River Site / Neches	West Gulf Coastal Plain	First observed in 2004 Last observed in March 2005 360 plants	Private / Recognized by owner as “unique site” and managed to avoid impacts. Located in acquisition boundary of recently approved Neches River NWR. EO rank = Not ranked.
Gregg	Jay Global Prairie / Currently Undisclosed	West Gulf Coastal Plain	First and last observed in 2012 4,000 plants	Private / Corporate land used for hunting. EO rank = Not ranked.
Harrison	Bayou Saline Prairie / Karnack	West Gulf Coastal Plain	First and last observed in 2009 1,806 plants	TPWD and Private / A portion of this population extends into the Caddo Lake State Park. The remainder is on unprotected private land. EO rank = Not ranked.
Panola	Horton Saline Prairie / Currently Undisclosed	West Gulf Coastal Plain	First observed in 2009 Last observed in 2013 200 plants	Private / No special protection in place. EO rank = Not ranked.

\* EO rank is a general ranking of the site assigned by MDC, ANHC, and LNHP biologists. Ranges from: A (excellent) – D (poor) (e.g., a large population of mature reproducing individuals occurring in an undisturbed area with no prospective human interference would receive the highest rank, A) (Butler in litt. 2006). These ranks have some subjectivity but are generally based on long-term trends rather than individual surveys. This is especially important for a species such as *Geocarpon* that exhibits high annual population variability (Smith in litt. 2006b).

Data for this table was provided by heritage data managers and botanists from each state (Baker in litt. 2015; Baker and Witsell 2015; Briggler in litt. 2015; Reid in litt. 2015; Singhurst in litt. 2015).