Walker's Manioc
(*Manihot walkerae*)

5-Year Review:
Summary and Evaluation

U.S. Fish and Wildlife Service
Corpus Christi Ecological Services Field Office
Corpus Christi, Texas

5-YEAR REVIEW
Walker's Manioc/*Manihot walkerae* Croizat

1.0 GENERAL INFORMATION

1.1 Reviewers

Lead Regional Office: Southwest (Region 2)
Contact: Wendy Brown, Recovery Coordinator, (505) 248-6664; Brady McGee, Regional Recovery Biologist, (505) 248-6657.

Lead Field Office: Corpus Christi Ecological Services Field Office
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Cooperating Field Office: Austin Ecological Services Field Office
Contact: Chris Best, Texas State Botanist, (512) 490-0057 ext. 225.

1.2 Methodology used to complete the review:

The public notice for this review was published in the Federal Register on April 23, 2007 (72 FR 20134). This review considers both new and previously existing information from Federal and State agencies, non-governmental organizations, academia, and the general public. Information used in the preparation of the review include the recovery plan, section 7 consultations, the Texas Parks and Wildlife Department (TPWD) Natural Diversity Database (NDD), section 6-funded endangered plant surveys in south Texas and in northeast Mexico, monitoring reports, unpublished documents, personal communications from botanists familiar with the species, and Internet web sites. The 5-year review document was prepared by staff in the Austin and Corpus Christi Ecological Services Field Offices without peer review.

1.3 Background:

1.3.1 FR Notice citation announcing initiation of this review:

72 Federal Register 20134 – 20136; April 23, 2007.

1.3.2 Listing history

Original Listing

FR notice: 56 Federal Register, 49850-49853.
Date listed: October 2, 1991
Entity listed: *Manihot walkerae* (Walker's manioc)
Classification: Endangered without Critical Habitat.

1.3.3 Associated rulemakings: n/a

1.3.4. Review History.

No previous 5-year review has been conducted for this species. Other review documents include:

Status Report [Manihot walkerae Croizat], July 15, 1982 (Turner 1982).
Status Summary of *Manihot walkerae,* 1991
Final Recovery Plan 1993

1.3.5 Species' Recovery Priority Number at start of 5-year review:

The species' Recovery Priority Number is 5, meaning there is a high degree of threat, the recovery potential is low, and the listed entity is a species.

1.3.6 Recovery Plan or Outline

Name of plan or outline: Walker's Manioc (*Manihot walkerae*) Recovery Plan
Date issued: December 12, 1993
Dates of previous revisions, if applicable: n/a

2.0 REVIEW ANALYSIS

2.1 Application of the 1996 Distinct Population Segment (DPS) policy.

The Distinct Population Segment policy does not apply to Walker's manioc, because it is not a vertebrate animal.

2.2 Recovery Criteria

2.2.1 Does the species have a final, approved recovery plan?

Yes.

2.2.1.1 Does the recovery plan contain objective, measurable criteria?

Yes.

2.2.2 Adequacy of recovery criteria.

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

No.

2.2.3 List the recovery criteria as they appear in the recovery plan, and discuss how each criterion has or has not been met, citing information:

The Walker's Manioc Recovery Plan (U.S. Fish and Wildlife Service 1993a) did not apply the five listing factors to the recovery criteria (see Section 2.3.2). Of the five factors used to determine whether a species is endangered or threatened as outlined in section 4 (a)(1)(b) of the Endangered Species Act, the factors relevant to conservation of Walker's manioc are: A) present or threatened destruction, modification or curtailment of its habitat or range; C) disease or predation; and D) inadequacy of existing regulatory mechanisms. The existing criteria do not address listing factors C or D.

Recovery Criterion 1. *"Establish or maintain 15 distinct self-sustaining populations of Walker's manioc in the United States. The establishment or maintenance of 15 populations is a target for downlisting. Many of the research tasks in this plan will provide quantitative criteria for delisting and possibly, a revision of the downlisting target of 15 populations. Each population should consist of at least 100 reproductive individuals and have an age class structure reflecting that which exists in the natural population which shows that plants are reproducing and becoming naturally established within the population. It is possible that many mature individuals could be needed to attract pollinators and produce viable seed."*

Discussion. For the purposes of this review, a "site" is a fairly precise geographic location where one or more individuals of the species have been found. A "population" may consist of one or many sites among which gene flow, such as pollination or seed dispersal, may occur. Geographic clusters of interacting populations may be considered "meta-populations," and the geographic area of a meta-population is a "macro-site." Therefore, while individual sites may have too few individuals to meet the criterion of minimally sustainable populations, a group of sites may function as components of a larger, more viable population if their proximity and the continuity of habitat allow for gene flow from site to site. Large expanses of unsuitable habitat, cropland, or urban and residential development may serve as barriers to gene flow. The criterion implies that a population must have 100 or more individuals in order to be self-sustaining. While this number is acceptable for practical purposes, it is not derived from scientific data on the genetics, reproductive biology or population ecology; these investigations have not yet been implemented.

When Walker's manioc was listed in 1991, only one extant site, consisting of a single individual, was known in the U.S. (U.S. Fish and Wildlife Service 1993b). The species had been collected four times in the U.S. between 1853 and 1940, near Rio Grande City, Mission, and La Joya, Texas. Mrs. E. J. Walker, a private citizen of La Joya, Texas, collected specimens near La Joya and Mission in 1940, which she sent to specialists for identification. In 1942, Venezuelan botanist Leon Croizat described Mrs. Walker's plants as a new species, which he named for her. Botanists began propagating the species, using material from Mrs. Walker's specimens, at the University of Texas in Austin, and later at San

Antonio Botanical Gardens. Cyrus Pringle collected a species of *Manihot* in Tamaulipas in 1888 (which he labeled *Jatropha* sp.), which was later determined to be *M. walkerae*. In 1960, Dr. M. C. Johnston discovered two populations in the Loreto sand plain of Tamaulipas (Johnston 1963).

The Texas Natural Diversity Database (2007) lists nine Walker's manioc sites that have been documented in the U.S. since 1990 (Table 1). The number of individuals at each site ranges from a single plant to about 90 plants at two sites. Three of the largest sites are on protected tracts of Lower Rio Grande Valley National Wildlife Refuge (LRGV NWR) (Carr 1995; Best 1996). Pronatura Noreste, a Mexican non-profit conservation organization, recently documented 24 Walker's manioc sites in the Mexican State of Tamaulipas (Contreras Arquieta 2005) (Table 2). Although the discovery of these new sites has not yet fulfilled the criterion of 15 U.S. populations with 100 or more individuals, this has increased the potential to recover the species.

This criterion implicitly addresses listing factor A (present or threatened destruction, modification or curtailment of its habitat or range). Section 4.0 describes recommendations for revised recovery criteria, based on new information on the range, habitat and life history.

Table 1. U.S. Populations of Walker's Manioc.
EO#s are Element Occurrences listed in the Texas Natural Diversity Database (2007).

EO #	1st Obs.	Investigators	Last Obs.	County	Site	Voucher	Population Size and Observations	Citations
n/a	1853	Arthur Schott	Jun 2, 1853	Starr	Ringgold Barracks	NYBG: A.C.V. Schott 52 (Co-type)	Unknown. Exact site not known. First identified as *Manihot carthaginensis*.	
1	May 9, 1990	Philip Clayton	Apr 30, 1992	Hidalgo	Near Peñitas	TEX: Philip Clayton 1014	One individual on private property at edge of dense brush.	Clayton 1990.
2	1940	E. J. Walker	1940	Hidalgo	S of Mission	Arnold, Walker s.n., (Holotype)	Unknown. Along Rio Grande south of Mission.	
3	Nov 12, 1940	V.L. Cory, E.J. Walker	Oct 22, 1941	Hidalgo	La Joya	Tracy: V.L. Cory 36162. TEX: Walker s.n.	Unknown.	
4	July 14, 1940		Jul 14, 1940	Starr	Rio Grande City	Tracy: H.B. Parks RX356	Gravel hills east edge of town.	
5	Jun 23, 1995	T. Patterson & C. Best	Jul 13, 1995	Starr	La Puerta tract, LRGV NWR		48 individuals in Jul 1995.	Carr 1995
6	1995	T. Patterson	Oct 15, 1996	Starr	Chicharra Banco tract, LRGV NWR		80-90 individuals in 1995.	Best 1998.
7	1995	T. Patterson	Jun 2, 2002	Hidalgo	Yturria Brush tract, LRGV NWR		±90 individuals in 1995.	Price 2002, Best 1998.
8	Mar 1997	R. Lonard, D. Dunlap, D. Price, C. Best	Feb 28, 2001	Hidalgo	FM 2221 ROW	TEX: D. Price 150	Up to 20 individuals on Mar 16, 2000	Price and Best, 2000
9	2000	B. Treviño	May 21, 2000	Starr	Sagunada Ranch Rd ROW		Several plants along ROW	Treviño. D. Price. Best 2000.
10	1997	A. Longoria, T. Patterson	Apr 4, 2002	Starr	Private property S of La Sagunada Rd.	TEX: D. Price s.n.	Up to 26 individuals.	Carr 2002. Best 1998.
11	Oct 10, 2002	B. Carr	Oct 10, 2002	Duval	Private land NW of Benavides	TEX: D. Price s.n.	30 individuals.	Carr 2002.
12	1997	C. Davis, T. Patterson, M. Pulich, M. Price, C. Best	Jun 2, 2002	Hidalgo	San Antonio Cemetery, Peñitas		13 individuals on June 2, 2002.	Best 2000, 2002. Price 2002.
n/a	2007	M. Castillo	2007	Starr	Along U.S. 83 near Alto Bonito		Population destroyed for commercial development; several individuals were rescued and are in cultivation at LRGV NWR.	Castillo, pers. com.

Table 2. Mexican Populations of Walker's Manioc.

First Obs.	Last Obs.	Investigator	Municipio	Site	Population Notes	Herbarium	Citations
1888	1998	C.G. Pringle, T. Patterson	Díaz Ordáz (Matamoros)	Caliche escapment at edge of town	Unknown	C.G. Pringle 2243 (GH).	
1960	2005	M.L. Johnston, F. González M., A. Contreras A., T. Patterson, D. Price, C. Best	San Fernando	Loreto Sand Plain macrosite	Contreras lists 17 collection sites at Rancho Loreto and 3 others in the Loreto Sand Plain. Sites 194, 195 and 344 had 49, 24 and 54 individuals respectively.	M.C. Johnston 5363-B (TEX-LL); M.C. Johnston & J. Crutchfield 5572-B (TEX-LL); F. González M. & G. G. Hernández M 17752, 17753, 17840, 17841 (IB-UNAM).	M. Johnston 1963, A. Contreras A. 2005
1993	1994	F. Gonzalez M.	Aldama	Private Ranch	In sandy soil over limestone near edge of cenote		González M. pers. com., C. Best 1994
2003	2005	A. Contreras A.	San Fernando	Hwy San Fernando to Carbonera	Site 317		A. Contreras A. 2005
2003	2005	A. Contreras A.	San Fernando	Benito Juárez	Site 254 (6 individuals on 3 ha).		A. Contreras A. 2005
2003	2005	A. Contreras A.	San Fernando	Puerto Los Ebanos	Site 276		A. Contreras A. 2005
2003	2005	A. Contreras A.	Reynosa	Rancho la Llorona Nueva Rd.	Site 266 (67 individuals).		A. Contreras A. 2005

Recovery Criterion 2. *"Establish agreements for the protection and management of all populations on private lands and incorporate management measures into management plans for populations on public lands."*

Discussion. The three largest U.S. sites (Element Occurrence numbers 5, 6, and 7 in the Texas Natural Diversity Database) were discovered on protected tracts of LRGV NWR by Americorps Member Tom Patterson in 1995 – 1996. Patterson, now a botanist at South Texas College in Rio Grande City, has provided to U.S. Fish and Wildlife Service (USFWS) a wealth of unpublished observations on Walker's manioc populations and ecology in Texas and Tamaulipas. The sites at LRGV NWR were accurately mapped and inventoried with a differentially-corrected global positioning system (d-GPS) by refuge personnel in 1995-1996. These sites are qualitatively monitored at least annually, but have not been quantitatively inventoried since 1996 (Best 2008).

In 1997, Dr. Robert Lonard of the University of Texas-Pan American (UT-Pan Am) discovered a cluster of Walker's manioc plants along the State-owned FM 2221 right-of-way (ROW) north of La Joya, in Hidalgo County. Subsequent monitoring detected up to 20 individuals at that site (Texas Natural Diversity Database 2007). Texas Department of Transportation (TXDOT) has designated a no-mowing zone to protect these plants (Velma Garcia 1997, pers. com.; Texas Department of Transportation 1998). While officially protected, the site remains vulnerable due to its small size and unrestricted access.

Also in 1997, Arturo Longoria, a biologist from McAllen, Texas, discovered a Walker's manioc site while surveying private property in Starr County south of La Sagunada Ranch Road. This site was subsequently surveyed by Bill Carr of The Nature Conservancy (TNC) (Carr 2002a). In 2001, Benito Treviño, a botanist from Rio Grande City, Texas, observed 26 Walker's manioc at that site. The landowner has signed a conservation agreement with TPWD allowing continued monitoring of the population (Price et. al. 2006.); the site was last surveyed in 2002.

From 2002 to 2006, two section 6-funded projects documented 205 new sites for federally-listed and other rare plant species on private lands in south Texas. These projects succeeded in establishing 20 private landowner Voluntary Conservation Agreements (VCA) that protect about 60,000 acres at 116 sites for 16 rare plant species. Although five of these species were federally-listed endangered plants, only one VCA included Walker's manioc (the site mentioned above, south of La Sagunada Ranch Road) (Price et. al. 2006, Janssen et. al. 2007). The VCAs have a duration of 10 years, and contain these provisions: the landowner agrees to leave rare plant populations in a natural state; the landowner will avoid mechanical or chemical disturbances to the populations; if the sites are grazed, the landowner will employ appropriate stocking rates; botanists from TPWD and TNC may access the sites at least once per year, with landowner permission, to monitor populations; population data may be shared with other agencies; the agreement may be revised or terminated by any party at any time.

In Mexico, Pronatura Noreste A.C., a non-profit conservation organization based in Monterrey, Nuevo León, negotiated two landowner conservation agreements to protect two populations in the state of Tamaulipas (discussed in more detail in Section 2.3.1.2). These include 17 sites on the privately-owned Rancho Loreto, in the Loreto sand plain, and Ejido Vicente Guerrero, located in the *municipio* of Reynosa, where 67 Walker's manioc plants were found (Contreras Arquieta 2005). Mexican *municipios* are roughly equivalent to U.S. counties; *ejidos* are communally-owned agricultural cooperatives in Mexico.

In summary, three viable Walker's manioc populations occur on protected tracts of LRGV NWR. One small site is managed by TXDOT along a state highway ROW. A landowner conservation agreement has been signed to protect one small site on private land in Texas. Two landowner conservation agreements have been signed to protect populations in Tamaulipas. Significant progress has been made to discover and locate new populations on both public and private lands in the U.S. and Mexico. However, the criterion as written states "Establish agreements for the protection and management of all populations on private lands..." Botanists from USFWS or other conservation organizations have no legal authority to search for endangered plants on private lands without landowner permission. Therefore, we cannot know how many undiscovered populations might exist on private lands, nor could we require private landowners to enter into agreements for the protection and management of such populations. This criterion is easily misinterpreted, and is likely to discourage private landowners from entering into voluntary conservation agreements with USFWS or other conservation organizations. Therefore, the criterion should be revised.

Recovery Criterion 3. *"Develop an ongoing monitoring program to include assessment of general conditions, number of individuals, age and size class, and reproductive success (seedling recruitment and establishment)."*

The surveys described under criteria 1 and 2 have yielded much new information about the habitat requirements and existing populations of Walker's manioc since the recovery plan was established in 1993. Additionally, valuable information has been generated by propagation studies conducted at San Antonio Botanical Garden and LRGV NWR. This new information is discussed in Section 2.3. However, no scientific investigations have been published on the population dynamics or reproductive biology to date. Therefore, significant progress has been made, but the criterion has not been met.

2.3 Updated Information and Current Species Status

2.3.1 Biology and Habitat

2.3.1.1 New information on the species' biology and life history:

Peer-reviewed scientific investigations have not been published on the biology or life history of Walker's manioc. Nevertheless, propagation efforts conducted at San Antonio Botanical Garden (SABG) and LRGV NWR have provided valuable

information. The species is self-fertile, and does not appear to require a rare or specialized pollinator (Best 2008). The fruit capsules contain up to three seeds, which are dispersed a distance of several meters by the spontaneous, violent dehiscence (rupturing) of the capsules upon drying, which impedes seed collection (Best 2008). Francisco González Medrano, a botanist at the *Universidad Nacional Autónoma de México* (UNAM), successfully collected seeds by affixing fine nylon mesh around the maturing capsules with light-gauge wire (Best 1994). Seeds may remain dormant for a year or more, but germination can be induced by exposure to heat and moisture (Simpson 1995), or gibberellic acid (a naturally occurring plant hormone) (Best 2008). Under ambient conditions in the soil, seeds may begin germinating in as little as nine months (Best 2008). Ants are attracted to the seed caruncle (a specialized seed appendage of many plants in the Euphorbiaceae family) and are involved in seed dispersal (Best 2008). Walker's manioc plants begin producing tubers when less than one year old (Best 2008). Individual plants have produced up to 20 rounded tubers 2 to 3 inches (5 to 7.5 cm) in diameter, after about 3 years' growth (Best 2008). This demonstrates that the species perenniates in the wild through both seeds and tubers (Best 2008).

2.3.1.2 Abundance, population trends (e.g. increasing, decreasing, stable), demographic features (e.g., age structure, sex ratio, family size, birth rate, age at mortality, mortality rate, etc.), or demographic trends:

After the Walker's Manioc Recovery Plan was published in 1993, extensive surveys documented nine Walker's manioc sites in Texas (including the single plant discovered by USFWS botanist Phil Clayton in 1990) and 25 sites in Tamaulipas.

United States Populations

Three sites on LRGV NWR, consisting of up to 90 individuals each, may be large enough to be considered viable populations. Five additional sites found in Texas have as many as 30 individuals. Four of these are on private lands and one site is along a TXDOT highway ROW. In addition to the sites mentioned in Section 2.2.3, in 1997, Christy Davis, a member of the Native Plant Project from Mission, Texas, reported Walker's manioc plants at San Antonio Cemetery in Peñitas, Hidalgo County. TPWD botanist Dr. Dana Price observed 13 individuals there on June 2, 2002 (Texas Natural Diversity Database 2007). These plants were inadvertently treated with glyphosate herbicide during routine maintenance operations (Best 2008). This population has recovered (Patterson 2008, pers. com.), indicating that the herbicide did not kill the perennial tubers of these plants. The Nature Conservancy staff found 30 Walker's manioc plants in 2002 while surveying private property in Duval County, northwest of Benavides (Carr 2002b). In 2006, a consultant reported two Walker's manioc plants from a different location in Duval County, between Benavides and Rosita, on the privately-owned site of a proposed Uranium mine (Scheinost 2008, pers. com). These Duval County records represent the northernmost known populations of the species.

By themselves, these smaller sites probably do not constitute viable populations, but some may function as components of yet undiscovered viable populations occurring on adjacent private lands. Access for continued surveys on private lands and the negotiation of landowner conservation agreements are subject to the approval of conservation-minded private landowners.

The most recent new discovery of Walker's manioc was in 2007 at a site near Alto Bonito, in Starr County, that was being cleared for development. Although this population was destroyed, the landowner allowed volunteers to rescue seven individuals that are now being propagated by USFWS personnel (Castillo 2008, pers. com.).

Mexico Populations

In 1992, the U.S. Fish and Wildlife Service Cooperative Program for Mexico supported a survey of endangered plants in Tamaulipas, which botanist Francisco González Medrano (UNAM) implemented from 1992 – 1994. In 1993, USFWS also established a Cooperative Agreement with González Medrano and UNAM to study seed germination, pollination, and threats to Walker's manioc populations in Tamaulipas (U.S. Fish and Wildlife Service 1993a; González Medrano 1993, pers. com.). Unfortunately, USFWS has not located the final reports from these projects. Nevertheless, we learned a great deal through our communications and site visits with González Medrano (who has often been incorrectly cited as Francisco Medrano in English-language publications). González Medrano located two Walker's manioc sites on *ejido* land in the Loreto sand plain of Tamaulipas. These sites were observed by two USFWS personnel (Angela Brooks and Chris Best) during site visits in 1993 and 1994 (Brooks 1993, pers. com.; Best 1994). González Medrano also discovered a population in shallow sandy soil over limestone near the edge of a *cenote* (karst sinkhole) on a private ranch near Aldama, Tamaulipas. We have not found documentation of the exact location of the Aldama population, and to our knowledge, no botanists have visited this site since 1994. This intriguing report represents the southernmost population known, and the only one found over a limestone rather than caliche substrate.

Pronatura Noreste conducted a section 6-funded study of U.S.-listed endangered plants in northeast Mexico from 2003 – 2005. The principal investigator, Alberto Contreras Arquieta, documented 24 extant sites for Walker's manioc in Tamaulipas, which he meticulously surveyed and mapped with GPS. He found several hundred Walker's manioc plants at 17 sites on the 61,775 ac (25,000 ha) Rancho Loreto, a privately-owned cattle ranch (Contreras Arquieta 2005). Dr. Marshall Johnston documented Walker's manioc and many other plant species of concern at Rancho Loreto in 1960 (Johnston 1963), but these populations had not been monitored since then. The manioc sites are all situated in cattle pastures which are managed with a high intensity, low frequency grazing system. This ranch grazes about 1,600 head of cattle on 40,000 ac (16,000 ha) of caliche sand prairies. The cattle are frequently moved through about 64 separate pastures

centered around eight windmills. Although shrub vegetation continues to encroach on the sand prairies, Rancho Loreto supports the largest and most intact habitat known for Walker's manioc (Best 2005). Pronatura Noreste is currently working with the landowner to conduct prescribed burning trials, which may benefit the rare plant populations as well as the sustained grazing productivity of the pastures. Contreras Arquieta documented three additional sites on *ejido* land in the Loreto sand plain, which may correspond to the sites found by González Medrano in 1994, and four additional sites in scattered locations in the *municipios* of Reynosa and San Fernando. The San Fernando sites have relatively few individuals, but some may also serve as components of larger populations on adjacent lands. Following the completion of this investigation, Contreras Arquieta discovered four or five new sites in Tamaulipas, all of which have very few plants and are threatened by development (Contreras Arquieta 2008, pers. com.). The Aldama site has not been mapped or surveyed since it was reported by González Medrano in 1994.

2.3.1.3 Genetics, genetic variation, or trends in genetic variation (e.g., loss of genetic variation, genetic drift, inbreeding, etc.):

The genetics, reproduction, and population dynamics of Walker's manioc have not been formally investigated.

2.3.1.4 Taxonomic classification or changes in nomenclature:

Leon Croizat (1942) described Walker's manioc as a distinct species. Rogers and Appan (1973) place it within section *Parvibracteatae* of the genus *Manihot*. Its closest relative may be *M. subspicata*, another rare plant of south Texas and northeast Mexico found on caliche or rocky limestone substrates. Tom Patterson observed that the ranges of these two species overlap in the Loreto sand plain of Tamaulipas (Patterson 2008, pers. com.).

2.3.1.5 Spatial distribution, trends in spatial distribution (e.g. increasingly fragmented, increased numbers of corridors, etc.), or historic range (e.g. corrections to the historical range, change in distribution of the species' within its historic range, etc.):

All known Walker's manioc populations, with one exception, occur in close association with exposed outcrops of caliche pertaining to the Goliad geological formation; Gonzalez Medrano reported a single population from Aldama, Tamaulipas, in shallow sandy soil overlying limestone. "Caliche" is a word of Spanish origin, which in various regions indicates a variety of whitish mineral deposits. With regard to geology of the Tamaulipan ecological region, caliche refers specifically to strata of calcium carbonate that have precipitated from the soil solution through evaporation (Spearing 1998); in contrast, limestone consists of calcium carbonate strata that formed through marine deposition. This specific type of caliche forms in warm arid and semi-arid regions where evapo-transpiration (depletion of soil moisture through evaporation and absorption by

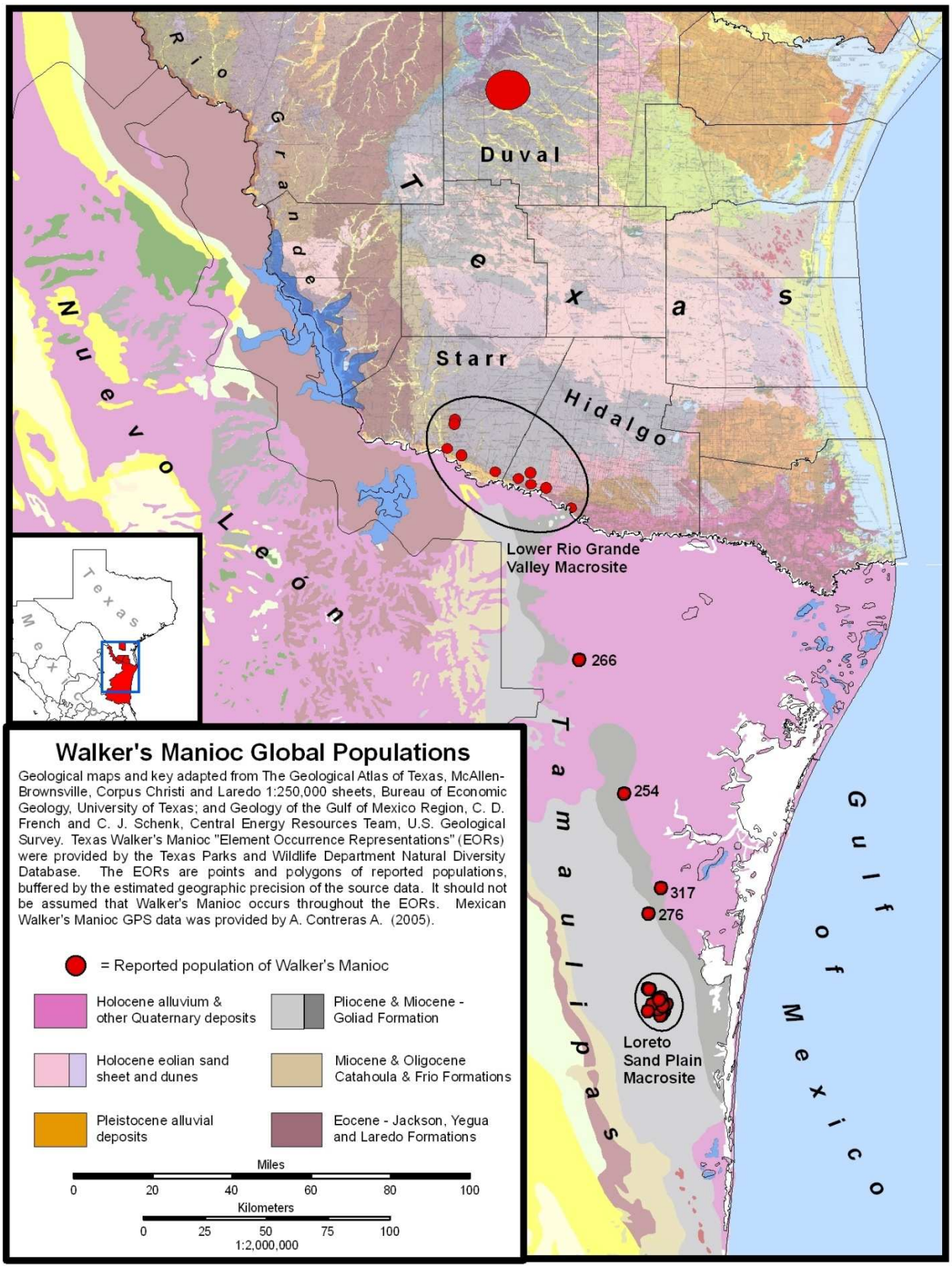
plants) exceeds annual precipitation. Caliche may be indurated (rock-like) or soft and powdery.

The Goliad formation dates to the Miocene or Pliocene epochs (Bureau of Economic Geology 1975 - 1976). It occurs in a broad arc along an ancient coastline parallel to the modern Gulf of Mexico (Figure 1). The Goliad formation extends near Victoria, Texas, southward though south Texas and northeast Tamaulipas, where it reaches the Gulf just north of La Pesca. Exposed caliche outcrops occur in discontinuous locations along this formation.

Walker's manioc plants occupy only a small portion of the upland vegetation of the Goliad geological formation, in shallow, calcareous sandy soil overlying indurated caliche. The soil depth is often 12 in (30 cm) or less. Botanists have learned to focus search efforts where indurated caliche is exposed at the soil surface. Occupied habitats are often less than 1 ac (0.4 ha) in size. These areas may be narrow fringes adjacent to slopes, where caliche strata are very close to the surface, or centered around caliche outcrops on level ground. Populations may consist of widely-spaced individual plants along bands of shallow soil, or small clusters of a few dozen individuals.

Cyrus Pringle collected Walker's manioc (labeled as *Jatropha sp*.) in 1888 during a trip from Camargo to Matamoros, Tamaulipas. This collection has been traditionally attributed to a Matamoros locality. However, Tom Patterson (2008, pers. com.) has provided convincing evidence, based on Pringle's specimen numbers and field notes (Davis 1936), that Pringle actually collected Walker's manioc near the present-day town of Díaz Ordáz, which was then known as San Miguel.

Figure 1. Global Range of Walker's Manioc Populations.



2.3.1.6 Habitat or ecosystem conditions (e.g., amount, distribution, and suitability of the habitat or ecosystem):

Johnston (1963), Best (1995, 2005), and Poole et al. (2007) have described plant species found in close association with Walker's manioc. These include short native grasses and herbaceous plants, and low shrubs and sub-shrubs. Typical grass associates include purple threeawn (*Aristida purpurea*), slender grama (*Bouteloua repens* and *B. radicosa*), hairy grama (*B. hirsuta*), Texas grama (*B. rigidiseta*), red grama (*B. trifida*), gummy lovegrass (*Eragrostis curtipedicellata*), filly Panicum (*Panicum hallii* var. *filipes*), slim Tridens (*Tridens muticus*), and Texas Tridens (*T. texanus*). Broadleaf herbaceous plants at these sites include blackfoot daisy (*Melampodium cinereum*), awnless bush sunflower (*Simsia calva*), cardinal feather (*Acalypha radians*), flor de San Juan (*Macrosiphonia lanuginosa* var. *macrosiphon*), *Dyssodia tenuiloba*, *D. pentachaeta,* and several prostrate species of *Chamaesyce*. Typical sub-shrubs include sangre de drago (*Jatropha dioica*), orange Zexmenia (*Wedelia texana*), skeleton-leaf goldeneye (*Viguiera stenoloba*), *Calliandra conferta*, calderona (*Krameria ramosissima*), damiana (*Turnera diffusa*), wild oregano (*Lippia graveolens*), and hierba del soldado (*Waltheria indica*). Larger shrubs present here include coyotillo (*Karwinskia humboldtiana*), colima (*Zanthoxylum fagara*), cenizo (*Leucophyllum frutescens*), guayacán (*Guaiacum angustifolium*), anacahuita (*Cordia boissieri*), blackbrush (*Acacia rigidula*), guajillo (*Acacia berlandieri*), elbowbush (*Forestiera angustifolia*), brasil (*Condalia hookeri*), Mexican fiddlewood (*Citharexylum brachyanthum*), and coma (*Sideroxylon celastrinum*). These shrubs tend to increase as a result of poor grazing management, and may dominate the sites. Honey mesquite (*Prosopis glandulosa* var. *glandulosa*) may also be present as a low shrub. Walker's manioc is usually not found where the soil is deep enough to support larger mesquite trees. In addition to Walker's manioc, many rare plants are associated with caliche outcrops, such as south Texas rushpea (*Caesalpinia phyllanthoides*), Runyon's huaco (*Manfreda longiflora*), *Euphorbia johnstonii*, Runyon's cory-cactus (*Coryphantha macromeris* var. *runyonii*), Chihuahua balloonvine (*Cardiospermum dissectum*), and prostrate milkweed (*Asclepias prostrata*).

Many of the known populations of Walker's manioc occur on current or former cattle ranches. Cattle grazing does not appear to adversely affect the species, and may help to reduce competition from buffelgrass or other highly-competitive introduced grasses. However, increasing shrub density has altered much of the native grassland and savanna habitats of south Texas and northeast Mexico since the beginning of Spanish colonization in the mid-eighteenth century (Berlandier 1850, 1980; Mier y Terán 2000; McClintock 1930; Clover 1937; Inglis 1961; Best 2004). This conversion to dense shrubland may have been influenced by periods of intense sheep grazing in the nineteenth century (Lehman 1969), fencing of rangeland (Bogusch 1952), and cessation of wildfire (Johnston 1963). Archer et. al. (1988) documented the conversion of south Texas grassland to shrubland during several decades of grazing, which they attributed largely to the scarification and dissemination of honey mesquite seeds by cattle. Prescribed burning has been promoted to limit shrub increase and improve forage production

of south Texas rangelands (Texas Agricultural Extension Service 1980; Scifres and Hamilton 1993). Many tropical species of *Manihot* are believed to benefit from periodic disturbance, such as fire, and this may also be true for Walker's manioc. Consequently, improved rangeland management may be very compatible with conservation and management of habitat for this endangered plant species.

The single plant found by Philip Clayton in 1990 (U.S. Fish and Wildlife Service 1990a and 1990b, Clayton 1990) occurred along the edge of an unpaved road on private land near Peñitas, Texas, bordered by a small patch of intact forest dominated by Texas ebony (*Chloroleucon ebano*), anacua (*Ehretia anacua*), and honey mesquite. This led to an erroneous assumption that this more mesic (relatively moist) habitat was suitable for the species. However, thorough surveying of the site, and similar vegetation, did not detect any other manioc plants. In retrospect, it is not unusual to find upland plants along the margins of roads that have been surfaced with caliche. It is possible that tubers or seeds of Walker's manioc were transported to this atypical site with a load of caliche for road surfacing.

Francisco González Medrano discovered an unusual site at Ejido Morales, in the Loreto sand plain of Tamaulipas, where several dozen Walker's manioc plants were growing in a small cultivated maize field (Best 1994). González Medrano learned that members of the *ejido* had first cleared the site a few years before, and had not used herbicides there. The manioc plants had sprouted from fragments of tubers that were apparently spread by farm equipment. The field was adjacent to an area of exposed caliche, the likely source of the tubers. It is unlikely that the species would persist very long as an agricultural weed; this phenomenon has not been observed elsewhere.

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

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

The primary threats to Walker's manioc are habitat loss and competition from invasive grasses. Although the caliche outcrops where the species occurs are not conducive to production of row crops, extensive surface mining of caliche supplies much of the base material for highways, unpaved roads, well-drilling pads, and parking lots throughout the region. Surface mining of caliche is therefore a major threat to species, such as Walker's manioc, that are endemic to exposed caliche outcrops.

Urban and residential development continues at a rapid pace throughout the border region of south Texas and northern Mexico. The human populations of Starr and Hidalgo Counties are projected to grow 67% and 88%, respectively, between 2000 and 2025 (Texas State Data Center 2008). Habitat loss is likely to continue both through development of sites as well as increased surface mining of caliche for construction of roads and parking lots.

Intensive energy exploration continues throughout the entire range of Walker's manioc in south Texas and northeast Mexico. Under Texas and Mexican law, mineral rights owners take precedence over surface owners. Seismic exploration, pipelines, oil and gas wells, and access roads have proliferated on private lands as well as tracts of LRGV NWR, incrementally augmenting the loss of potential habitat of this and other listed plant and animal species. Habitats and populations at LRGV NWR are potentially vulnerable to impacts from oil and gas exploration, since USFWS does not own the mineral rights pertaining to most of the refuge's tracts.

Many species of Old World grasses have been introduced in the Tamaulipan region of south Texas and northeast Mexico for cattle forage and erosion control, including several that are now highly invasive (Best, in press). The "common variety" of buffelgrass (*Pennisetum ciliare*) was derived from a single apomictic individual from northern Kenya (Holt 1985). Common buffelgrass was introduced in south Texas beginning in 1946 and is now abundant from Texas and Tamaulipas to Arizona and Sonora. Buffelgrass is well adapted to the well-drained calcareous soils where Walker's manioc occurs. This forage grass is typically established by root-plowing sites with powerful tracked vehicles, then broadcasting the seed in the disturbed soil. A large amount of potentially suitable habitat for Walker's manioc has been converted to root-plowed buffelgrass pasture. Buffelgrass often increases following soil disturbance, allowing it to spread rapidly along road, powerline, and pipeline rights-of-way. It is present at most Walker's manioc sites, frequently dominating the herbaceous vegetation and suppressing most native species including Walker's manioc. In the Loreto sand plain another introduced grass, pitted bluestem (*Bothriochloa pertusa*), may also compete with Walker's manioc (Best 2005).

2.3.2.2 Overutilization for commercial, recreational, scientific, or educational purposes:

Wild populations of Walker's manioc have not been utilized for commercial, recreational, scientific, or education purposes. A closely related plant, cassava (*Manihot esculenta*), is an important staple crop throughout the tropics. Walker's manioc may serve as a source of genetic material for the development of improved cassava cultivars (U.S. Fish and Wildlife Service 1990b, 1993a). The storage life of edible cassava roots is significantly diminished by post-harvest physiological deterioration (PPD). Researchers created an inter-specific hybrid between cassava and propagated specimens of a Mexican collection of *M. walkerae* which is the only known source of resistance to PPD (Centro Internacional de Agricultura Tropical 2005; Cuambe 2007). This research has not directly affected wild populations, since the source material came from cultivated plants. However, if the inter-specific hybrid or cultivars derived from it are able to back-cross with wild plants, this could threaten wild populations through genetic swamping.

2.3.2.3 Disease or predation:

In September 2003, Tom Patterson reported an incidence of digging in the exact locations of Walker's manioc plants on three tracts of LRGV NWR (Patterson 2003, pers. com.). These plants had been precisely mapped with GPS, and had been identified with numbered aluminum tags. A refuge law enforcement officer (who is a skilled tracker) and the plant ecologist investigated these sites. They determined that the digging had not been done by humans and identified numerous tracks of javelina (collared peckary) at these sites. Javelina feed heavily on plant seeds and tubers (Leopold 1972). The refuge staff observed that some partially-eaten tuber fragments had sprouted new roots and shoots (Best 2008). Feral hogs are abundant in the region, and may also constitute a serious threat to Walker's manioc populations (Patterson 2008, pers. com.). Patterson also observed rabbits consuming the stems and leaves of Walker's manioc (Patterson 1996, pers. com.).

2.3.2.4 Inadequacy of existing regulatory mechanisms:

Federally-listed plants occurring on private lands have very limited protection under the Endangered Species Act (ESA), unless also protected by State laws; the State of Texas provides very little protection to listed plant species on private lands. Therefore, most known sites of Walker's manioc are not protected under existing laws.

Chapter 88 of the Texas Parks and Wildlife Code lists plant species as State-threatened or endangered once they are federally-listed with these statuses. Therefore, Walker's manioc is listed as endangered by the State of Texas. The State prohibits taking and/or possession for commercial sale of all or any part of an endangered, threatened, or protected plant from public land. TPWD requires commercial permits for the commercial use of listed plants collected from private land. Scientific permits are required for collection of endangered plants or plant parts from public lands for scientific or education purposes. In addition to State endangered species regulations, other State laws may apply. State law prohibits the destruction or removal of any plant species from State lands without a TPWD permit.

The Endangered Species Act (ESA) does provide some protection for listed plants on land under Federal jurisdiction (including National Wildlife Refuges) or where Federal funding and projects are involved. The Department of Homeland Security's (DHS) Secure Border Initiative calls for construction of 225 miles of pedestrian barriers along the Texas – Mexico border, in addition to surveillance towers and other infrastructure (U.S. Department of Homeland Security 2008). Some of these proposed projects could affect populations and habitat of Walker's manioc and other endangered plants and animals, both on and off the refuge. The Department of Homeland Security, under authority of the Real ID Act of 2005 (Section 102 of H.R. 1268), waived consultation with USFWS required under section 7 of the Endangered Species Act. However, DHS and USFWS jointly prepared a Biological Resource Plan as part of the DHS Environmental

Stewardship Plan. The DHS proposed the following best management practices for Walker's manioc along the proposed fence segments in both Starr and Hidalgo Counties: 1) surveys will be conducted in the impact corridor on all intact habitat before beginning any construction activities; 2) invasive plants will be controlled to deter colonization of un-infested native habitat following disturbance; 3) if Walker's manioc plants are found within the impact corridor, permanent impacts to individual populations and habitats will be minimized; 4) the duration of impacts to populations and habitats will be minimized; and 5) where vegetation must be temporarily removed, plants will be cut above ground level rather than cleared with bulldozers, root plows, or other soil-disturbing implements. Since pre-project surveys did not detect Walker's manioc plants within the impact corridor, DHS determined that their activities were "not likely to adversely affect" the species in Starr and Hidalgo counties.

Approximately half of the range of Walker's manioc occurs in Mexico. However, this species is not protected under Mexican protected species regulations (Secretaría del Medio Ambiente y Recursos Naturales 2008).

2.3.2.5 Other natural or manmade factors affecting its continued existence:

According to the Intergovernmental Panel on Climate Change (IPCC) (2007) "Warming of the climate system is unequivocal, as is now evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice, and rising global average sea level." Average Northern Hemisphere temperatures during the second half of the 20th century were very likely higher than during any other 50-year period in the last 500 years and likely the highest in at least the past 1300 years (IPCC 2007). It is very likely that over the past 50 years cold days, cold nights and frosts have become less frequent over most land areas, and hot days and hot nights have become more frequent (IPCC 2007). It is likely that heat waves have become more frequent over most land areas, and the frequency of heavy precipitation events has increased over most areas (IPCC 2007, p. 1).

The IPCC (2007) predicts that changes in the global climate system during the 21st century are very likely to be larger than those observed during the 20th century. For the next two decades a warming of about 0.2°C (0.4°F) per decade is projected (IPCC 2007). Afterwards, temperature projections increasingly depend on specific emission scenarios (IPCC 2007). Various emissions scenarios suggest that by the end of the 21st century, average global temperatures are expected to increase 0.6°C to 4.0°C (1.1°F to 7.2°F) with the greatest warming expected over land (IPCC 2007). Localized projections suggest the southwest may experience the greatest temperature increase of any area in the lower 48 States (IPCC 2007). The IPCC says it is very likely hot extremes, heat waves, and heavy precipitation will increase in frequency (IPCC 2007). There is also high confidence that many semi-arid areas like the western United States will suffer a decrease in water resources due to climate change (IPCC 2007). Milly et al. (2005) project a 10–30 percent decrease in precipitation in mid-latitude western North America by the year 2050 based on an ensemble of 12 climate models.

We do not know whether the climate changes that have already occurred have affected Walker's manioc populations or distribution, nor can we predict how the species will be affected by the type and degree of climate changes forecast by a range of models. The known populations of Walker's manioc are distributed along isolated caliche outcrops in the southern half of the Goliad geological formation, which forms a narrow arc parallel to the Gulf of Mexico extending 350 miles (550 km) north to south. Although the tubers can survive a hard freeze, even light frost kills the stems and leaves of Walker's manioc. Rising temperatures might enable the species to survive further north that at present, but might also reduce the southern limit of the range. However, the discontiguous nature of the populations and potential habitat, the limited seed dispersal range, and the existence of new, anthropogenic barriers to migration, would probably prevent the spontaneous extension of the range.

Some climate change models also predict increased precipitation along the Gulf Coast, largely due to increased tropical storm activity and severity (Twilley et. al. 2001). Since the species now occurs in some of the most xeric of regional habitats, increasing rainfall could reduce its competitive advantage in those marginal sites. Regardless of how changes in temperature and rainfall amounts and patterns may affect the autecology of Walker's manioc, the altered synecology may be far more significant. For example, higher winter temperatures and increased precipitation could augment competition from buffelgrass or other introduced invasive grasses. Conversely, the same changes could expand the range or increase the pathogenicity of *Pyricularia grisea*, a rust fungus that attacks buffelgrass, thereby reducing its invasiveness. The possible effects of climate change on the synecology of Walker's manioc habitat are infinitely complex. Therefore, we will continue to monitor the species and its habitat, and will adapt our recovery and management strategies when necessary to address the changing conditions.

Walker's Manioc Images.

FWS botanist Philip Clayton discovered this Walker's manioc plant near Peñitas, TX in 1990.

Tubers on container-grown seedling of Walker's manioc, LRGV NWR.

Shrub savanna at Rancho Loreto, Tamaulipas, where 17 Walker's manioc sites were found.

Walker's manioc was found in the caliche outcrop in the center of this image, from Ejido Morales, Loreto sand plain of Tamaulipas.

Root plowing operation in Starr County, TX.

Buffelgrass (*Pennisetum ciliare*), an introduced forage grass.

2.4 Synthesis.

Although none of the original three recovery criteria have been met, there has been significant progress toward fulfilling all three. Specifically, we now have a much better understanding of the species' physical requirements, such as geological substrate and soil, associated species and habitat, life history, and geographic range. Botanists have documented Walker's manioc at a total of 33 sites, nine in Texas and 24 in Tamaulipas, Mexico. Three of the largest U.S. populations are on protected tracts of LRGV NWR. Three private landowners have signed voluntary conservation agreements to protect the species, two in Tamaulipas and one in Texas. We also have a greater understanding of the threats, which include surface mining of caliche, competition from buffelgrass, urban and residential development, petroleum and natural gas exploration, and herbivory by native and introduced wildlife. All known sites are subject to one or more of these threats. Because none of the criteria outlined in the recovery plan have been met and there are significant threats that affect the continuing existence of the species, the recommended action is to retain the "endangered" classification. Additional recommendations are listed in Section 4.0.

3.0 RESULTS

3.1 Recommended Classification:

____ **Downlist to Threatened**
____ **Uplist to Endangered**
____ **Delist** (*Indicate reasons for delisting per 50 CFR 424.11):*
    ____ *Extinction*
    ____ *Recovery*
    ____ *Original data for classification in error*
_X_ **No change is needed**

3.2 New Recovery Priority Number: 8C.

Brief Rationale:

Walker's manioc was listed with a recovery priority number of 5. The discovery of new sites reduces the degree of threat from imminent extinction. However, essentially all sites in both Texas and Tamaulipas face significant threats from caliche mining, oil and gas exploration, invasive grass competition, and urban and residential development. Therefore, the degree of threat is moderate. The discovery of new populations and increased knowledge of the species' range, habitat, life history, and propagation contribute to increase the recovery potential to high. The taxonomic status of Walker's manioc as a unique species remains unchanged. This edaphic endemic is found only in close association with outcrops of caliche. Surface mining of caliche, and oil and gas exploration, will continue to impact the remaining habitat. Therefore, the "C" designation indicates potential conflict with economic activity.

4.0 RECOMMENDATIONS FOR FUTURE ACTIONS.

The Walker's Manioc Recovery Plan should be revised to include criteria that incorporate the five-factor analysis (2.3.2) and that take into account new information regarding the species' range, edaphic endemism, habitat, life history, and threats. The revised criteria should identify and seek to remedy gaps in knowledge necessary for effective management and recovery. The criteria must also be achievable and quantifiable. Specific revisions may include, but are not limited to, the following:

- Criterion 1 calls for establishment or maintenance of at least 15 self-sustaining populations of 100 or more individuals. This criterion should be revised using updated methods to describe what constitutes a viable population, and the number and geographic distribution of populations necessary for recovery.
- Criterion 2 requires establishment of "agreements for the protection and management of all populations on private lands..." However, USFWS has no authority to require private landowners to protect endangered plants. Furthermore, because the USFWS cannot survey private lands without the owner's permission, it is not possible to quantify the number of populations requiring protection. The criterion, as currently written, tends to promulgate misinterpretation of the authority of the Endangered Species Act, and might discourage landowners from cooperating with USFWS in the conservation of this species. Finally, successful recovery may be possible without protecting all known sites. This criterion should be revised to establish quantifiable, attainable objectives.
- The plan should have a recovery criterion that addresses seed banking, establishment of refugium populations and reintroduction efforts, all of which serve as safeguards against the unavoidable loss of populations to development, competition from invasive species, or catastrophic events.

The most important recovery actions during the next five years include, but are not limited to, the following:

- Periodic monitoring and surveys of known sites in Texas and Tamaulipas. In particular, a quantitative survey should be conducted at the three sites on LRGV NWR to detect population trends at those sites.
- Additional surveys of potential habitat in Texas and Tamaulipas, focusing on sites with Goliad-formation caliche outcrops that have not previously been surveyed.
- Seed collection for propagation and seed banking, establishment of seed increase plots, and pilot reintroduction projects.
- In-situ investigation of reproductive biology and population dynamics.
- Investigation of the genetic structure of known populations throughout the species range.
- Establish cooperative efforts to promote the conservation of Goliad formation caliche outcrops.
- Promote cooperative efforts with Mexican agencies, scientists, and non-profit conservation organizations to conserve populations in Mexico.
- Conduct public outreach efforts to encourage conservation of the species and its habitat on private lands.
- Determine whether inter-specific hybrids of *M. esculenta* and *M. walkerae*, or cultivars derived from those hybrids, are able to create fertile progeny with wild *M. walkerae*.

To date, a recovery team has not been formally established for Walker's manioc. The South Texas Plant Conservation Alliance (a sub-committee of the Texas Native Plant Conservation Alliance) has proposed the formation of an official recovery team to focus on all listed and candidate plant species in south Texas, including Walker's manioc (Texas Native Plant Conservation Alliance 2008).

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PHOTOGRAPHIC IMAGES

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U.S. FISH AND WILDLIFE SERVICE
5-YEAR REVIEW of *MANIHOT WALKERAE*

Current Classification: Endangered.

Recommendation resulting from the 5-Year Review:

____ Downlist to Threatened
____ Uplist to Endangered
____ Delist
_X_ No change needed

Appropriate Listing/Reclassification Priority Number, if applicable: n/a.

Review Conducted By: Chris Best, Austin Ecological Services Field Office, and Amber Miller and Robyn Cobb, Corpus Christi Ecological Services Field Office.

FIELD OFFICE APPROVAL:

Lead Field Supervisor, U.S. Fish and Wildlife Service

Approve Allan M. Strand Date 05-05-09

REGIONAL OFFICE APPROVAL:

Assistant Regional Director, Ecological Services, U.S. Fish and Wildlife Service

Approve Nancy Gloman Date 6/4/09