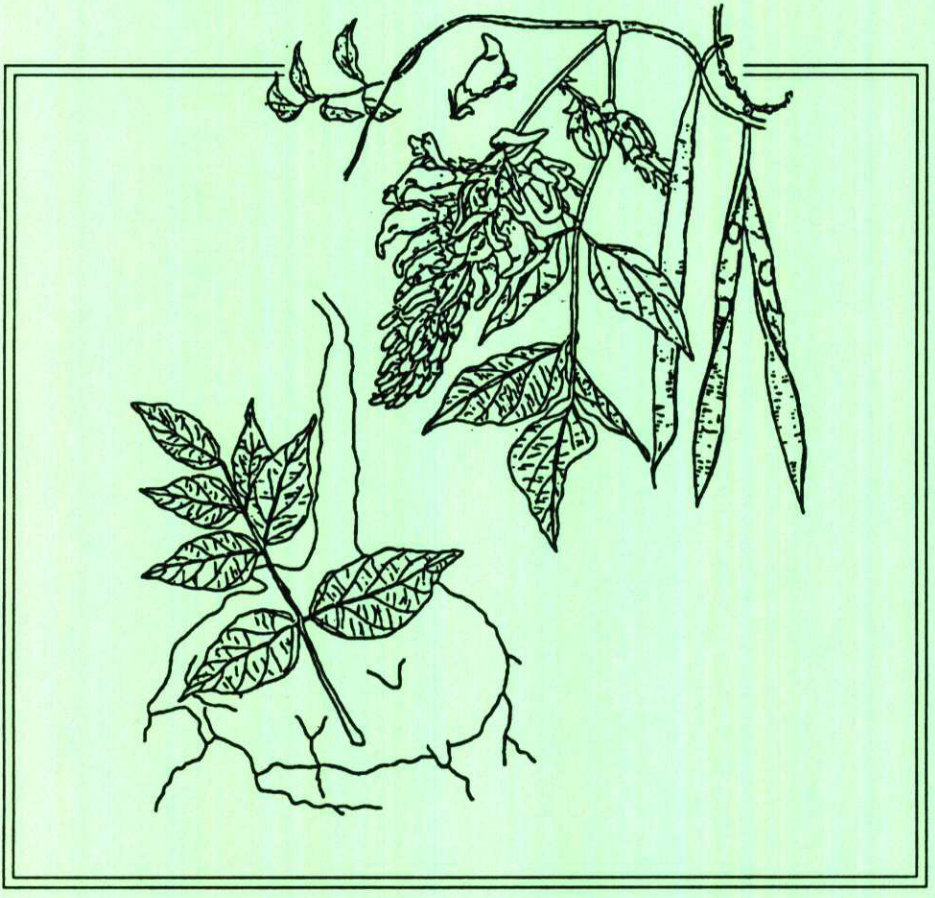
Recovery Plan

Price's Potato-Bean

(Apios priceana)



U.S. Fish and Wildlife Service

RECOVERY PLAN

for

PRICE'S POTATO-BEAN

(APIOS PRICEANA)

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for

U.S. Fish and Wildlife Service
Jackson, Mississippi

Southeast Region
Atlanta, Georgia

Approved: 

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Regional Director, U.S. Fish and Wildlife Service

Date: February 10, 1993

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Literature citations should read as follows:

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EXECUTIVE SUMMARY

Current Status: There are 25 known populations of *Apios priceana* in four States: Alabama, Kentucky, Mississippi, and Tennessee. Eleven populations, including the only known populations from Illinois, have not been relocated and are assumed to be extirpated. The species was listed as threatened by the U.S. Fish and Wildlife Service (1990) due to the small number of populations and the threats to its habitat.

Habitat Requirements and Limiting Factors: *Apios priceana* is found in open forests, along forest edges, and along the edges of creeks and rivers. Evidence suggests that excessive shading by canopy trees results in reduced growth and reproduction of the species.

Recovery Objective: Delisting.

Recovery Criteria: Price's potato-bean will be considered for delisting when there are at least 25 geographically distinct, self-sustaining, protected populations and they have been maintained for 10 years. A population will be considered self-sustaining if the population size is stable and there is evidence of successful reproduction. Protected populations will have appropriate legal protection and appropriate management.

Actions Needed:

(1) Protect known populations.
(2) Investigate effects of potential management techniques.
(3) Search for new populations.
(4) Study biology of *Apios priceana*.
(5) Maintain plants and seeds *ex situ*.
(6) Provide public information.

Costs ($000):

Fiscal Year	Need 1	Need 2	Need 3	Need 4	Need 5	Need 6	Total
1992	24.0	10.25	42.0	36.00	1.15	6.0	119.4
1993	9.0	4.5	42.0	9.75	0.4	6.0	71.65
1994	9.0	3.75	-	8.25	0.4	6.0	27.4
1995	-	3.75	-	7.5	0.4	6.0	17.65
1996	-	3.75	-	7.5	0.4	6.0	17.65
1997-2010	-	64.5	-	84.0	5.6	84.0	238.1
Total Cost of Recovery	42.0	90.5	84.0	153.00	8.35	114.0	491.85

Date of Recovery: 2010, if recovery criteria are met.

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I. INTRODUCTION

Background Information

Price's potato-bean (Apios priceana B.L. Robinson), a herbaceous vine in the pea family, is currently known from four States in the Southeast United States: Alabama, Kentucky, Mississippi and Tennessee. Two populations from Illinois have not been relocated despite repeated searches (Hutchinson 1990). The U.S. Fish and Wildlife Service (1990) listed the species in 1990 as threatened due to the small number of known populations and evidence of destruction of its habitat. Apios priceana is officially State listed as endangered in Illinois (Sheviak 1981) and Tennessee (Somers 1989). It is also considered endangered in Kentucky (Kentucky State Nature Preserves Commission 1991), Alabama (Alabama Natural Heritage Program 1991), and Mississippi (Ken Gordon, Mississippi Natural Heritage Program, personal communication, 1991). The Nature Conservancy ranks A. priceana as globally imperiled (G1).

If recovery of this threatened species is successful, its future might include development as a food crop. The large, starchy tubers of A. priceana are a good source of protein once the non-essential amino acids are extracted by boiling in alcohol (Walter et al. 1986). Apios americana (ground nut), the only other North American member of this genus, forms many small, sweet tubers that were a food source for native Americans (Yanovsky 1936). In the future, A. priceana and A. americana might be hybridized to improve their crop potential (Walter et al. 1986).

Description and Taxonomic Status

Apios priceana, a member of the pea family (Fabaceae), is a twining, herbaceous, perennial vine that grows from a stout, thick, roundish tuber often 18 centimeters (cm) or 7.2 inches (in.) in diameter (Figure 1). The stem is round in cross section, somewhat twisted and slightly ridged. It is finely hairy early in its growth, but later becomes smooth and glabrous. Leaves of the main stem are 20 to 30 cm (8 to 12 in.) long, alternate, and pinnately compound with 7 (5 to 9) leaflets. The leaflets are 4 to 10 cm (1.6 to 4.0 in.) long and half as wide, ovate and obtuse or rounded at the base and on 3 to 5 millimeter (mm) (0.1 to 0.2 in.) hairy stalks. The upper leaflet surface is smooth at maturity, and the lower surface is pale, slightly hairy, and veiny. Leaves and leaflets of branches are smaller than those of the main stem.

Racemes are 5 to 15 cm (2 to 6 in.) long, dense with flowers (50 to 70) and are usually in clusters of two and three in the axils of the leaves. Pedicels (flower stalks) are thin and 3 to 5 mm (0.1 to 0.2 in.) long; the bracts (small leaves at base of flowers) are longer than the pedicels and are ovate with a slender, tapering tip. The greenish-white or brownish pink flowers are 1 cm long (0.4 in.) and tinged with magenta at the apex. The standard (large, upper petal) is bi-auriculate (ear-shaped appendages) at the base with a fleshy beak-like apex, the wings (lateral petals) are shorter and narrowly oblong but rounded at the base, and the keel (bottom, ridged petals) are fleshy and curved upward.

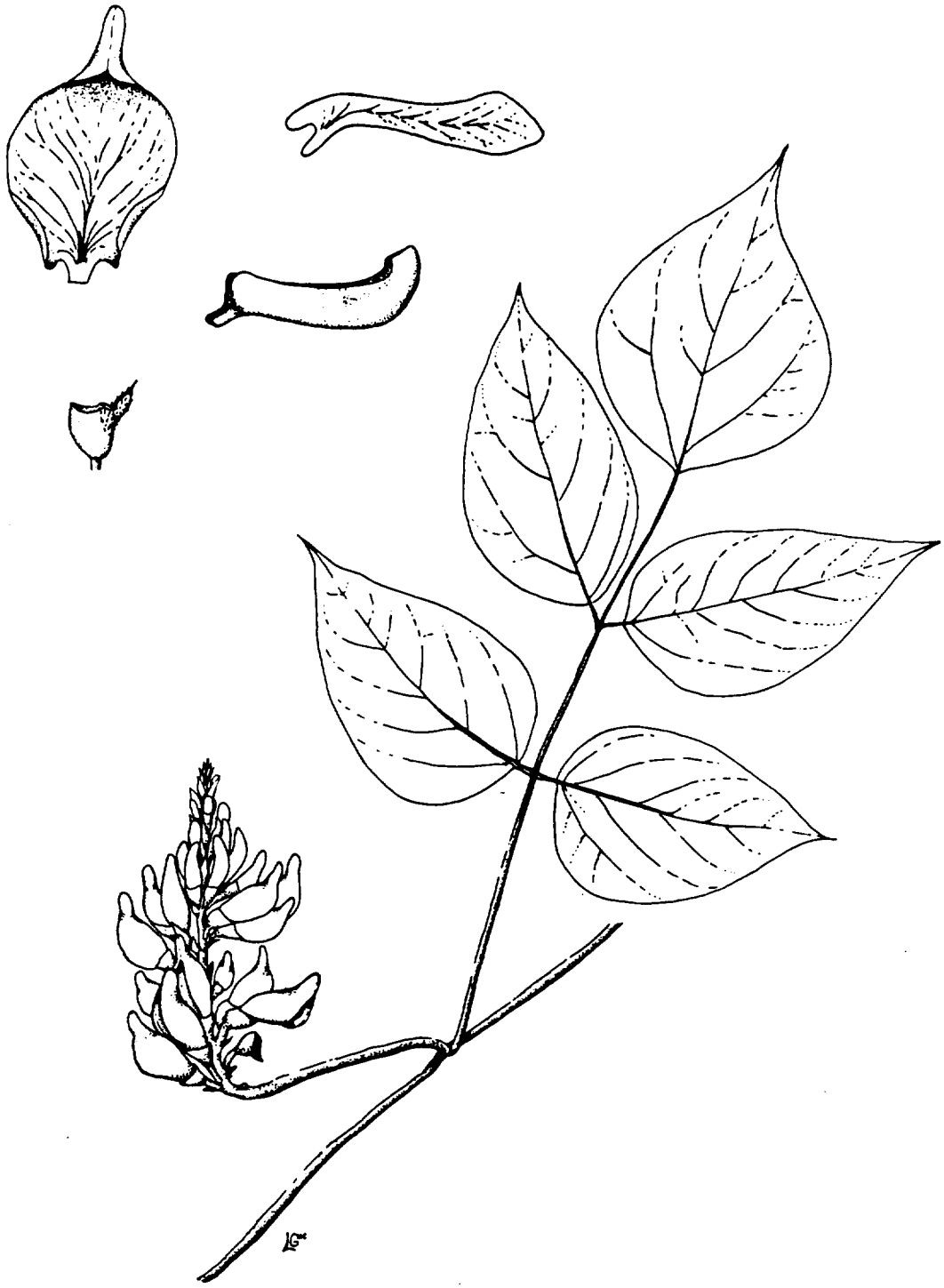

Figure 1. Illustration of Price's potato-bean (by Linda Gucciardo)

Pods are 12 to 15 cm (5 to 6 in.) long, 1 cm (0.4 in.) wide, and tapering at both ends. There are usually 4 to 10 seeds per pod. Seeds are 7 to 8 mm (0.3 in.) long and separated in the pod by a silvery white endocarp. The roots of A. priceana produce nodules 2 to 3.5 mm (0.1 in.) in diameter (Robinson 1898; Kral 1980; Woods 1988; Isely 1990; L. McCook, Missouri Botanical Garden, personal communication, 1992).

Apios americana and A. priceana are most clearly distinguished by their tuber morphology. Apios americana grows from a string of small tubers, while A. priceana grows from one large spheroidal tuber, 18 cm in diameter (Robinson 1898). Apios priceana also has a larger flower with a distinctive thick appendage at the apex of its standard, a longer pod, larger leaves, and more leaflets than A. americana (Robinson 1898, Kral 1983, U.S. Fish and Wildlife Service 1989).

Several above-ground characteristics can differentiate these species when they are not in flower. Leaves of A. priceana have three to five prominent, secondary veins whereas A. americana leaves have five to seven, rarely nine (Heiser 1990). The veins of A. priceana are more raised above the lower leaflet surface than the veins of A. americana (Heiser 1990). Schwegman (1990) reports that A. priceana has four secondary veins (excepting the marginal vein) and A. americana has five secondary veins (excepting the marginal vein). In Apios priceana, the secondary vein closest to the base of a leaflet (excepting the marginal vein) is straight, creates an angle of 45 degrees with the main vein and joins the main vein close to the base of the leaf. In Apios americana, the secondary vein closest to the base of a leaflet (excepting the marginal vein) is curved, meets the main vein 1 mm (0.04 in) or more from the base of the leaflet, and forms a 60 degree angle with the main vein. Apios americana often has a reddish color at the point on the rachis (axis of compound leaf) where the leaflets emerge, and the hairs on the pulvinus (swelling at the base of the leaf stalk) are also a reddish-orange color. In contrast, the rachis of A. priceana is not reported to have any reddish color, and the hairs on the pulvinus are buff (Heiser 1990).

These two species also can be distinguished in the seedling stage. The first eophylls (seedling leaves) of A. priceana are opposite and the third or fourth eophyll is bi- or trifoliate. In contrast, the first eophylls of A. americana are alternate and none of the first five eophylls are trifoliate (Duke 1983).

The genus Apios was described by Cornut in 1633; however, Linnaeus called the genus Glycine in 1753. In 1905, at the botanical congress in Vienna, Apios was conserved over Glycine (pro parte). The genus consists of three ~~Asian~~ species and two North American species (Woods 1988). Common names for Apios priceana include Price's potato-bean, Sadie Price's potato-bean, ~~potato-bean~~, and Price's ground nut. Type specimens are in the Gray Herbarium, Cambridge, Massachusetts.

Distribution

Price's potato-bean was originally found in 1896 by Sadie Price in open woods near Bowling Green in Warren County, Kentucky (Robinson 1898). This population was last seen in 1920. Since its discovery, 36 populations of A. priceana have been found in 22 Counties of five States: Alabama, Illinois, Kentucky, Mississippi, and Tennessee (Figure 2). Twenty-five populations are extant and are found in 15 Counties of four States (Table 1). Most of the extant occurrences are in Tennessee. Eleven populations are assumed to be extirpated, including the only known populations from Illinois (Table 2). Apios priceana is found within the Coastal Plain, Interior Low Plateaus, and Appalachian Plateaus physiographic provinces of the United States (Fenneman 1938). Information on the physiographic regions of extant populations is summarized in Table 1.

It is very likely that undiscovered populations of A. priceana exist in open woods, forest edges, road edges (in low areas near a creek) and streambanks within its known range and in adjacent States. The species does not flower every year and is difficult to identify without flowers; therefore, populations have probably been passed over in their vegetative state.

Habitat

Apios priceana thrives in open, wooded areas, often in forest gaps or along forest edges (Medley 1980). The species seems to prefer mesic areas and is often found in open, low areas near a stream or along the banks of streams and rivers. The species is sometimes found near the base of small limestone bluffs (Medley 1980, Kral 1983). Most populations are located in cleared areas associated with powerline or roadside rights-of-way.

Apios priceana often grows in well drained loams or old alluvium over limestone on rocky, sloping terrains (Kral 1983). The species can survive a broad range of pH from less than five (Duke 1983) to greater than eight (Walter et al. 1986).

Common associates, present at least half of the sites where information is available, include: Acer saccharum (sugar maple), Amphicarpa bracteata (hog peanut), Campanula americana (bluebell), Cercis canadensis (redbud), Lindera benzoin (spicebush), Quercus muhlenbergii (chestnut oak), Tilia americana (basswood), Toxicodendron radicans (poison ivy) and Ulmus rubra (slippery elm). Nomenclature follows Kartesz and Kartesz (1980).

Life History

Apios priceana flowers from late mid-July through mid-August and produces fruit in August and September. The flowers are pollinated by the long tailed skipper (Urbanus proteus Linnaeus) and by honey bees (Apis mellifera Linn.) and bumble bees (Subfamily Apinae, Tribe Bombini), although bees are reported to have some difficulty accessing the nectar (Robinson 1898). Flowers in the genus Apios have a tripping mechanism that causes the keel to coil when triggered by an insect. When the keel coils, it exposes the anthers and pistil, allowing pollination to occur (Bruneau and Anderson 1988).

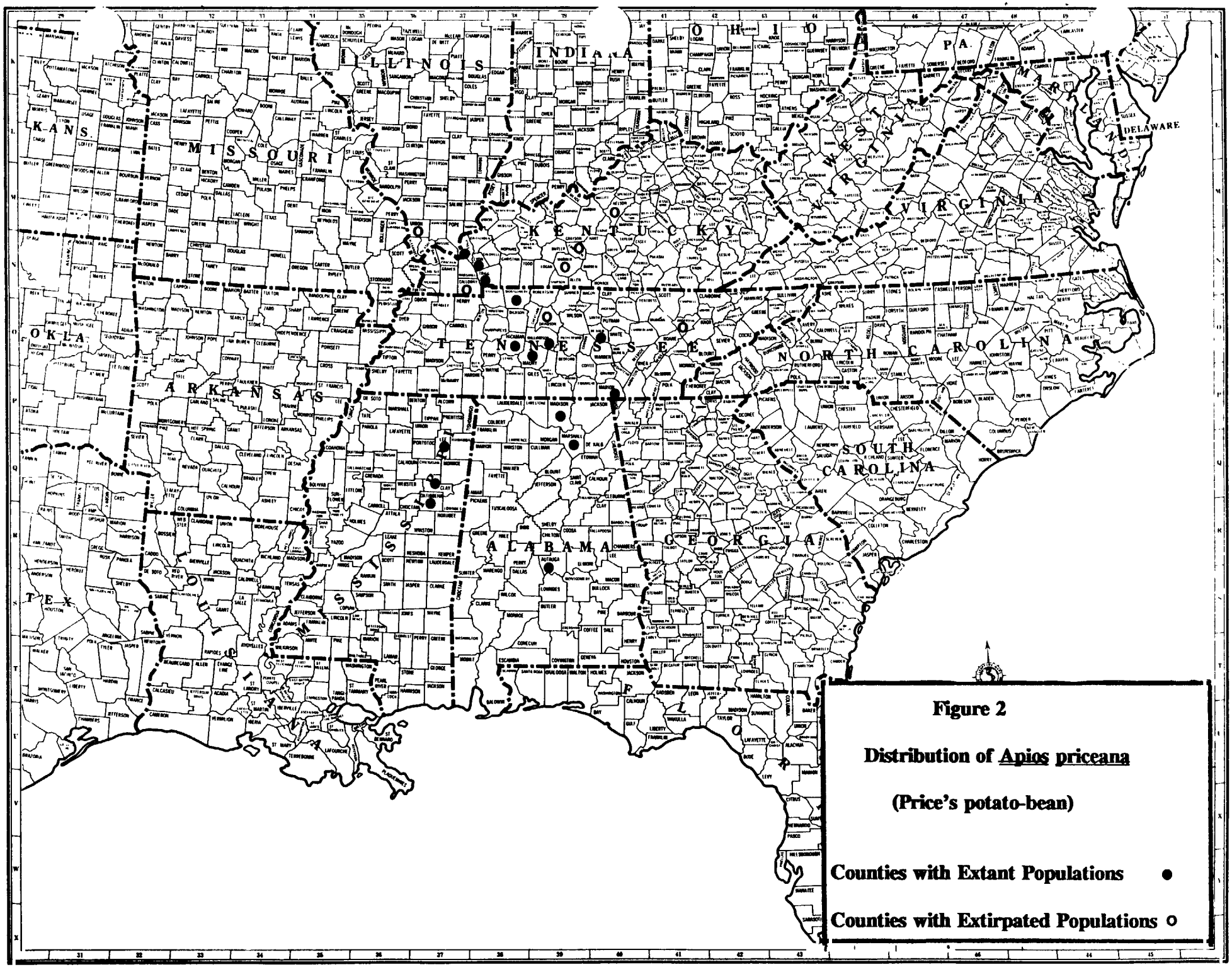

Figure 2

Distribution of Apios priceana

(Price's potato-bean)

Counties with Extant Populations ●

Counties with Extirpated Populations o

Table 1. Extant populations of Price's Potato-bean. Physiographic province codes are as follows: AP= Appalachian Plateaus Physiographic Province, CP=Coastal Plain Physiographic Province, ILP=Interior Low Plateaus Physiographic Province (Fenneman 1938, Quarterman and Powell 1978, Powell 1983).

State/County (Site Name)	Ownership	Population Size (# vines)	Last Seen	Threats	Physiographic Section and (Province)
Alabama					
1) Autauga County (Alabama River)	US Army Corps of Engineers	1	1982	Small population size.	Fall Line Hills Section (CP)
2) Autauga County (Ivy Creek)	US Army Corps of Engineers	6	1988	None known.	Fall Line Hills Section (CP)
3) Madison County	Private	15-30	Not known.	None known.	Highland Rim Section (ILP)
4) Marshall County	Private	5 or less	1991	Shading.	Highland Rim Section (ILP)
Kentucky					
5) Livingston County	Private	30	1985	Trampling by cattle.	Shawnee Hills Section (ILP)
6) Lyon County	Private	7	1990	Road and power line maintenance.	Highland Rim Section (ILP)
7) Trigg County (Hematite Lake)	Tennessee Valley Authority	<25	1989	Shading by trees.	Highland Rim Section (ILP)

Table 1. Continued.

State/County (Site Name)	Ownership	Population Size (# vines)	Last Seen	Threats	Physiographic Section and (Province)
8) Trigg County (Land Between the Lakes)	Tennessee Valley Authority	30-50	1989	Crown vetch and roadside mowing.	Highland Rim Section (ILP)
Mississippi					
9) Clay County	Private, Registered Natural Area	15-20	1986	Grazing, renewal of lime mining.	(ILP)
10) Lee County	Private, Registered Natural Area	1,000	1983	Power line maintenance.	(ILP)
11) Oktibbeha County (Sand Creek Chalk Bluffs)	Private	10-16	1988	Grazing, power line maintenance.	Pontotoc Ridge - Black Prairie Transition Area (ILP)
12) Oktibbeha County (Rock Hill)	Private	85	1983	Grazing, shading and erosion.	(ILP)
Tennessee					
13) DeKalb County	Private	25-50	1990	Road maintenance.	Highland Rim Section (ILP)
14) Hickman County (Dog Creek)	Private	25	1990	Shading, road maintenance, predation, drought.	Highland Rim Section (ILP)
15) Hickman County (Bell Branch)	Private	4	1991	Low reproduction.	Highland Rim Section (ILP)

Table 1. Continued.

State/County (Site Name)	Ownership	Population Size (# vines)	Last Seen	Threats	Physiographic Section and (Province)
16) Hickman County (Brigg's Chapel Hollow)	Private	7-10	1991	None known.	Highland Rim Section (ILP)
17) Hickman County (Defeated Creek)	Private	12	1991	Competition with other plants.	Highland Rim Section (ILP)
18) Hickman County (East Fork Defeated Creek)	Private	6	1991	Drought stress.	Highland Rim Section (ILP)
19) Hickman County (Duck River Mile 47)	Private	1-2	1991	Small population size.	Highland Rim Section (ILP)
20) Marion County	Private, Registered Natural Area	100-200	1990	Road and power line maintenance.	Cumberland Plateau Section (AP)
21) Maury County	Private	24	1990	Road maintenance.	Highland Rim Section (ILP)
22) Montgomery County	The Nature Conservancy	30-40	1990	Shading.	Highland Rim Section (ILP)
23) Williamson County (Basin Spring)	Private, Registered Natural Area	18	1990	Road maintenance, herbivory.	Highland Rim Section (ILP)
24) Williamson County (North Fork Lick Creek)	Private	45	1990	Shading, drought stress, predation.	Highland Rim Section (ILP)
25) Williamson County (Lick Creek)	Private	7	1990	Shading, drought, road maintenance.	Highland Rim Section (ILP)

Table 2. Extirpated populations of Price's potato-bean.

State/County (Site Name)	Last Seen
Illinois	
Union County (Wolf Lake)	1941
Union County (LaRue Swamp)	1977
Kentucky	
Calloway County (near Kenlake State Park)	1964
Calloway County (Devils Pulpit)	1965
Edmonson County	1951
Lyon County	1947
Nelson County	no information
Warren County	1920
Tennessee	
Anderson County	no information
Davidson County (Bull Run)	1935
Davidson County (Little Marrowbone Creek)	1938

Apios priceana is the only species of Apios in which the keel bends backwards after tripping rather than coiling (Woods 1988). This tripping mechanism prevents automatic self-pollination of the flowers. A single plant of A. priceana growing in a private garden has been observed to set seed, indicating that the species is self-compatible (E. Croom, University of Mississippi, personal communication, 1992).

Apios priceana plants have been observed to produce few seeds (Robinson 1898; Chester and Holt 1990; P. Olwell, Center for Plant Conservation, personal communication, 1992). Several factors could explain this low seed set. Shading of the plants by trees and shrubs (Medley 1980, Woods 1988, U.S. Fish and Wildlife Service 1989), drought, and insect damage to flowers and fruits of A. priceana (E. Chester, Austin Peay University, personal communication, 1991) may all contribute to low seed set. Observations of a Mississippi population suggests that water availability may limit seed set; greater seed set has been observed in years with higher rainfall (E. Croom, personal communication, 1992). Vegetative reproduction, if prevalent, would result in low genetic diversity that could reduce the success of sexual reproduction.

Low fruit production also is seen in A. americana. Several populations of the species have been found to have a triploid chromosome number which precludes sexual reproduction (Bruneau and Anderson 1988). Bruneau and Anderson (1988) also found low fruit production (6 percent) in diploid populations. They attribute low levels of fruit and seed production in these populations to both limited resources and limited pollinators. A population of A. priceana in Kentucky was found to be diploid with a somatic chromosome number of 22 (Seabrook and Dionne 1976). It is possible, however, that other populations are composed of sterile, triploid plants. More studies are needed to determine the reasons for low seed production in A. priceana.

When seeds are produced, they germinate readily with scarification (Walter et al. 1986; C. Baskin, University of Kentucky, personal communication, 1991; L. McCook, personal communication, 1992). In a small germination test, 18 of 20 seeds germinated after scarification (C. Baskin, personal communication, 1991). Temperature fluctuations probably act to break the impermeable seed coat in the wild (C. Baskin, personal communication, 1991). No information is available on when the seeds germinate in the wild.

This perennial species grows from a single large tuber, whereas A. americana grows from several small tubers (U.S. Fish and Wildlife Service 1989). Perhaps having a single tuber limits dispersal and vegetative reproduction of A. priceana. Tubers of A. americana are dispersed when floods carry them to a new location (Seabrook and Dionne 1976). Tubers and seeds of A. priceana, frequently found near streams, also may be dispersed by water. No studies have investigated the dispersal mechanisms of the species. Plants do not flower during their first year of growth, but they can grow as much as 5 to 6 feet in their first season (C. Baskin, personal communication, 1991). Observations also indicate that the tuber can remain dormant during a growing season yet still show vigorous growth the following year (L. McCook, personal communication, 1992). No work has been done on the survival of seedlings in the wild.

Reasons for Listing

A number of factors threaten the continued survival of A. priceana, including aspects of its biology, human disturbances, and interactions with other species. There are only 25 known populations of the species with approximately 1,500 to 1,700 vines. A total of 36 populations have been discovered; however, 11 are now considered to be extirpated. Apios priceana plants produce very few seeds (Robinson 1898, Chester and Holt 1990). This low level of sexual reproduction may result in small population sizes and little dispersal of the species to new sites. It also is likely to result in low genetic diversity within populations. It is not known whether A. priceana reproduces vegetatively; however, its growth from a single tuber may limit vegetative reproduction.

Logging may threaten A. priceana populations. Selective removal of trees that shade plants can enhance growth and reproduction of A. priceana by increasing levels of light; however, clearcutting or heavy logging can eliminate populations (U.S. Fish and Wildlife Service 1989). It is unclear whether clearcutting will result in permanent destruction of populations. Populations of A. priceana are found in secondary-growth forest suggesting that the species may recover after heavy logging (Kral 1983). The species may survive heavy logging by remaining dormant until conditions are appropriate for its growth. It is also possible that the plants found in secondary-growth forest colonized the area after it was logged.

Twenty-one of the 25 occurrences of A. priceana are on privately-owned land. Four of the privately-owned populations are State Registered Natural Areas, two in Mississippi and two in Tennessee. Registry is a temporary, non-binding agreement by the owner to preserve the species and its habitat. One of the privately-owned populations is owned by The Nature Conservancy, a non-profit conservation organization. The remaining 17 privately-owned populations are completely unprotected and vulnerable to damage from all types of habitat manipulation. Landowners who do not know that the species is on their land or who are not interested in its continued survival may make land management decisions that are harmful to the species.

The location of 11 populations on rights-of-way (road edges, powerlines, etc.) is also a potential threat to the species. Maintenance of these areas by herbicides, mowing, and clearing of trees could damage or extirpate these populations (U.S. Fish and Wildlife Service 1989, Chester and Holt 1990). Clearing trees may be harmful if the debris is piled on top of the populations. Widening of a road adjacent to an A. priceana population could easily wipe out an entire population. Mining for limestone is a potential threat to A. priceana populations found over limestone bedrock (Kral 1983).

Several species interactions damage populations of A. priceana. Shading by canopy trees may result in reduced growth and reproduction of A. priceana plants (Medley 1980, Woods 1988, U.S. Fish and Wildlife Service 1989). Grazing and trampling of plants by cattle can cause severe damage. The erosion of soil that results from heavy grazing and trampling also can harm the species (Medley 1980). A variety of pests are reported to damage A. priceana plants, including spider mites (D. Wright, Missouri Botanical Garden,

personal communication, 1991), a powdery mildew virus, and root-knot nematodes (Blackmon and Reynolds 1986). An unidentified insect has been observed to damage the flowers and fruits of A. priceana (E. Chester, personal communication, 1991). These pests may have a significant effect on A. priceana. An introduced, invasive plant, Coronilla varia (crown vetch), is threatening to outcompete one Kentucky population (Chester and Holt 1990). Other exotics, Ligustrum sinense and Rosa multiflora, are reported to be competing with populations in Mississippi (M. Morris, University of Florida, personal communication, 1992).

Conservation Measures

Apios priceana plants are being grown artificially in several locations. These plants will provide seeds and tubers for further studies of the species. Seeds from these plants also may be used in the future to reestablish extirpated populations. Carol and Jerry Baskin are growing approximately 10 plants of A. priceana in the rich soil and open light of their garden (C. Baskin, personal communication, 1991). They are hoping that these conditions will result in greater seed production and will provide them with plants and seeds for further investigations. Apios priceana also has been planted in Kentucky near the nature center at Land Between the Lakes and in the Missouri Botanical Garden. The four plants at Land Between the Lakes were planted early in the summer of 1990 (E. Ray, Tennessee Valley Authority, personal communication, 1991). The nine plants growing at the Missouri Botanical Garden are 2 years old (D. Wright, personal communication, 1991). None of these A. priceana plants have flowered yet; however, they could be an important seed source in the future. Ed Croom of University of Mississippi has one plant growing in his yard and he has been observing its growth and seed production.

Work is also being done to protect several naturally occurring populations of A. priceana. Four populations are Registered Natural Areas. Although this is not legally binding protection, it does indicate that the owners of the property are showing an active interest in the survival of the species. A population in Tennessee has been purchased by The Nature Conservancy (Table 1, number 22).

Four populations are on federally-owned land. These populations are legally protected by the Endangered Species Act. Two populations in Kentucky are on land owned by the Tennessee Valley Authority within an area designated as a Conservation Education Center (Table 1, number 7 and number 8) (U.S. Fish and Wildlife Service 1990). TVA has shown active involvement in the protection of the species. Two populations in Alabama are owned by the U.S. Army Corps of Engineers (Table 1, number 1 and number 2) (U.S. Fish and Wildlife Service 1990).

Only one of the four States with extant populations of A. priceana provides limited legal protection for the species. In Tennessee, under the Rare Plant Protection and Conservation Act of 1985, collecting the plant is prohibited without the permission of the landowner, and sale of the species is prohibited without a license from the Tennessee Department of Conservation (Somers 1989). Alabama, Kentucky and Mississippi provide no legal protection for the species.

Searches for new populations of A. priceana were carried out in Tennessee and Illinois during the 1990 growing season. The search in Tennessee resulted in the discovery of four new occurrences of the species (Tennessee Department of Conservation 1991). The Illinois search did not result in the discovery of new sites or the relocation of the two populations previously known from the State (Hutchinson 1990). A search for the species in Tennessee in 1991 resulted in the discovery of five new populations (Tennessee Department of Conservation 1991).

Strategy of Recovery

Privately-owned A. priceana populations must be provided with adequate legal protection. Landowners should be informed of the presence of the species on their property and the threats to its survival should be explained. After this initial contact, the most appropriate legal protection should be determined for each occurrence based on population size, habitat condition and the interest of the owner. Legal protection of land could be in the form of a management agreement, a conservation easement, acquisition, or dedication as a State nature preserve. Dedication as a State nature preserve provides a piece of land with legal protection against uses that would harm its natural features. This form of protection is available in Mississippi and Kentucky; however, dedication is not a legal procedure in Alabama or Tennessee. An additional type of protection is registry of land, which can be useful as a temporary means of protecting a site, but is not permanent or binding. Comparisons of legally protected areas should be made to determine the appropriate buffer area to surround populations. It is important that sites are protected in each State where the species occurs so that the entire range of the species is preserved.

Management plans should be developed for legally protected sites, including populations on property owned by the Federal government. Plans for populations that occur along roadsides and powerline rights-of-way should include contacting maintenance crews to prevent herbicide spraying, mowing and piling debris at these sites. For populations that have been damaged by grazing and trampling by cattle, the management plan should discuss methods of preventing this damage in the future. Studies will be necessary to determine the effectiveness of other possible management techniques. If these techniques are found to be effective, they should be included in the management plans. Possible management techniques include: clearing trees that shade A. priceana, nutrient addition to enhance reproduction of the species, removal of invasive plant species, and reestablishing extirpated populations. Observations of each population's vigor should be made annually. These observations will help detect problems within the populations before they become irreversible.

Research on the population biology of the species, including its habitat requirements, vegetative reproduction, pollination biology, seed dispersal and germination requirements, demography, interactions with pests, and the genetic make-up of populations will provide information necessary to manage the populations appropriately. The search for new populations of A. priceana should continue. Because the species is difficult to identify when it is not in flower, it is likely that there are undiscovered populations in the States

where it is now found and possibly in adjacent States as well. Inventories for the species should be made within its known range and adjacent areas. Seeds and plants should be maintained under artificial conditions so that material will be available for transplanting if natural populations decline or disappear.

II. RECOVERY

Recovery Objective

Apios priceana will be considered for delisting when 25 geographically distinct, self-sustaining populations are adequately protected and they have been maintained for 10 years. The projected year of recovery completion is 2010, if recovery tasks are carried out as scheduled. A population will be considered to be adequately protected when it is legally protected and actively managed. A population will be considered to be self-sustaining if it is observed to be successfully reproducing and the size is stable or increasing. The minimum population size necessary for a self-sustaining population should be determined in future demographic studies. The requirements for delisting are preliminary and may change as more information about the biology of the species is discovered.

Narrative

1. Protect known populations.

Twenty-one of the 25 known populations of A. priceana are on privately-owned land; the remaining four populations are on federally-owned land. One of the privately-owned populations is owned by The Nature Conservancy and is adequately protected. Four of the privately-owned populations are Registered Natural Areas. The remaining 16 privately-owned populations are unprotected. Legal protection of these areas is necessary to provide long-term security and prevent land use that is harmful to the species. Management plans should be developed for all populations that are protected, particularly those owned by the Federal government and conservation organizations. Management plans should be developed for the remaining populations once some sort of protection is achieved. Without this protection, A. priceana habitat will continue to be destroyed, and the species may become extinct.

1.1. Prioritize sites. All known privately-owned sites should be ranked according to population size, vigor of the plants, and the condition of the habitat. Work should be done to protect high-ranking populations first. The distribution of protected sites should be

considered; it is important that populations throughout the range of the species are protected in order to maintain a greater level of genetic diversity. As information on the genetic composition of populations becomes available, it should be considered in the ranking of populations. Genetically diverse populations should be given high priority for protection.

1.2. Contact landowners, determine and provide appropriate level of protection. At the very least, landowners must be contacted, informed that A. priceana is on their land, and told of the potential threats to the species. If the landowner is receptive to protecting the species, negotiations should begin to achieve the desired level of protection. Types of protection include: management agreement, conservation easement, acquisition, and dedication as a State nature preserve. Dedication is a potential type of protection in Mississippi and Kentucky, but not in Alabama or Tennessee. Land can also be registered as a natural area; however, this is temporary, non-binding protection. The appropriate buffer area for the species has not been determined. Future work (Task 2.5.) will help determine the area of land necessary to adequately protect a population of the species. The cost of implementing this work will vary depending on the type of protection chosen and the amount of buffer area that is determined to be necessary.

1.3. Develop management plan for each protected population. The appropriate management for populations of A. priceana will be difficult to determine until studies on the biology of the species (Task 4) and the effects of certain management techniques (Task 2) are completed. Preliminary plans can deal with threats to the species that require immediate action such as invasive species (Task 2.3), trampling by cattle, and rights-of-way maintenance. Any management for the species should be carefully recorded and observations should be made to evaluate the effectiveness of the action. Management plans should be revised as more information on the biological and physical requirements of the species is discovered. Management plans should be written for populations owned by the Federal government and The Nature Conservancy, and for the remaining populations when they receive some type of protection.

2. Investigate effects of potential management techniques. Potential management techniques for A. priceana should be tested to determine their effectiveness. Because there

are few populations of A. priceana and population sizes are small, it is essential that work begins to enhance growth and reproduction of plants and to reestablish populations (if found necessary). Without this active management, the species is likely to become extinct. The selection of populations used for these experiments should be based on their need for this type of management and the size and vigor of the population. The experimental treatment should be applied within replicated plots. The number and size of the plots should be determined by the size of the population and the density of the plants. An equal number of unmanipulated plots should be established as controls.

2.1. Determine optimal light level for the species. Shading by canopy trees is reported to reduce growth and reproduction of A. priceana (Medley 1980, Chester and Holt 1990). In order to determine the appropriate level of canopy clearing above populations of A. priceana, the optimal light level for the species should be determined in a greenhouse experiment. Corresponding field experiments should be performed to determine the level of overstory removal needed.

2.2. Study effect of nutrient and water addition on seed production. Apios priceana produces few fruits and seeds (Robinson 1898). Bruneau and Anderson (1988) suggest that resource limitation may be partially responsible for similar low seed set observed in A. americana. It has also been suggested that water availability might limit seed set (E. Croom, University of Mississippi, personal communication, 1992). Plants should be grown in the greenhouse in soil taken from field sites of A. priceana and supplemented with different levels of nutrients and water. All flowers should be hand pollinated so that pollen availability is not limiting. Seed production and growth should be compared between the different treatment levels and the control plants. Observations of these plants should be continued for 5 years after plants begin flowering. Treatments should continue throughout the experiment. The time necessary to carry this experiment to completion is uncertain. It is not known at what age A. priceana plants begin to produce flowers; however, they do not flower in their first year. The length of this initial sterile period will affect the length and cost of this experiment.

2.3. Test management to control invasive species. Invasive species that establish in A. priceana habitat may compete with this threatened species and reduce its growth and reproduction. Hand pulling of the invasive

species, mowing of the habitat while the A. priceana plants are dormant, selective herbicide application, and fire are all potential tools for controlling invasive species. The method used should be determined by knowledge of its effect on the particular invasive species. If there is no knowledge of the appropriate method to control a species, the least obtrusive method should be used first. All management should be carefully documented over several subsequent years. Portions of the populations should be left untreated to act as controls. Species composition and growth, reproduction, and seedling establishment of A. priceana should be compared between treated and control areas. The cost of these studies will depend on the number of sites affected by invasive species.

Particular care should be taken with the use of fire as a means of removing plants that compete with A. priceana. Kral (1983) reports to have seen A. priceana plants in an area that was recently burned; however, there is no evidence to suggest that fire is a normal occurrence in A. priceana habitat. The effect of fire on A. priceana plants, especially the tubers and seeds, should be investigated before a controlled burn is performed.

2.4. Enhance populations with low viability and reestablish extirpated populations, if necessary. Plants should be reintroduced into dwindling or extirpated populations only if loss of individuals and populations continues despite efforts to protect and manage populations. If possible, the introduced plants should be from nearby, genetically diverse populations. Plants from the Missouri Botanical Garden could also be used for these reintroductions. Reestablished populations should be carefully monitored to determine their success. The cost of this work will vary depending on the number of populations that need to be reestablished.

2.5. Determine appropriate buffer area surrounding populations. To determine the appropriate buffer area needed around A. priceana populations, the success of protected populations with different amounts of buffer area should be observed and compared. These observations may help determine the amount of land that should be protected to ensure that each population survives.

2.6. Long-term monitoring of populations. All populations should be monitored annually to check on the number of individuals and their vigor. This will allow problems

within populations to be detected early. If problems are caught before they become serious, management can be used to prevent the demise of populations.

3. Search for new populations. The search for new populations of A. priceana must continue. The most accurate information on the number and distribution of populations is necessary to make appropriate decisions about management of the species.

   3.1. Search for new populations within the known range. Priority should be placed on searching for additional populations of A. priceana within its known range of Alabama, Illinois, Kentucky, Mississippi, and Tennessee.

   3.2. Search for new populations in adjacent States. Searches should be conducted in appropriate habitats in States adjacent to the known range of A. priceana (Arkansas, Georgia, Indiana, Louisiana, Missouri, North Carolina, Ohio, Virginia, and West Virginia). Although Wisconsin and Iowa are adjacent to the known range, these States were both glaciated. Apios priceana has only been found in areas that were not glaciated. Populations found outside of the currently known range are likely to increase the number of known genotypes of the species. This may help in future management to prevent inbreeding in small, isolated populations.

4. Study biology of Apios priceana. An increased understanding of the biology of A. priceana is necessary to develop appropriate management practices for the species.

   4.1. Determine biological and physical requirements.

      4.1.1. Soil analysis. Soils should be analyzed for texture, pH, mineral composition, organic content, and moisture. Samples should be taken from all known sites where the species occurs.

      4.1.2. Study rhizobial associates. Woods (1988) reported the presence of nodules on the roots of A. priceana. The presence of nitrogen-fixing root nodules may allow the plants to grow in nutrient-poor soil. All populations should be surveyed for the presence of functioning root nodules. The species of Rhizobium that forms these nodules should be determined. This work will be less expensive than predicted in the implementation schedule if no rhizobial associates are found.

4.2. Study long-term demography. Permanent plots should be established in at least two populations per State, preferably in every population. These plots should be set up in the larger populations first; however, the small populations also should be studied if possible. Each stem should be mapped and counted so that recruitment of new individuals can be measured. Every year, or as often as possible, the plots should be checked to determine mortality and the number of new plants that became established within the plots. New plants should be observed to determine whether they are seedlings or shoots from the tuber of another plant. Physical disturbances to the populations, especially flooding and scouring, should be observed to determine their contribution to seedling and adult mortality. The number of fruits produced per plant should be recorded. The size and number of plots should be determined by the density and number of plants at the site. Seedlings and adult plants of A. priceana should be studied to determine whether pests or habitat characteristics limit their growth and survival. In the smallest populations, replicated plots may not be possible but observations should still be made. Studies of field populations should be made to determine the minimum population size necessary for a self-sustaining population. The effects of interspecific and intraspecific competition on A. priceana plants should be studied in a greenhouse experiment. Without knowledge of establishment and survival of new plants of the species, extinction of the species is possible.

4.3. Study reproduction. Population sizes of A. priceana are small; 63 percent of the known populations have fewer than 30 individuals. Evidence suggests that levels of sexual and vegetative reproduction are low in the species (Robinson 1898, Seabrook and Dionne 1976). In order to guarantee the continued existence of the species, ways to enhance its reproduction must be discovered.

4.3.1. Pollination biology. Observations and experiments should be used to learn more about the pollination biology of the species. Volume and sugar concentration of nectar produced by A. priceana flowers should be measured. The timing and frequency of insect visitors to the flowers also should be observed. Frequency of pollinator visits will help to determine if seed production is limited by the number of pollinators visiting the flowers. Visitors to the flowers should be observed to determine

whether they contact the stigma. These insect visitors should be collected for identification and to determine if they are carrying A. priceana pollen. The presence of other insect-pollinated plants near A. priceana populations should be recorded. The presence of other flowering plants may enhance pollinator visits to the plants or compete with A. priceana for pollinator visits. Hand pollinations should be performed to determine if flowers of A. priceana can be self-pollinated and if the addition of supplemental pollen increases seed production. If supplemental pollination increases seed production and few pollinators are seen visiting the flowers, this will suggest that seed production is limited by available pollen. If pollen availability limits seed production, flowers may need to be hand-pollinated each year to maintain higher levels of seed production.

4.3.2. Study vegetative reproduction. The production of new shoots from A. priceana's single large tuber should be investigated. It has been suggested that the single tuber of A. priceana may result in low levels of vegetative reproduction (Seabrook and Dionne 1976). Apios americana, in contrast, has a number of small tubers which could break apart and be transported by spring flood water. The ability of a tuber of A. priceana to form multiple shoots should be investigated. Observations of greenhouse-grown plants should be made over several years to determine whether multiple shoots develop from single tubers. Botanists at the Missouri Botanical Garden have expressed their interest in observing vegetative reproduction of the plants at the Garden (L. McCook, personal communication, 1992). Dormancy of the tubers also should be studied. Artificially grown plants should be used as a source of tubers for these investigations.

4.4. Observe effects of pest damage. Reports suggest that a number of pests damage the flowers, fruits, tubers, and leaves of A. priceana, including spider mites, powdery mildew virus, and root-knot nematodes (Blackmon and Reynolds 1986; E. Chester, personal communication, 1991; D. Wright, personal communication, 1991; K. Gordon, Mississippi Natural Heritage Program, personal communication, 1992). Observations of this damage should be made within the permanent plots set up to study the long-term demography of the species. Species

observed to damage the plants should be collected and identified. The extent of leaf damage should be measured. The number of fruits and flowers that are damaged by insects should be recorded for all vines within the permanent plots. The effect of this damage on seed production and vegetative growth should be measured.

4.5. Study seed biology. Preliminary work has been done on the germination of A. priceana seeds, indicating that they have a high rate of germination after scarification (C. Baskin, personal communication, 1991). Because of the low level of seed production in wild plants, however, it is difficult to obtain enough seeds to thoroughly perform these experiments. Artificially grown plants should be used as a seed source to determine germination requirements and seed viability. Soil should be collected within population sites of the species and placed in a greenhouse to determine the number of germinable A. priceana seeds present. Seed traps should be placed at several distances from isolated plants in order to discover the distance at which these seeds can be dispersed. Since a number of populations occur adjacent to creeks, mesh seed traps should also be placed in several of these creeks in order to determine whether seeds are dispersed by water. An understanding of the species' seed biology is necessary to prevent the extinction of the species.

4.6. Determine genetic diversity and chromosome number of populations. Electrophoresis should be used to determine the degree of genetic variability within and among populations of A. priceana. The more diverse populations may be healthier and more likely to survive and reproduce successfully. The most genetically diverse populations should be given a high priority for protection. Information on genetic variability will help to determine the number of populations and population size necessary to successfully maintain the species. If possible, all populations should be sampled. Research on A. americana indicates that sterile, triploid populations exist (Bruneau and Anderson 1988). Chromosome number should be determined in all populations (or as many as is feasible) to determine if any sterile triploid populations exist. This may account for reports of low seed production by A. priceana. Leaf and bud material could be obtained from the plants at the Missouri Botanical Garden.

5. Maintain plants and seeds ex situ. Plant material should be preserved in artificial conditions in case catastrophes destroy all or most populations of the species. This stored material also could be used to establish new populations if natural populations become depleted. The Center for Plant Conservation (Center) has extensive experience in this area and should be involved in the planning and implementation of these tasks.

   5.1. Maintain seeds. Seeds should be put into long-term storage at the U.S. Department of Agriculture Agricultural Research Service National Seed Storage Laboratory in Fort Collins, Colorado. Storage requirements for the species should be tested and the success of seed storage for the species should be monitored.

   5.2. Maintain plants ex situ. Apios priceana plants should continue to be maintained by the Center for Plant Conservation at the Missouri Botanical Garden in order to ensure the survival of the species. Seeds produced by these plants could be used for propagation if natural populations become depleted. Artificial populations are being maintained at the Missouri Botanical Garden (as part of the Center's National Collection of Endangered Plants); Land Between the Lakes; and on privately-owned property in Kentucky. These artificial populations could be important for public education and as a seed source for further studies of the species.

6. Provide public information about the species. Priority should be given to providing landowners with information about the species. Apios priceana is already on display at the Missouri Botanical Garden (a member botanical garden of the Center for Plant Conservation) and is used to educate the public about rare plants and conservation needs. The artificial population at Land Between the Lakes should be maintained and similarly used to educate the public. Providing the public with information about the species could also encourage amateur and professional naturalists to search for new A. priceana populations.

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III. IMPLEMENTATION SCHEDULE

The following implementation schedule outlines recovery actions and their estimated costs. Labor was estimated to cost $750 per week. It is a guide for meeting the objectives discussed in Section II of this plan. This schedule lists recovery tasks, outline numbers, priority, expected duration, responsible agencies and expected costs. These actions, when accomplished, should bring about the recovery of Apios priceana and protect its habitat.

Recovery Action Priorities

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

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

3 - All other actions necessary to provide for full recovery of the species.

KEY TO ABBREVIATIONS

AL	Alabama Natural Heritage Program
AR	Arkansas Natural Heritage Inventory
CPC	Center for Plant Conservation
FWE	Fish and Wildlife Enhancement
GA	Georgia Natural Heritage Inventory
IL	Illinois Natural Heritage Inventory
IN	Indiana Heritage Program
KY	Kentucky State Nature Preserves Commission
LA	Louisiana Natural Heritage Program
MO	Missouri Natural Heritage Inventory
MS	Mississippi Natural Heritage Program
NC	North Carolina Natural Heritage
OH	Ohio Natural Heritage Program
TN	Tennessee Department of Conservation - Ecological Services Division
TNC	The Nature Conservancy
TVA	Tennessee Valley Authority
USA	U.S. Army, Corps of Engineers
USDA	U.S. Department of Agriculture
VA	Virginia Natural Heritage Program
WV	West Virginia Natural Heritage Program

IMPLEMENTATION SCHEDULE

PRIORITY #	TASK #	TASK DESCRIPTION	TASK DURATION	RESPONSIBLE PARTY			COST ESTIMATES ($K)			COMMENTS/NOTES
				USFWS						
				Region	Division	Other	FY 1	FY 2	FY 3	
1	1.1	Prioritize sites.	1	4	FWE	AL, KY, MS, TN	3.0	-	-	1 person, 1 week, 4 States
1	1.2	Contact landowners and negotiate protection.	3	4	FWE	AL,KY,MS TN, TNC	9.0	9.0	9.0	1 person, 3 weeks, 4 States. Cost of possible acquisitions not included.
1	1.3	Develop management plans.	1	4	FWE	AL,KY,MS TN,TVA, COE,TNC	12.0	-	-	1 person, 4 weeks, 4 States.
1	2.1	Determine optimal light level.	2	4	FWE	KY	3.25	0.75	-	1 person, 3 weeks first year, 1 week following year, $1000 for equipment.
1	2.2	Study effects of nutrient and water addition.	7	4	FWE	KY	4.0	0.75	0.75	1 person, 4 weeks and $1000 for equipment first year. 1 person, 1 week subsequent years.
1	2.3	Control invasive species.	As needed	4	FWE	AL, KY, MS, TN	-	-	-	$6,000 in the future as necessary. 1 person, 2 weeks, 4 States for management and monitoring.
1	2.5	Determine appropriate buffer area.	1	4	FWE	AL, KY, MS, TN	-	-	-	$3,000 in the future after some areas are protected. 1 person, 1 week, 4 States.

IMPLEMENTATION SCHEDULE

PRIORITY #	TASK #	TASK DESCRIPTION	TASK DURATION	RESPONSIBLE PARTY			COST ESTIMATES ($K)			COMMENTS/NOTES *
				USFWS						
				Region	Division	Other	FY 1	FY 2	FY 3	
1	2.6	Monitor populations.	continuous	4	FWE	AL, KY, MS, TN	3.0	3/0	3.0	1 person, 1 week, 4 States.
1	4.2	Study demography.	continuous	4	FWE	AL, KY, MS, TN	6.0	6.0	6.0	1 person, 2 weeks, 4 States.
1	4.3.1	Study pollination biology.	2	4	FWE	KY	2.5	1.5	-	1 person, 2 weeks and $1000 for equipment first year. 1 person, 2 weeks second year.
1	4.3.2	Study vegetative reproduction.	5	4	FWE	KY	2.75	1.5	1.5	1 person, 3 weeks and $500 for equipment the first year. 1 person, 2 weeks subsequent years.
1	4.5	Study seed biology.	3	4	FWE	KY	3.75	0.75	0.75	1 person, 3 weeks and $1500 for equipment the first year. 1 person, 1 week subsequent years.
2	3.1	Search for new populations within known range.	2	4	FWE	AL,IL,KY MS, TN	15.0	15.0	-	1 person, 4 weeks, 5 States, 2 years.
2	4.1.1	Analyze soils.	1	4	FWE	AL, KY, MS, TN	4.0	-	-	1 person, 1 week, 4 States and $1,000 for analysis.
2	4.1.2	Determine rhizobial associates.	1	4	FWE	KY	4.5	-	-	1 person, 4 weeks, $1500 for equipment.
2	4.4	Observe impact of pest damage.	continuous	4	FWE	AL, KY, MS, TN	-	-	-	Funding for this included in long-term demography study.

IMPLEMENTATION SCHEDULE

PRIORITY #	TASK #	TASK DESCRIPTION	TASK DURATION	RESPONSIBLE PARTY			COST ESTIMATES ($K)			COMMENTS/NOTES *
				USFWS						
				Region	Division	Other	FY 1	FY 2	FY 3	
2	4.6	Determine genetic diversity and chromosome numbers.	1	4	FWE	KY	12.5	-	-	1 person, 6 weeks collecting plants, 8 weeks lab work, $2,000 for equipment.
2	5.1	Collect and deposit seeds into seedbank.	1	4	FWE	KY, USDA CPC	0.75	-	-	1 person, 1 week collecting seeds.
2	5.2	Maintain plants et situ.	continuous	4	FWE	CPC	0.4	0.4	0.4	$400 per year to maintain the plants. Funding for collecting seeds is included in 5.1.
3	2.4	Reestablish/establish new populations if necessary.	As needed	4	FWE	AL, KY, MS, TN, CPC	-	-	-	$12,000 in the future if necessary. 1 person, 4 weeks, 4 States for field work and monitoring.
3	3.2	Search for new populations outside of known range.	2	4	FWE	AK, GA, IN, LA, MO, NC, OH, VA, WV	27.0	27.0	-	1 person, 4 weeks, 9 States.
3	6.0	Education efforts.	continuous	4	FWE	AL, KY, MS, TN, CPC	6.0	6.0	6.0	1 person, 2 weeks, 4 States.

IV. APPENDIX

A. Habitat Descriptions of Sites

Below is a description of the habitat and associate species (when available) for all the known Apios priceana sites. The numbering of populations corresponds to Table 1.

1. **Autauga County, Alabama** (Alabama River)

   Habitat: The plants are growing along the banks of the Alabama River in sandy clay mud at the edge of the woods in partial sun.

   Associated Species: Information not available.

2. **Autauga County, Alabama** (Ivy Creek)

   Habitat: This population is found along the edge of Ivy Creek.

   Associated Species: Information not available.

3. **Madison County, Alabama**

   Habitat: Apios priceana is growing in a hardwoods-juniper forest among limestone boulders at the base of Green Mountain (R. Kral, Vanderbilt University, personal communication, 1990).

   Associated Species: Information not available.

4. **Marshall County, Alabama**

   Habitat: This population is at the bottom of a large, limestone sinkhole near the bank of an ephemeral stream in sandy loam soil (J. Bartig, Auburn University, personal communication, 1990). The mesic, deciduous forest at this site was selectively cut in 1974 or 1975 (Medley 1980).

   Associated Species:

   Woody Species: Acer rubrum, Fagus grandifolia, Fraxinus sp., Hydrangea quercifolia, Liriodendron tulipifera, Lonicera japonica, Magnolia grandiflora, Parthenocissus quinquefolia, Privet sp., Tilia americana, Ulmus serotina, and Vitis sp.

Herbaceous Species: Hydrophyllum canadense, Pilea pumila, Polymnia canadensis var. radiata, Polystichum acrostichoides, Smilax rotundifolia, and Tradescantia sp. (J. Bartig, personal communication, 1990).

5. **Livingston County, Kentucky**

Habitat: This A. priceana site is at the base of a cliff along the Ohio River floodplain in woods dominated by Acer saccharum. The site is at the edge of an old road on a bouldery limestone talus (Kentucky Natural Heritage Program 1990).

Associated Species:

Woody Species: Acer saccharum, Asimina triloba, Carya cordiformis, Carya laciniosa, Cercis canadensis, Gymnocladus dioicus, Lindera benzoin, Liquidambar styraciflua, Morus alba, Nyssa sylvatica, Quercus alba, Q. rubra, Tilia americana, Toxicodendron radicans, and Ulmus americana.

Herbaceous Species: Amorpha fruticosa, Amphicarpa bracteata, Asplenium platyneuron, Campanula americana, Cassia nictitans, Chasmanthium latifolium, Collinsonia canadensis, Desmodium paniculatum, Dioscorea quaternata, D. villosa, Dryopteris marginalis, Eupatorium purpureum, Elymus virginicus, Lysimachia ciliata, Oxalis sp., Panicum clandestinum, Plantago rugelii, Prunella vulgaris, Smilax herbacea, S. tamnoides, and Solidago canadensis (Medley 1980).

6. **Lyon County, Kentucky**

Habitat: Plants at this site are growing along a brushy roadside beneath a powerline right-of-way. The adjoining woods are dominated by oaks (Kentucky Natural Heritage Program 1990). The soil is a silt loam overlaying a silty clay loam (Humphrey 1981) and the underlying bedrock is Mississippian-age St. Louis and Salem limestones (Weis and Theobald 1964).

Associated Species:

Woody Species: Acer saccharum, Arundinaria gigantea, Carpinus caroliniana, Carya sp., Cornus florida, Fagus grandifolia, Lindera benzoin, Liquidambar styraciflua, Parthenocissus sp., Prunus serotina, Quercus alba, Q. muhlenbergii, Q. rubra, Rhus copallina, R. glabra, Toxicodendron radicans, Rubus allegheniensis, Sassafras albidum, Tilia americana, Ulmus rubra, and Vitis sp.

Herbaceous Species: Agrimonia rostellata, Amphicarpa bracteata, Blephilia hirsuta, Campanula americana, Carex rosea, Cystopteris protrusa, Desmodium paniculatum, Eupatorium purpureum, Galium aparine, G. circaezans, Hypericum punctatum, Laportea canadensis, Panicum boscii, Sanicula canadensis, S. gregaria, Spigelia marilandica, and Verbesina alternifolia (Medley 1980).

7. **Trigg County, Kentucky** (Hematite Lake)

Habitat: This site is along a hiking trail at the base of a wooded, southeast-facing slope with many limestone outcrops; a man-made lake is nearby (Chester and Holt 1990). The soil is a silt loam with a silty clay loam beneath (Humphrey 1981) and the bedrock is Mississippian-age Warsaw Limestone (Weis and Theobald 1964).

Associated Species:

Woody Species: Acer saccharum, Carya ovata, Celtis laevigata, C. occidentalis, Ulmus rubra, Quercus muhlenbergii, Ostrya virginiana, and Symphoricarpos orbiculatus.

Herbaceous Species: Agrimonia rostellata, Amphicarpa bracteata, Hystrix patula, Lobelia inflata, Matelea gonocarpa, Panicum sp., and Solidago rugosa (Chester and Holt 1990).

8. **Trigg County, Kentucky** (Land Between the Lakes)

Habitat: Apios priceana is growing along a roadside adjacent to a mesophytic woods on a southeast-facing slope with many limestone outcrops (Chester and Holt 1990). The soil is a silty clay loam over clay (Humphrey 1981) and the bedrock is Mississippian-age Warsaw Limestone (Rogers 1965).

Associated Species:

Woody Species: Acer saccharum, Carpinus caroliniana, Cercis canadensis, Fraxinus americana, Morus rubra, Ptelea trifoliata, Quercus muhlenbergii, Ulmus rubra, and U. serotina.

Herbaceous Species: Anemone virginiana, Campanula americana, Cimicifuga racemosa, Geum canadense, Lactuca canadensis, Melilotus officinalis, Rudbeckia triloba, and Spigelia marilandica (Chester and Holt 1990).

9. **Clay County, Mississippi**

Habitat: The wooded banks of an intermittent prairie stream are habitat for this population of A. priceana. The soil is a heavy clay alluvium over the Demopolis Formation with a pH ranging from 6.6 to 8.4 (Mississippi Natural Heritage Program 1990).

Associated Species:

Woody Species: Berchemia scandens, Campsis radicans, Carpinus caroliniana, Carya sp., Fraxinus americana, Juniperus virginiana, Lonicera japonica, Parthenocissus quinquefolia, Quercus muhlenbergii, Q. shumardii, Rhamnus caroliniana, Staphylea trifolia, Toxicodendron radicans, and Viburnum rufidulum.

Herbaceous Species: Aster sagittifolius, Brickellia eupatorioides, Campanula americana, Dasystoma macrophylla, Desmodium sp., Elephantopus carolinianus, Passiflora lutea, and Smilax sp. (Mississippi Natural Heritage Program in Medley 1980).

10. **Lee County, Mississippi**

Habitat: This site is a mesic, deciduous forest on a rich, calcareous north-facing bluff overlooking an expanse of the Northeast Prairie Belt. The site is above a creek and near a powerline right-of-way. The soil is a marly clay of the Sumter Series underlain by a marine white chalk deposit. The soil pH ranges from 7.4 to 8.4 (Mississippi Natural Heritage Program 1990).

Associated Species:

Woody Species: Acer rubrum, Berchemia scandens, Carya sp., Cercis canadensis, Cornus florida, C. foemina, Euonymus atropurpureus, Fraxinus americana, F. quadrangulata, Parthenocissus quinquefolia, Quercus michauxii, Q. muhlenbergii, Rhamnus caroliniana, Staphylea trifolia, Toxicodendron radicans, Ulmus rubra, and Vitis sp.

Herbaceous Species: Angelica venenosa, Blephilia ciliata, Campanula americana, Dioscorea villosa, Menispermum canadense, Passiflora lutea, Ruellia strepens, Sanicula gregaria, Smilax sp., and Triosteum angustifolium (Mississippi Natural Heritage Program in Medley 1980).

11. **Oktibbeha County, Mississippi** (Sand Creek Chalk Bluffs)

Habitat: Apios priceana grows on a small floodplain next to a forested bluff at this site. The plants are growing near an intermittent stream and near a powerline (Mississippi Natural Heritage Program 1990).

Associated Species:

Woody Species: Acer floridanum, A. negundo, Aesculus glabra, A. pavia, Berchemia scandens, Bumelia lycioides, Carya myristicaeformis, Celtis laevigata, Cercis canadensis, Cornus drummondii, Fraxinus americana, F. pensylvanica, Ilex decidua, Juniperus virginiana, Liquidambar styraciflua, Liriodendron tulipifera, Populus deltoides, Quercus muhlenbergii, Q. shumardii, Rhamnus caroliniana, Toxicodendron radicans, Ulmus alata, U. americana, U. rubra, Viburnum rufidulum, Vitis aestivalis, and Vitis rotundifolia.

Herbaceous Species: Allium canadense, Anemone virginiana, Campanula americana, Carex blanda, C. cherokeensis, C. oxylepis, Clematis crispa, Dasystoma macrophylla, Geum canadense, Phlox divaricata, Ruellia strepens, Sanicula canadensis, Spigelia marilandica, Vernonia gigantea, and Vicia caroliniana (W. Morris, University of Florida, personal communication, 1991).

12. **Oktibbeha County, Mississippi** (Rock Hill)

Habitat: Plants at this site grow in a mesic, deciduous forest covering a calcareous, north-facing slope above a broad expanse of the Northeast Prairie Belt. The soil is a marly clay of the Sumter Series with a pH ranging from 7.4 to 8.4 (Mississippi Natural Heritage Program 1990).

Associated Species:

Woody Species: Arundinaria gigantea, Callicarpa americana, Carya myristicaeformis, C. sp., Cercis canadensis, Cornus florida, Crataegus sp., Fraxinus americana, F. quadrangulata, Juglans nigra, Juniperus virginiana, Lindera benzoin, Magnolia acuminata, Parthenocissus quinquefolia, Ptelea trifoliata, Quercus michauxii, Q. muhlenbergii, Q. shumardii, Rhamnus caroliniana, Toxicodendron radicans, Viburnum rufidulum, and Vitis rotundifolia.

Herbaceous Species: Actaea pachypoda, Arisaema triphyllum, Asarum canadense, Campanula americana, Cryptotaenia canadensis, Dioscorea villosa, Hexalectris spicata, Lithospermum tuberosum, Menispermum canadense, Panax quinquefolius, Passiflora lutea, Phlox sp., Physalis sp., Polymnia uvedalia, Ruellia strepens, Sanicula gregaria, Silene stellata, Taenidia integerrima, Thaspium sp., Trillium recurvatum, and Viola walteri (Mississippi Natural Heritage Program in Medley 1980).

13. **DeKalb County, Tennessee**

Habitat: This population (two distinct colonies) is growing in clayey soil on a slide area at the base of a southeast-facing slope along a road and near a stream (Tennessee Department of Conservation 1991).

Associated Species: Colony Number 1

Woody Species: Acer negundo, A. saccharum, Aesculus pavia, Ailanthus altissima, Arundinaria gigantea ssp. tecta, Bignonia capreolata, Campsis radicans, Carya cordiformis, Cercis canadensis, Fraxinus sp., Hydrangea arborescens, Juniperus virginiana, Parthenocissus quinquefolia, Platanus occidentalis, Populus deltoides, Prunus serotina, Quercus muhlenbergii, Rhamnus caroliniana, Staphylea trifolia, Toxicodendron radicans, Ulmus rubra, Viburnum rufidulum, and Vitis rotundifolia.

Herbaceous Species: Allium sp., Anemone virginiana, Arisaema dracontium, Asplenium platyneuron, Aster shortii, Blephilia ciliata, Campanula americana, Chasmanthium latifolium, Clematis viorna, Desmodium sp., Diarrhena americana, Dioscorea quaternata, Elymus svensonii, E. villosus, Erysimum capitatum, Galium triflorum, Geum canadense, Hystrix patula, Impatiens capensis, Lactuca sp., Microstegium vimineum, Oxalis grandis, Panicum sp., Penstemon calycosus, Plantago major, Polygonatum biflorum, Polymnia uvedalia, Ruellia strepens, Rumex sp., Salvia lyrata, Saxifraga virginiensis, Silphium asteriscus ssp. trifoliatum, Smilax sp., Solidago spathulata, Tradescantia subaspera, Triosteum sp., Verbena sp., and Woodsia obtusa.

Associated Species: Colony Number 2

Woody Species: Acer negundo, Cercis canadensis, Juniperus virginiana, Platanus occidentalis, Populus deltoides, Quercus muhlenbergii, Rhus typhina, Staphylea trifolia, Ulmus sp., and Vitis sp.

Herbaceous Species: Acalypha sp., Ambrosia trifida, Anemone virginiana, Aster sp., Blephilia ciliata, Campanula americana, Chasmanthium latifolium, Chrysopsis mariana, Clematis viorna, Cocculus carolinus, Hystrix patula, Ipomea pandurata, Polygonatum biflorum, Setaria sp., Silphium asteriscus ssp. trifoliatum, Solidago spathulata, Thaspium pinnatifidum, and Tradescantia subaspera (Tennessee Department of Conservation 1991).

14. **Hickman County, Tennessee** (Dog Creek)

Habitat: At this location, A. priceana grows along the lower, south-facing side of a hill between a creek and a road. The bedrock is limestone (Tennessee Department of Conservation 1991).

Associated Species:

Woody Species: Acer negundo, A. saccharum, Ailanthus sp., Bignonia capreolata, Carpinus caroliniana, Celtis laevigata, Cercis canadensis, Diospyros virginiana, Fagus sp., Fraxinus spp., Gleditsia triacanthos, Hydrangea arborescens, Juglans nigra, Juniperus virginiana, Lindera benzoin, Liriodendron tulipifera, Lonicera japonica, Morus rubra, Ostrya virginiana, Parthenocissus quinquifolia, Platanus occidentalis, Pueraria lobata, Quercus muhlenbergii, Q. velutina, Rhamnus caroliniana, Rhus glabra, Staphylea trifolia, Toxicodendron radicans, Ulmus rubra, Viburnum rufidulum and Vitis sp.

Herbaceous Species: Ambrosia artemisiifolia, Anemone sp., Aralia sp., Arisaema triphyllum, Cirsium sp., Desmodium sp., Dioscorea sp., Galium sp., Hystrix sp., Microstegium sp., Phytolacca americana, Rudbeckia sp., Smilax sp., Solidago sp., Verbascum sp., and Vernonia sp. (Tennessee Department of Conservation 1991).

15. **Hickman County, Tennessee** (Bell Branch)

Habitat: The site is found just above the level of the creek in a young oak-hickory forest. The understory is sparse and the habitat is dry relative to other sites for the species (Tennessee Department of Conservation 1991).

Associated Species:

Woody Species: Acer sp., Carya sp., Quercus sp., and Ulmus sp. (Tennessee Department of Conservation 1991).

16. **Hickman County, Tennessee** (Briggs Chapel Hollow)

Habitat: The plants are found along a hillside in a mixed mesophytic forest with a well-developed understory. This is a lush and moist site with large limestone rock outcrops (Tennessee Department of Conservation 1991).

Associated Species: No information is available.

17. **Hickman County, Tennessee** (Defeated Creek)

Habitat: The plants are growing on a wet hillside. The surrounding forest is mixed mesophytic growing over a limestone bedrock (Tennessee Department of Conservation 1991).

Associated Species: No information is available.

18. **Hickman County, Tennessee** (East Fork Defeated Creek)

Habitat: The plants are found in a mixed mesophytic forest. The site is relatively dry with limestone outcrops scattered throughout (Tennessee Department of Conservation 1991).

Associated Species: No information is available.

19. **Hickman County, Tennessee** (Duck River Mile 47)

Habitat: This population is found in a wet area along a very steep hillside/limestone cliff area (Tennessee Department of Conservation 1991).

Associated Species:

Woody Species: Acer sp., Fraxinus sp., Juniperus sp., Pinus sp., and Quercus sp. (Tennessee Department of Conservation 1991).

20. **Marion County, Tennessee**

Habitat: This site is located on the lower and middle portion of an east-facing slope with limestone bedrock. The lower slope is an early successional western mesophytic forest and the upper slope is an oak-hickory forest. The site is along a road and near a creek (Tennessee Department of Conservation 1991).

Associated Species: Lower Slope

Woody Species: Ailanthus altissima, Arundinaria gigantea, Campsis radicans, Cercis canadensis, Fraxinus americana, Hydrangea arborescens, Liquidambar styraciflua, Liriodendron tulipifera, Lonicera japonica, Magnolia acuminata, Magnolia macrophylla, Quercus alba, Q. rubra, Rhus typhina, Rubus sp., Sambucus canadensis, Tilia americana, Toxicodendron radicans, and Ulmus rubra.

Herbaceous Species: Ambrosia artemisiifolia, Ambrosia trifida, Aster shortii, Campanula americana, Daucus carota, Festuca arundinacea, F. ovina, Helianthus sp., Hypericum sp., Impatiens capensis, Phytolacca americana, Plantago major, Rudbeckia sp., Verbascum thapsus, and Verbesina sp.

Associated Species: Upper Slope

Woody Species: Acer saccharum, Aesculus flava, Bignonia capreolata, Callicarpa americana, Calycanthus floridus, Carya cordiformis, C. tomentosa, Cornus florida, Corylus americana, Fagus grandifolia, Juglans nigra, Nyssa sylvatica, Ostrya virginiana, Parthenocissus quinquefolia, Prunus sp., Robinia pseudoacacia, Smilax rotundifolia, Staphylea trifolia, Quercus montana, Sassafras albidum, and Vitis rotundifolia.

Herbaceous Species: Anemone virginiana, Aralia nudicaulis, A. racemosa, Asplenium platyneuron, Asplenium rhizophyllum, Aureolaria virginica, Bromus purgans, Cacalia atriplicifolia, Chimaphila sp., Collinsonia canadensis, Desmodium rotundifolium, D. sp., Eupatorium rugosum, E. sp., Galium sp., Geranium maculatum, Geum canadense, Hepatica nobilis var. acuta, Hexastylis sp., Hystrix patula, Ipomea pandurata, Lactuca sp., Lindera benzoin, Monarda sp., Oxalis grandis, Panicum boscii, Pedicularis canadensis, Phryma leptostachya, Polygonatum biflorum, Polymnia canadensis, Polystichum acrostichoides, Pycnanthemum incanum, Ruellia sp., Sanicula sp., Saxifraga virginiensis, Scutellaria sp., Silphium asteriscus spp. trifoliatum, Smilacina racemosa, Solidago curtisii, Spigelia marilandica, and Vicia sp. (Tennessee Department of Conservation 1991).

21. **Maury County, Tennessee**

Habitat: Apios priceana is growing on an open, wet slide area of the lower portion of an east-facing slope. The site is on a roadside next to a small creek. The bedrock is Ordovician-age limestone of the Fernvale Formation and Silurian-age limestone of the Brassfield Formation (Tennessee Department of Conservation 1991).

Associated Species:

Woody Species: Acer negundo, A. saccharum, Aesculus sp., Asimina triloba, Bignonia capreolata, Carya cordiformis, C. ovata, Celtis sp., Cercis canadensis, Cornus florida, Crataegus sp., Euonymus americanus, E. atropurpureus, Fagus grandifolia, Fraxinus sp., Gleditsia triacanthos, Hydrangea arborescens, Juglans nigra, Lindera benzoin, Liriodendron

tulipifera, Morus rubra, Ostrya virginiana, Parthenocissus quinquefolia, Prunus serotina, Quercus alba, Q. muhlenbergii, Q. rubra, Rhamnus caroliniana, Rhus glabra, Sassafras albidum, Toxicodendron radicans, Ulmus rubra, Viburnum rufidulum, and Vitis sp.

Herbaceous Species: Ambrosia artemisiifolia, Anemone virginiana, Aralia spinosa, Arisaema triphyllum, Asarum canadense, Asplenium platyneuron, A. rhizophyllum, Aster pilosus, A. shortii, Aureolaria virginica, Campanula americana, Carex sp., Cirsium sp., Dioscorea villosa, Elephantopus sp., Hystrix patula, Impatiens capensis, Microstegium vimineum, Monarda sp., Panax quinquefolius, Phlox sp., Prenanthes altissima, Pycnanthemum sp., Rudbeckia triloba, Saxifraga virginiensis, Smilacina racemosa, Smilax sp., Solidago sp. and Staphylea trifolia (Tennessee Department of Conservation 1991).

22. **Montgomery County, Tennessee**

Habitat: This population of A. priceana is found in a western mesophytic forest at the base of a steep slope near the junction of two creeks. Some of the plants are in the woods along the creek. The rest of the plants are at the base of the slope near two cave entrances and on a gravelly creek bar. The bedrock in this area is Mississippian-age limestone, either the Warsaw Formation or the St. Louis Formation (Tennessee Department of Conservation 1991).

Associated Species: In the woods, along the creek.

Woody Species: Asimina triloba, Lindera benzoin, and Ostrya virginiana.

Herbaceous Species: Dioscorea quaternata, Eupatorium fistulosum, Uvularia grandiflora, and Viola sororia.

Associated Species: At the base of the slope.

Woody Species: Acer saccharum, Carya sp., Hydrangea arborescens, Juglans cinerea, Liriodendron tulipifera, Prunus serotina, and Staphylea trifolia.

Herbaceous Species: Amphicarpa bracteata, Asarum canadense, Cystopteris protrusa, Dasystoma macrophylla, Dioscorea quaternata, Hybanthus concolor, Hystrix patula, Sanicula sp., Senecio aureus, Smilacina racemosa, Smilax hispida, and Solidago caesia.

Associated Species: On the gravelly creek bar.

Woody Species: Acer saccharum, Cercis canadensis, Clematis virginiana, Crataegus sp., Diospyros virginiana, Fraxinus pennsylvanica, Hydrangea arborescens, Juniperus virginiana, Platanus occidentalis, Quercus muhlenbergii, Symphoricarpos orbiculatus, and Ulmus rubra.

Herbaceous Species: ~~Aster lateriflorus~~, A. ~~shortii~~, Erigeron philadelphicus, and Solidago caesia (Medley 1980).

23. **Williamson County, Tennessee** (Basin Spring)

Habitat: Apios priceana is growing at the edge of a second-growth mesic oak woods, along the side of a road near a stream. Two small subpopulations are growing near a larger main population. The soil is a Lindside silt loam and Phosphatic or Humphrey's silt loam on an eroded 5 to 12 percent slope. The underlying bedrock is Ordovician-age limestone (Tennessee Department of Conservation 1991).

Associated Species: Information not available.

24. **Williamson County, Tennessee** (North Fork Lick Creek)

Habitat: Apios priceana is found on shady and dry limestone outcrops on the lower portion of a north-northeast-facing slope near a road and a creek (Tennessee Department of Conservation 1991).

Associated Species:

Woody Species: Acer saccharum, Aesculus sp., Arundinaria sp., Asimina triloba, Bignonia capreolata, Campsis radicans, Carpinus caroliniana, Carya ovata, Celtis laevigata, C. occidentalis, Cercis canadensis, Cornus sp., Fraxinus spp., Hamamelis virginiana, Hydrangea arborescens, Juglans nigra, Juniperus virginiana, Lindera benzoin, Liriodendron tulipifera, Morus rubra, Ostrya virginiana, Parthenocissus quinquefolia, Plantago sp., Platanus sp., Quercus alba, Q. muhlenbergii, Q. velutina, Rhus sp., Sambucus sp., Sassafras albidum, Staphylea sp., Toxicodendron radicans, Ulmus rubra, Viburnum rufidulum, and Vitis sp.

Herbaceous Species: Adiantum pedatum, Ambrosia artemisiifolia, Campanula americana, Desmodium spp., Galium sp., Heuchera sp., Impatiens capensis, Microstegium sp., Monarda sp., Rubus sp., Rudbeckia sp., Sedum sp., Smilacina sp., Smilax sp., Solidago, sp. and Urtica dioica (Tennessee Department of Conservation 1991).

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