Tobusch Fishhook Cactus
(*Sclerocactus brevihamatus* ssp. *tobuschii*)

5-Year Review:
Summary and Evaluation

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

5-YEAR REVIEW
Tobusch Fishhook Cactus/*Sclerocactus brevihamatus* ssp. *tobuschii*

1.0 GENERAL INFORMATION

1.1 Reviewers

Lead Regional Office: Southwest (Region 2)
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Lead Field Office: Austin Ecological Services Field Office
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1.2 Methodology used to complete the review:

The public notice for this review was published in the Federal Register on March 20, 2008 (73 FR 14995). 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Diversity Database (NDD), final reports of section 6-funded projects, monitoring reports, scientific publications, unpublished documents, personal communications from botanists familiar with the species, and Internet web sites. The 5-year review document was prepared by personnel of the Austin Ecological Services Field Office without peer review.

1.3 Background:

Tobusch fishhook cactus was federally-listed as endangered without critical habitat on November 7, 1979 (44 FR 64736). The State of Texas listed the species as endangered on April 29, 1983.

The current scientific literature refers to Tobusch fishhook cactus by several synonyms, including *Ancistrocactus brevihamatus* and *Sclerocactus brevihamatus* subspecies *tobuschii.* We use the latter synonym here for the reasons explained in section 2.3.1.4. For brevity, because both the common and scientific names are unwieldy, this report uses the abbreviation “SCLTOB” where the taxon is referred to repeatedly. Similarly, this document employs the term “species” in a general sense to indicate species or subspecies, depending on the botanical authority.

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. 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.

1.3.1 FR Notice citation announcing initiation of this review:

73 Federal Register 14995-14997, March 20, 2008.

1.3.2 Listing history

Original Listing

FR notice: 44 Federal Register, 64736-64738.
Date listed: November 7, 1979.
Entity listed: *Ancistrocactus tobuschii* (Tobusch fishhook cactus).
Classification: Endangered without Critical Habitat.

1.3.3 Associated rulemakings: n/a

1.3.4 Review History

A 5-year review was initiated on November 6, 1991 (56 FR 56882) for all species listed before 1991, but no document was prepared for this species. Other review documents include: Status Report (Weniger 1979), Final Recovery Plan (U.S. Fish and Wildlife Service 1987), and Status Update (Poole and Janssen 2002).

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

The Recovery Priority Number at the start of this 5-year review was 2, meaning a high degree of threat, the recovery potential is high, and the listed entity is a species.

1.3.6 Recovery Plan or Outline

Name of plan or outline: Tobusch Fishhook Cactus (*Ancistrocactus tobuschii*) Recovery Plan.
Date issued: March 18, 1987.
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 applies only to vertebrate animals.

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, but it only has a single downlisting criterion that addresses one recovery objective. There are no delisting criteria, nor any that address the other six recovery objectives.

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 recovery plan (U.S. Fish and Wildlife Service [USFWS] 1987) lists seven major objectives, but has only a single downlisting criterion for the first objective:

> "The criteria for downlisting Tobusch fishhook cactus to threatened will be to establish at least four safe sites that contain at least 3,000 plants each. Delisting criteria have not yet been established. The implementation of studies in this recovery plan will provide the necessary data from which quantified delisting criteria can be established…When downlisting is accomplished this plan will be re-evaluated to determine delisting criteria."

The step-down outline of the recovery plan lists the recovery objectives, which are repeated here together with descriptions of accomplishments.

Objective 1. Remove immediate human threats to *Ancistrocactus tobuschii* by protecting known populations from collecting and habitat destruction.

11. Establish four safe sites for protection of presently known populations of the cactus.
12. Develop a management plan for each safe site.
13. Ensure that the safe sites are secure from possible impacts.

The most recent update of the TPWD NDD for Tobusch fishhook cactus (July 15, 2009) indicates that the species has been documented on 10 protected reserves

(see Table 4 and discussion in Section 2.3.1.2). Seven of these sites are managed by TPWD, two are managed by The Nature Conservancy, and one is managed by the Natural Areas Preservation Association, Inc. These populations have fluctuated greatly in size, and none come close to the criterion of 3,000 individuals; however, this may not be a realistic or attainable criterion (see Sections 2.3.1.1. and 2.3.2.3.). The largest documented population, at Devil's Sinkhole State Natural Area (SNA) in Edwards County, reached 1,100 individuals in 1994, but declined to only 16 individuals by 2000.

Objective 2. Establish a permanent living collection at a botanical garden or university.

The Desert Botanical Garden, in Phoenix, Arizona, is listed as the primary custodian for SCLTOB in the Center for Plant Conservation (CPC) National Collection of Endangered Plants (Center for Plant Conservation 2009). The SCLTOB plants that were salvaged from a highway construction project were stored at the Desert Botanical Garden; one of these was later provided to William Calvert for parasite research (Poole et al. 2003). However, the Desert Botanical Garden does not include SCLTOB among the 36 species currently under its care in the national living collection (Desert Botanical Garden 2009). In July 2009, we requested information from Desert Botanical Garden regarding their efforts to conserve SCLTOB, but have not received a response. Researchers at San Antonio Botanical Garden, another CPC institution, have propagated SCLTOB from wild-collected seeds (Center for Plant Conservation 2009).

Objective 3. Minimize long-range threats to *Ancistrocactus tobuschii* by development of biological information relevant to recovery.

Nine published research projects have contributed significantly to the knowledge of the biology, life history, and management of SCLTOB. These projects (Baccus 1999, Butterworth et al. 2002, Emmett 1995a and 1995b, Lockwood 1995, Poole 1991, Poole et al. 2003, Poole and Janssen 1997 and 2002, Sutton 1997, Sutton et al. 1997) are discussed in Section 2.3.1. Section 6-funded grants supported five of these projects. Conservation measures from a formal section 7 consultation created support for two projects. These projects include a master's thesis and a doctoral dissertation.

Objective 4. Establish a long-term (five year) survey program to more precisely determine the true distribution of the species.

Personnel from TPWD and other organizations have monitored known populations annually beginning in 1991. In 2008, TPWD monitored 28 sites at Walter Buck Wildlife Management Area (WMA), Devil's Sinkhole SNA, Garner State Park (SP), a highway right-of-way (ROW) near Junction, Kerr WMA, Kickapoo Caverns SNA, Lost Maples SNA, and Pole Hollow (Poole 2009). This data tracks the life histories of several thousand individual SCLTOB.

Objective 5. Develop a comprehensive trade management plan for all cacti.

The recovery plans for several cactus species, including Brady pincushion cactus (*Pediocactus bradyi*), bunched cory cactus (*Coryphantha ramillosa*), Knowlton cactus (*Pediocactus knowltonii*), and Wright fishhook cactus (*Sclerocactus wrightii*) all include this objective without indicating what organization is responsible for its development and implementation. Not surprisingly, a comprehensive cactus trade management plan has not been developed. However, one section 6-funded project (Poole 1991) did investigate the extent of legal trade in a number of rare, threatened, and endangered cactus species.

Objective 6. Develop a program to provide propagated plants and seeds to the commercial market.

Poole (1991) found six occurrences of legal trade in seeds of SCLTOB. The species has been difficult to maintain in cultivation, and there appears to be relatively little commercial interest in either wild or propagated individuals.

Objective 7. Develop public awareness, appreciation, and support for preservation of the species.

TPWD and the Natural Resources Conservation Service (NRCS) produced a pamphlet with photographs and information on Tobusch fishhook cactus, which has been distributed to private landowners in the counties where the cactus is known to occur.

Section 7 Consultations.

Six formal consultations under section 7 of the Endangered Species Act (ESA) have led to actions that address one or more objectives listed in the recovery plan; actions under one other formal consultation had no effect on SCLTOB (see Table 1 for a summary of formal consultations related to Tobusch fishhook cactus). These actions were described variously as "conservation measures," "conservation recommendations," or "proposed minimizations to offset impacts to listed species" in USFWS biological opinions. Three consultations (2-15-95-F-352, 2-15-03-F-0039 and 21450-2006-F-117) involved Federal Aid Wildlife Restoration Grants to TPWD for habitat management projects at Walter Buck WMA and Kerr WMA. The primary objective of these projects was to reduce Ashe juniper density through mechanical cutting, prescribed burning, and prescribed grazing over a period of eight years. The TPWD proposals included conducting a 5-year pilot study at Walter Buck WMA to examine the response of SCLTOB to these treatments, to be conducted by Dr. John Baccus of Southwest Texas State University. One of Dr. Baccus's graduate students, Kari Sutton, based her master's thesis on data collected during this study (discussed in Section 2.3.1.6.). TPWD also proposed to monitor these sites for 10 years to detect

delayed or indirect effects of the treatments. The monitoring program was extended in 2006; by this time, 149 SCLTOB plants were monitored annually in fifty 20 meter-square (m^2) plots established within the burn units. The biological opinion states that previous monitoring indicates that the effects of prescribed burning, juniper clearing, and grazing were comparable to controls. However, it is more accurate to say that the analysis of data did not detect significant differences between some of the treatments and the controls, which may have been due to the experimental design.

The biological opinion (February 17, 2000) for the Longhorn Pipeline consultation (2-25-00-F-413) states that the permittee will make a monetary contribution to the Tobusch Fishhook Cactus Conservation Fund for impacts to an estimated 213.2 acres (ac) of potential habitat, valued at $255,840. This funding is to be used to acquire land for conservation of SCLTOB habitat. However, when the project was implemented, the actual amounts contributed in two payments totaled $158,605.05. This difference may reflect that the Longhorn Project disturbed less habitat than was originally predicted.

Table 1. Summary of Biological Opinions Involving Tobusch Fishhook Cactus.

Consult. No.	Date Concluded	Action Agency / Nexus	Non-Federal Entity / Project	Counties	Conservation Measures, Conservation Recommendations, and Minimizations to Offset Impacts to Listed Species
2-15-93-F-069	30 Mar, 1993	USFHA	TxDOT 5.673 miles of upgrades on US Hwy 277.	Val Verde	• Seven SCLTOB found at three sites within project area. • Four SCLTOB will be lost, three indirectly affected. • All seven SCLTOB to be removed and donated to a CPC conservation collection. • Describe site characteristics, including soil, vegetation, and drainage. • Avoid damage to SCLTOB habitat during construction. • Conduct reintroduction study, develop site management plan, monitor sites and collect data from reintroduction plots and comparison plots for five years. • Complete land clearing prior to April 15.
2-15-95-F-352	12 Apr, 1996	USFWS (Federal Aid)	TPWD Juniper control, prescribed burning and grazing on Buck Wildlife Management Area	Kimble	• Juniper cutting, prescribed burning and grazing over eight-year period. • Project sites will be surveyed; avoid disturbance to SCLTOB plants; juniper not to be piled on cactus. • Five-year pilot study to be conducted by Dr. John Baccus, STSU, to determine response of SCLTOB, prior to implementing project on entire WMA. • Project sites will be monitored for additional 10 years. • If prescribed burning is conducted prior to completion of five-year pilot study, protect most vulnerable 30% of SCLTOB with burn boxes or similar device. • If pilot study or monitoring indicate SCLTOB population decline of >20% compared to controls, or 40% compared to baseline, must reinitiate discussion with USFWS. • Provide copies of annual and final reports of pilot study and monitoring to USFWS; publish results in peer-reviewed scientific journals.

Consult. No.	Date Concluded	Action Agency / Nexus	Non-Federal Entity / Project	Counties	Conservation Measures, Conservation Recommendations, and Minimizations to Offset Impacts to Listed Species
2-15-00-F-0763	18 Dec, 2000	USFWS Safe Harbor Enhancement of Survival permit	Environmental Defense, Inc. (ED).	25 TX Hill Country counties	• Permit for restoration of habitat of black-capped vireo and golden-cheeked warbler. Project area includes 19 listed species, including SCLTOB, and 1 proposed and 1 candidate species; project may impact SCLTOB. • ED will survey potential SCLTOB habitat prior to conducting prescribed burning. All SCLTOB will be mapped with GPS and protected with burn boxes or similar means. ED will report SCLTOB populations to USFWS. • SCLTOB may benefit from reductions in cattle stocking rate. • Clearing of dense shrubs should not impact SCLTOB. Herbicides, if used, will be applied only as spot treatments to cut stumps. Project is not likely to jeopardize SCLTOB.
2-15-00-F-413	17 Feb, 2000	USEPA and USDOT	Longhorn Pipeline Partners, L.P. Maintenance and minor construction of 723-mile pipeline from Houston to El Paso.	Numerous	• No SCLTOB were observed in pipeline ROW, but entire ROW in Kimble Co. is suitable habitat. • Longhorn will compensate for impacts to 213.2 ac of SCLTOB habitat x 1.2 x fair market value of land in the area ($1,000/ac) = $255,840, to be used for habitat acquisition. • Longhorn will conduct a blooming period survey (March to April 2000) within the ROW throughout Kimble County to determine the species' distribution and abundance. • All SCLTOB found within ROW will be transplanted and provided to Desert Botanical Garden for seed propagation. • USEPA and USDOT must ensure proposed plan is implemented.
2-15-03-F-0039	24 Mar, 2006	USFWS (Federal Aid)	TPWD Prescribed Burn at Walter Buck WMA	Kimble	• Project is expansion of cool-season prescribed burning in 12 units of Walter Buck WMA, according to prescribed burn management plan. • Four restricted burn units have > five SCLTOB. Eight unrestricted burn units have < five SCLTOB. • Maximum of 25% of each restricted burn unit and 25% of WMA to be burned in one year; restricted units will not be burned more frequently than once per three years. • Continue long-term monitoring program. Previous monitoring indicated effects of prescribed burning, juniper control and grazing on SCLTOB were comparable to controls. • Action is not likely to jeopardize continued existence of SCLTOB. • USFWS and State partners should encourage and participate in additional research and recovery of SCLTOB.

Consult. No.	Date Concluded	Action Agency / Nexus	Non-Federal Entity / Project	Counties	Conservation Measures, Conservation Recommendations, and Minimizations to Offset Impacts to Listed Species
2-15-2005-F-0049	4 Apr, 2006	USFCC	Cingular Wireless Kaolin Hollow Cell communications tower	Uvalde	• No effect on SCLTOB.
21450-2006-F-0117	21 Jun, 2006	USFWS (Federal Aid)	TPWD Wildlife Restoration Project at Kerr WMA	Kerr	• Wildlife Restoration Project Grant W-124-M prescribed burning at Kerr WMA. • Summer burns will not be conducted where SCLTOB is present. • TPWD proposes burning no more often than one time per three years. • Annual monitoring of SCLTOB in areas subjected to summer burns. • No effect on SCLTOB.

Cooperative Agreements.

USFWS and the National Fish and Wildlife Foundation (NFWF) signed a letter of agreement in 2000, establishing a Tobusch Fishhook Cactus Conservation Fund (Fund), to be administered by NFWF, to receive and distribute appropriately funds raised to benefit the species' conservation, such as the compensation funds generated by the USFWS biological opinions described above (USFWS and NFWF 2000). The original term of the agreement was from 2000 to 2005, but was extended to September 30, 2006 (David Brunner, pers. comm. 2005). The purpose of the fund is "to provide an avenue for payment of private or public funds to be used exclusively for the conservation and recovery of the Tobusch fishhook cactus and the habitats on which it depend…All interest and earnings accruing to the Fund shall be reinvested in the segregated account and used for the purposes specified ..." The NFWF received an initial administrative reimbursement of five percent at the time of fund contributions, as well as reimbursement of bank fees. The specific use of each compensation contribution is stipulated in the corresponding biological opinions. In 2005, the Tobusch Fishhook Cactus Conservation Fund was transferred to Lady Bird Johnson Wildflower Center (LBJWC) through a Memorandum of Agreement (MOA; USFWS and LBJWC 2005). The terms of the MOA are similar to the previous agreement, except that it does not indicate how to use interest that the account earns. Consequently, the Tobusch Fishhook Cactus Conservation Fund managed by LBJWC does not accrue interest. The current amount and designated uses of the conservation fund are summarized in Table 2.

Table 2. Tobusch Fishhook Cactus Conservation Fund.

Date	Fund Contributor	Fund Manager	Credits	Less 5% Fee	Other Debits	Net Activity	Account Balance	Total Accumulated Interest
6 Oct, 2000	Longhorn Partners Pipeline; 2-15-00-F-413	NFWF	$158,090.88	$7,904.54	$0.00	$150,186.34	$150,186.34	$0.00
1 Apr, 2002	Interest accumulated by this date	NFWF	$11,467.64	$0.00	$0.00	$11,467.64	$161,653.98	$11,467.64
1 Apr, 2002	Longhorn Partners Pipeline; 2-15-00-F-413	NFWF	$514.17	$0.00	$0.00	$514.17	$162,168.15	
30 Sep, 2003	Unexplained credit	NFWF	$783.06	$0.00	$0.00	$783.06	$162,951.21	
30 Sep, 2004	Presumed interest earned FY 2004	NFWF	$2,738.57	$0.00	$0.00	$2,738.57	$165,689.78	$14,206.21
30 Sep, 2005	Interest earned FY 2005	NFWF	$3,822.53	$0.00	$0.00	$3,822.53	$169,512.31	$18,028.74
30 Sep, 2004	Bank Fee	NFWF	$0.00	$0.00	$301.26	-$301.26	$169,211.05	
30 Sep, 2005	Bank Fee	NFWF	$0.00	$0.00	$209.30	-$209.30	$169,001.75	
8 Nov, 2005	Transfer to LBJWC	LBJWC	$0.00	$8,450.09	$0.00	-$8,450.09	$160,551.66	
23 Jul, 2009	Current Balance	LBJWC	$0.00	$0.00	$0.00	$0.00	$160,901.97	

Note: the current account balance managed by LBJWC is slightly greater than the final balance, as calculated here, transferred from NFWF to LBJWC. We believe this discrepancy of $350.31 may reflect additional interest earned after NFWF's last account statement (Sept. 30, 2005) and before the date of fund transfer (Nov. 8, 2005).

Section 6-Funded Grants.

"The Cooperative Endangered Species Conservation Fund (section 6 of the ESA) provides grants to States and territories to participate in a wide array of voluntary conservation projects for candidate, proposed, and listed species. The program provides funding to States and territories for species and habitat conservation actions on non-Federal lands" (USFWS 2009). The USFWS has awarded five section 6 grants in Texas that support SCLTOB conservation. These projects are briefly summarized in Table 3; the results of these projects are discussed in further detail in Section 2.3.1.

Table 3. Section 6 Grants Involving Tobusch Fishhook Cactus.

Job no./ Grant no.	Year completed	Principal investigator and literature citation.	Project title
Job no. 10	1991	J.M. Poole (Poole 1991).	Cactus trade and collection impact monitoring.
Project no. 30, grants E-1-3 through E-1-7	1995	Raymond Emmett (Emmett 1995a, 1995b).	A study of the reproductive biology of the Tobusch fishhook cactus (*Ancistrocactus tobuschii*).
Project 35, Grant E-1-6	1997	J.M. Poole and G. Janssen (Poole and Janssen 1997).	Managing and monitoring rare and endangered plants on highway right-of-ways in Texas.
Project WER22(67), Grant E-1-11	2002	J.M. Poole and G. Janssen (Poole and Janssen 2002).	Status update of Tobusch fishhook cactus (*Ancistrocactus tobuschii*).
Project WER56	2003	J.M. Poole, S.J. Birnbaum and W. Calvert (Poole et al. 2003).	Annual monitoring of Tobusch fishhook cactus (*Ancistrocactus tobuschii*) to address the requirement of possible delisting and an assessment of the threat of *Gerstaecheria* sp.

Additionally, section 6 grant no. E-1 (Project WER71) contributed to the creation of Rare Plants of Texas (Poole et al. 2007), an invaluable compilation of data on 232 rare, threatened, and endangered plants of Texas, including Tobusch fishhook cactus.

Summary of accomplishments toward meeting the recovery criteria.

- Tobusch fishhook cactus has been documented at 10 protected sites. Botanists from TPWD monitor the SCLTOB populations of eight of these sites annually. In 2008, these monitored populations ranged from 34 to 1,090 SCLTOB plants, and their total was 3,139 plants.

- Six formal section 7 consultations have involved SCLTOB. Three consultations led to scientific investigations of the impacts of management practices on SCLTOB populations, and long-term monitoring of these populations at Walter Buck and Kerr WMAs. Another consultation generated a contribution of $158,090.88 for acquisition of SCLTOB habitat.
- The LBJWC manages the Tobusch Fishhook Cactus Conservation Fund through a MOA with USFWS. The current fund account balance is $160,901.97.
- Five section 6 grants have supported scientific investigations and extensive inventory and monitoring of SCLTOB on State Highway ROWs, State Parks, Wildlife Management Areas, and State Natural Areas.

2.3 Updated Information and Current Species Status

Note: The glossary on page 48 defines many of the technical terms in sections 2.3.1 and 2.3.2.

2.3.1 Biology and Habitat

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

Lockwood (1995) described the life history of a SCLTOB population discovered in February 1992 at Kickapoo Caverns SNA in Kinney County. This population occupied an area of 0.65 ha on a south-facing slope, from 579 – 586 m elevation. The SCLTOB plants occurred in shallow, gravelly soils among blocks of exposed Cretaceous limestone. Associated species included Peruvian spike-moss (*Selaginella peruviana*), scattered paper-shell pinyon (*Pinus remota*) and sandpaper oak (*Quercus pungens*), button cactus (*Epithelantha micromeris*), scarlet hedgehog cactus (*Echinocereus coccineus*), pitaya (*E. enneacanthus*) and pricklypear (*Opuntia* spp). Lockwood (1995) reported 94 individual SCLTOB in 1992. In 1993, 14 individuals had died, and 21 new individuals were found. In 1994, eight individuals died and seven new plants were detected. Lockwood (1995) collected nine insect species visiting the flowers, and noted that the bee *Dialictus cumulus* and the common honey bee (*Apis mellifera*) were the probable pollinators. He also observed other halictid bees, including *Dialictus pruinosiformis*, *Lasioglossum morrilli*, *Osmia subfaciata*, and *Agapostemon* sp. The only other native plant flowering concurrently with SCLTOB at the site, in late January to early February, was ten-petal anemone (*Anemone heterophylla*). A native shrub, agarita (*Berberis trifoliata*) blooms in mid-February.

Raymond Emmett investigated the pollination, seed ecology, mortality, reproduction, and growth of SCLTOB for his doctoral dissertation (Emmett 1995b; section 6 project 30, grant nos. E-1-3 through E-1-7). From 1991 to 1994, he collected field data from three populations at Walter Buck WMA, Devil's

Sinkhole SNA, and Kickapoo Caverns SNA. He reported that SCLTOB flowers once per year, from early February to mid-March. Up to eight or more yellow to yellow-green flowers per plant arise from the axils of previous-year tubercles. The flowers remain open for up to one week, or until they are pollinated. The green to greenish-pink fruits ripen in mid-May, and split open when dry. Each fruit produces from 20 to 40 papillate seeds that are 1.5 millimeters (mm) long by 1 to 1.5 mm wide. The only known means of reproduction is through sexually-produced seeds.

Poole and Janssen (2002) observed that SCLTOB flowering lasts two to three weeks, starting as early as late January in the southern portion of the species' range, and lasting as late as mid-March in the northern part of the range.

Emmett (1995b) observed that several species of Halictid bees were the most common floral visitors. At Devil's Sinkhole SNA, *Lasioglossum* (*Dialictus*) *morrilli* was the most commonly observed floral visitor. In controlled pollination experiments, he found that cross-pollinated flowers had 98 percent fruit set, averaging 38.9 seeds per flower, while self-pollinated flowers had only 5 percent fruit set and 1.1 seeds per flower. Cross-pollinated seeds had a germination rate of 22.7 percent versus only 6.3 percent for self-pollinated seeds. Therefore, SCLTOB is almost completely self-incompatible. He found no significant difference in the effectiveness of pollen collected from neighboring plants and pollen from distant colonies with respect to fruit set, seed set, and seed germination rate. Noting that bee pollinators typically visit flowers within a small area before moving to more distant areas, he concluded that "…the general degree of interrelatedness of plants within each colony is not that great; the self-incompatibility system is functioning adequately to reduce the level of inbreeding; there is sufficient genetic diversity within the colonies and/or that *A. tobuschii* at this site are not especially prone to the potentially negative effects of inbreeding."

Emmett determined that SCLTOB plants at his study sites produced an average of 112 seeds per plant per year. He observed that a species of ant, *Forelius foetidus* (Dolichoderinae), quickly removed up to 85 percent of seeds from split fruits, and carried the seeds, fruit pulp, and the funiculi to their mounds. However, Emmett did not investigate the fate of the seeds taken to ant mounds. Gravity and rainwater dispersed the remaining seeds. Most of the SCLTOB progeny he observed were in the immediate vicinity of mature, reproductive plants. Seed germination in the laboratory ranged from 1 percent to 67 percent; almost all seeds germinated within 7 to 10 days. Emmett placed seeds in protective exclosures *in-situ* at Walter Buck WMA and Devil's Sinkhole SNA. Seven percent and 27 percent of the seeds germinated at these sites within one year; 62 percent and 89 percent (respectively) of the *in-situ* germination occurred between February and May.

Emmett attempted to quantify the soil seed bank by extracting soil cores that measured 20 mm in diameter by 40 mm in depth. The sampling was done in late

March and April, prior to dispersal of the current year's seeds. After initial sampling strategies detected no seeds, he employed a biased sampling of soil adjacent to reproductive plants. He recovered 19 seeds in 1993 and 21 in 1994, and concluded that moderate quantities of viable seeds were present in the soil seed bank, but that there was a very low probability of finding seeds more than a few decimeters from the parent plant.

Emmett found that stem diameter growth of SCLTOB plants ranged from one to several mm/year, but decreased during some years. The stems of many cactus species swell and shrink, depending on the amount of water they store. Based on observed growth rates, he estimated that SCLTOB plants take at least 9 years to reach reproductive size and 25 years to reach a diameter of 30 mm. The largest plants he observed, measuring 40 mm to 60 mm in diameter, could be over 50 years old.

Poole and Janssen (2002) stated that SCLTOB normally grows slowly, but can increase one centimeter (cm) in diameter in years of higher rainfall, which may be due to water stored in stem. Individuals begin reproducing when the stem diameter reaches 2 cm, and can live 10 years or more. The largest individuals they observed were 10 cm in diameter, but most populations have few individuals greater than 5 cm, and most measure from 1 to 5 cm.

The three-year mortality rate during Emmett's study at Walter Buck WMA and Devil's Sinkhole SNA was 55 percent and 69 percent, respectively (Emmett 1995b). The majority of attributable mortality was due to infestation by larvae of two Coleopteran cactus parasites, *Moneilema armata* LeConte (Cerambycidae) and an undescribed species of *Gerstaeckeria* (Curculionidae); these parasites always killed the host. Mammal herbivory accounted for a relatively minor amount of mortality. Emmett observed that SCLTOB plants browsed by mammals often sprout new stems.

The Tobusch fishhook cactus weevil, as it is now called, was investigated by William Calvert (Poole et al. 2003). This undescribed species of *Gerstaeckeria* accounted for 44.8 percent of mortality in 256 unhealthy SCLTOB that were collected from the field and studied in terrariums. Other causes of mortality included *Copestylum* fly larvae (15 percent), *Moneilema crassum* (7.5 percent), and an apparent type of rot. All *Gerstaeckeria* species are cactus parasites whose larvae feed and pupate inside cactus stems. Adults are primarily nocturnal and are flightless, due to fused elytra. Calvert found *Gerstaeckeria* spp. in other cactus species at the site (*Opuntia* and *Coryphantha*) that did not feed on SCLTOB. Similarly, the Tobusch weevil appears to be highly specific to SCLTOB. The weevil larvae overwinter inside the cactus stems. They emerge at the end of April into mid July, mate and oviposit after emergence. *Moneilema* pupae emerge from April to May.

In March 2007, botanists from USFWS and TPWD discovered three small populations, totaling 17 individuals, of SCLTOB on a privately-owned ranch in southwestern Bandera County (Best, USFWS, pers. comm. 2008). These populations occur where limestone strata emerge along gentle slopes. The gravelly soil is extremely shallow; abundant blue-green alga and lichens growing in the immediate vicinity of the cacti indicate that soil moisture trapped along the upper surface of the limestone is seeping to the soil surface there. Photographs a, b, c, e, f, and g (Figure 5) were taken at these sites. The landowner, Dr. Ashley McAllen, and his family have enthusiastically monitored these populations since their discovery. In July 2007, Dr. McAllen observed that an animal, probably a small rodent, had browsed several SCLTOB plants. He then constructed 14 cages of angle iron and hardware cloth, measuring 12- by 12- by 8-in, which he placed over all 17 plants. No further herbivory has been observed on the caged cacti. In March – April 2008, one of the SCLTOB had died of unknown causes, and 6 new mature individuals and 29 seedlings were observed (25 seedlings were inside the cages and 4 were outside). Dr. McAllen's initiative demonstrates both a method for protecting SCLTOB plants from mammal herbivory, as well as the potential benefit that conscientious landowners can have for the conservation of the species.

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:

TPWD manages the State's NDD, which compiles data on tracked plant and animal species that is submitted by a vast consortium of Federal, State, academic, non-governmental organizations (NGO), private researchers, and consultants. The NDD tracks 232 rare, threatened, and endangered plant species in Texas, including all 33 federally-listed plants (24 endangered, 6 threatened, and 3 candidate plant species). The geographic, population, and other relevant data for each species are tracked as Element Occurrences. "An Element Occurrence (EO) is an area of land and/or water in which a species or natural community is, or was, present," (NatureServe 2002). The EOs may consist of one or many "sites" as reported by surveyors. In the geographic information system (GIS) component of the NDD, EOs are displayed as points and polygons buffered by their estimated geographic precision. For this reason, historic reports that do not contain precise geographic coordinates are shown as relatively large polygons, while more recent survey data collected with geographic positioning system (GPS) instruments are represented by smaller polygons. Therefore, it must be understood that the tracked species occur within, but not necessarily throughout, the polygons displayed in the GIS. The NDD is an essential tool for the long-term conservation and management of species at risk. The USFWS makes frequent use of the NDD in listing actions, for planning and tracking recovery of listed species, for section 7 consultations, and for Habitat Conservation Plans.

Figure 4 shows the global range of Tobusch fishhook cactus populations tracked in the NDD. Currently, TPWD is revising the NDD to conform to the standard published by NatureServe (2002); the revisions relate specifically to the separation distances between EOs. The summary in Table 4 is our analysis of the most recent update of the NDD for Tobusch fishhook cactus, which was provided to USFWS on July 15, 2009 (Texas Natural Diversity Database 2009). However, this update does not include population data more recent than 1999; for this reason, the population sizes indicated here differ from those shown in other tables (see the discussion of data provided by Poole (2009) in this Section).

Table 4. Summary of NDD Element Occurrences for Tobusch fishhook cactus.

Element Occurrences	105
Maximum Population	3404
Extirpated EOs	6
Extirpated individuals	9
Extant EOs	99
Extant individuals	3395
EOs in Good to Excellent Condition	3
Individuals in EOs rated Good to Excellent Condition	263
Protected Area Populations:	
Coto de los Rincones (NAPA)	111
Devil's River SNA	3
Devil's Sinkhole SNA	1100
Dolan Falls Ranch Reserve (TNC)	100
Garner SP	3
Kerr WMA	5
Kickapoo Caverns SNA	399
Lost Maples SNA	522
Love Creek Preserve (TNC)	33
Walter Buck WMA	51
Protected Area Total	2327

From 1992-1994, Emmett (1995b) documented an annual mortality rate greater than 20 percent at Walter Buck WMA and Devil's Sinkhole SNA, and 9 percent at Kickapoo Caverns SNA. Annual flower, fruit, and seed production per plant decreased consistently and significantly at all populations during each year of this study. He stated, "If the trends observed during this investigation continue, the high mortality, decreasing reproductive effort and success, and apparently low seedling recruitment could lead to the rapid extinction of the study populations, especially at the BWM and DSH sites. While more information concerning the autecology of this cactus should be acquired prior at [sic] any attempts at

development of a long-range management strategy, it may be necessary to employ stop-gap measures in the mean time, and control of the grub-related mortality seems like an obvious starting point."

The density of SCLTOB at Emmett's study sites ranged from 1 plant per square meter (m^2) at Kickapoo Caverns SNA to 1 per 100 m^2 at Walter Buck WMA. Zimmerman (pers. comm. 1992, quoted in Emmett 1995b) believed that low population densities are less prone to weevil predation, and are therefore more secure.

Poole and Janssen (2002) visited 80 of 102 sites mapped in the NDD (they were not able to visit 22 reported sites due to access problems), and also continued and expanded the annual monitoring, begun by Emmett, of all populations within State parks and WMAs. They found no SCLTOB at 14 sites, although the habitat was still intact. The species had been misidentified at five sites. They were not able to find one site due to vague location data. They combined 21 previously-reported sites into five, following the EO guidance from NatureServe. Of 56 properties surveyed, 19 were publicly owned, including highway ROWs, State parks and WMAs, and 37 were privately owned; 29 properties had 1 or more SCLTOB population. They verified about 2000 individual SCLTOB in August 1999 in 53 populations, including 1,363 on 10 long-term monitoring plots. Twenty populations had 10 or fewer individuals, and 20 others had from 20 to 100 individuals. Four populations had more than 100 individuals, and the largest had more than 500.

The Devil's Sinkhole population, which had 1,100 individuals in 1994, had been reduced by weevil predation to only 24 in 1999 (Poole and Janssen 2002). These authors stated, "The Devil's River State Natural Area and the Devil's Sinkhole State Natural Area sites have experienced high mortality (>50 percent), and the populations are declining, that is the amount of mortality exceeds the number of new plants found in the plots. However, the addition of new plots does superficially increase the total live count, but does not represent recruitment for the site. The other sites have 20 percent mortality or less, and during most years, the number of new plants exceeds mortality losses. Some sites such as Lost Maple State Natural Area and the private preserve in Kerr County have less than 10 percent mortality..."

Poole and Janssen also observed that most mortality resulted from unknown causes, but did find larvae of *Gerstaeckeria* sp., *Moneilema armata*, and unidentified flies within the stems of many dead cacti. Some degree of mortality was also due to soil disturbance by armadillos, feral hogs or other animals, mammalian herbivory, trampling by people or animals, and fungus infections.

Poole and Janssen noted that new populations were discovered after the listing and recovery plan were published, and the species range was more extensive than previously understood. They observed that there was greater public awareness of

the species, and researchers had generated more information on the life history, demographics, and threats. However, many known populations, having fewer than 10 individuals, are probably not viable. Populations with 100 or more individuals appear stable, but the decimation of the Devil's Sinkhole population made none seem safe. The species continued survival will depend on our understanding of the impacts of weevil parasites, prescribed fire, and other factors.

Poole et al. (2003) reported the results of continued monitoring of 118 permanent plots at 12 sites, as well as a study of the Tobusch cactus weevil (*Gerstaeckeria* sp. nov.). By May 2003, 91 plots still had live plants. The authors stated, "Although the total number of live plants from all sites found at the end of the 2003 monitoring season (1,936) appears to be almost double that of the 1998 season, much of this increase is due to the finding of new, previously overlooked plants and populations rather than true recruitment." Within previously monitored plots, annual mortality consistently outweighed recruitment. Percent combined recruitment ranged from 1.6 percent in 1998 to 10.3 percent in 2003, and was not correlated to population size or number of reproductive individuals. Unknown causes and *Gerstaeckeria* weevils accounted for 64 percent and 20 percent of mortality, respectively, from 1998 – 2003.

Based on Pavlik's (1996) method, Poole et al. (2003) estimated that the minimum viable population for SCLTOB to be 1,200 individuals. The structure of monitored populations consisted of a ratio of about six reproductive individuals to four non-reproductive to one seedling. The largest and healthiest population was at Lost Maples SNA, where recruitment had exceeded mortality in four out of six years.

Significantly, Poole et al. (2003) reported new populations at Kerr WMA in 2001 and 2003, where previously-monitored plots had nearly been extirpated by weevils. Although populations with fewer than 10 individuals have a low probability of surviving, a small population at the Vireo Territory at Kickapoo Caverns SNA expanded miraculously, suggesting that "even sites where all plants have died should be checked occasionally." The authors ask, "If populations die off in an area, how do they become established at other sites and how often?" They recommend that prescribed burning not be conducted in occupied habitat during the species reproductive season (late January to early April). They conclude that, "At present the overall picture may appear stable, but mortality is high and not all sites are stable or increasing. It is too early to determine where the trends for the species as a whole are heading."

Poole (2009) generously provided to USFWS a series of spreadsheets that display the data from monitoring plots begun by Emmett (1995a, 1995b), Poole and Janssen (2002), and Poole et al. (2003), and continued annually by as-yet unpublished studies through 2009. Since 1991, these researchers have mapped and tagged thousands of individual SCLTOB in the field and recorded their

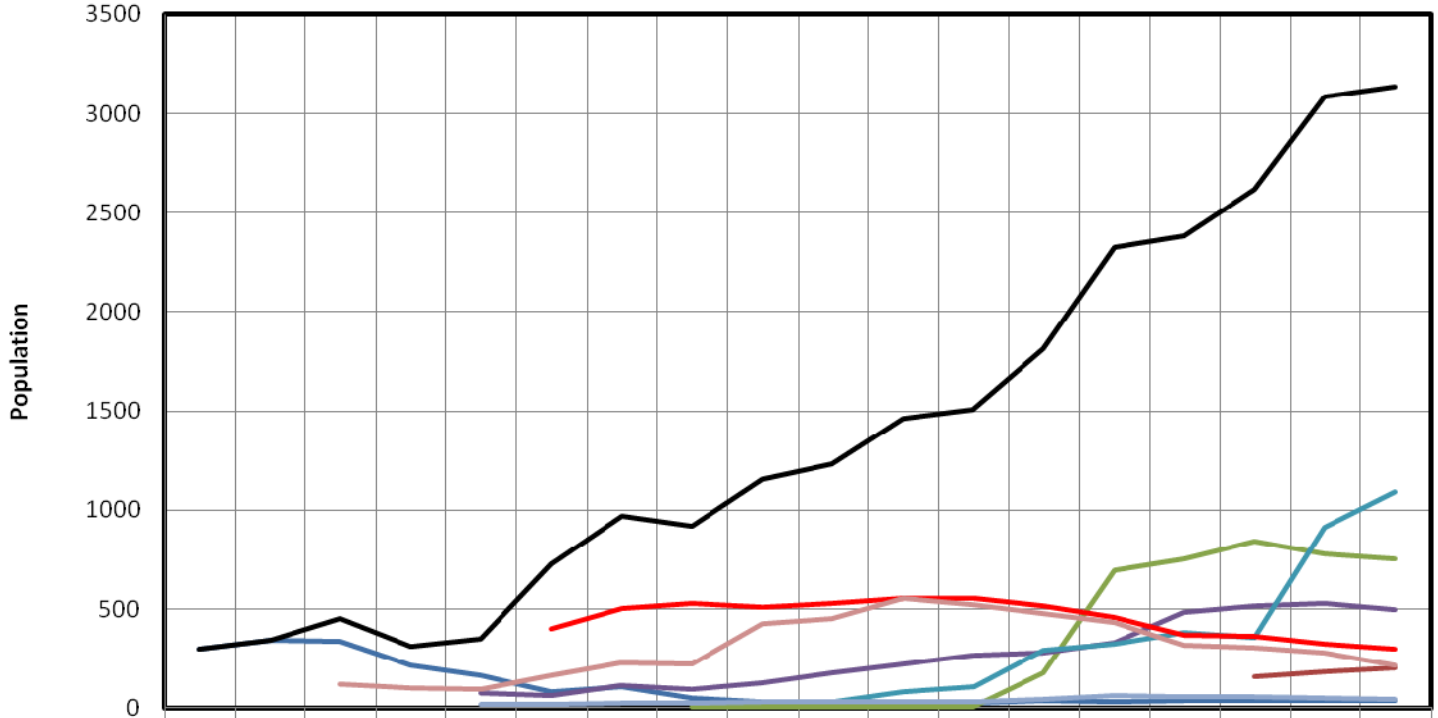
growth, reproduction, and mortality. This vast data set provides valuable information on the demographics and population dynamics of the species. Our preliminary analysis of this data indicates that in 2008, a total of 3,139 individual SCLTOB were recorded in 119 plots (stakes) at 28 sites in 8 monitored areas. The data are summarized in Figures 1-3. Figure 1 graphically illustrates the steady increase in the total numbers of individuals detected (black line) while the number of individuals at specific sites tends to fluctuate over time. Figure 2 summarizes the data from one managed area, Kickapoo Caverns SNA, where 28 monitoring plots are distributed among 21 sites. The total population reached a low of 95 individuals in 1995, then steadily increased to 554 in 2001, and has subsequently declined to 217 in 2008. The demographic pattern emerging from this data suggests an asymmetric oscillation, where colonies and populations establish and increase gradually, then rapidly decline from weevil infestations to a point too low to sustain the parasites. Although natural, these oscillations tend to obscure long-term population trends.

The emergence of new individuals and populations that were not detected in previously surveyed sites is a persistent theme in the 19 years since annual monitoring began. These discoveries may represent sites that were previously overlooked, or newly-establish sites, or both. However, Poole (pers. comm. 2009) believes that most newly-detected sites and plants were previously overlooked, and do not represent true recruitment. Poole and Janssen (2002) noted that healthy SCLTOB individuals can recede into gravel, soil, litter, or spikemosses during dry weather, unseen, and reemerge later (Figure 5). The ability to endure long droughts in a desiccated, dormant state may also allow some portion of a population to avoid outbreaks of weevil parasitism.

Figure 3 demonstrates the percentage of SCLTOB plants at the eight sites monitored by TPWD that were observed in flower and/or fruit each year. The percentage of reproductive plants has remained fairly constant, ranging from 75 percent to 100 percent. The table indicates that more than 100 percent of plants were reproductive in 1994; this anomaly is apparently due to more plants being observed during a secondary survey of reproductive plants than were initially observed (Poole, pers. comm. 2009).

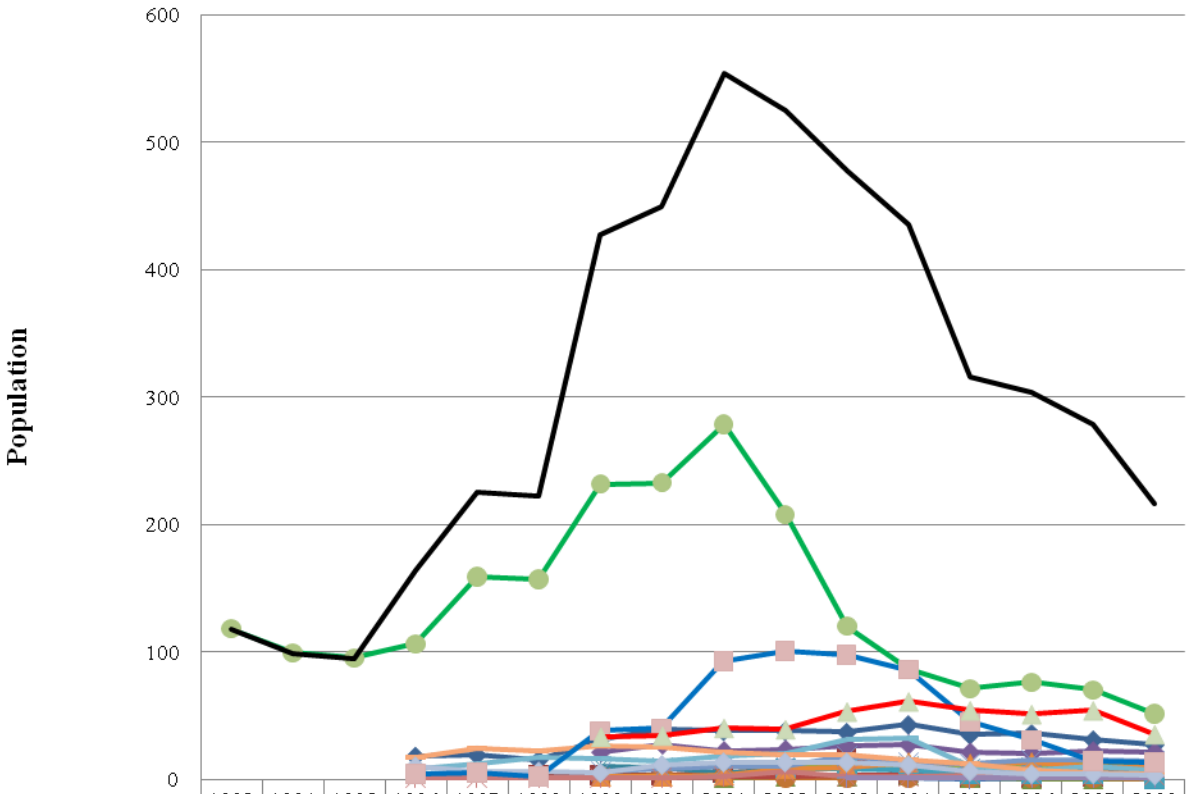
The question raised by Emmett (1995b) regarding the fate of SCLTOB seeds carried away by ants has not been resolved. González-Espinosa and Quintana-Ascencio (1986) observed that harvester ants (*Pogonomyrmex barbatus*) in central Mexico collected and carried into their nests up to 400 seeds of *Opuntia robusta* and *O. streptacantha* per day. The ants removed the seed funiculus (or adhering pulp) without killing the embryos and ejected most of the seeds into the surrounding gravel disks. More than 80 percent of dyed seeds offered to the ants were ejected into gravel mounds within 24 hours. These ants rarely foraged more than 10 to 12 m from their nests.

Figure 1. TPWD Annual Surveys of Tobusch Fishhook Cactus Sites

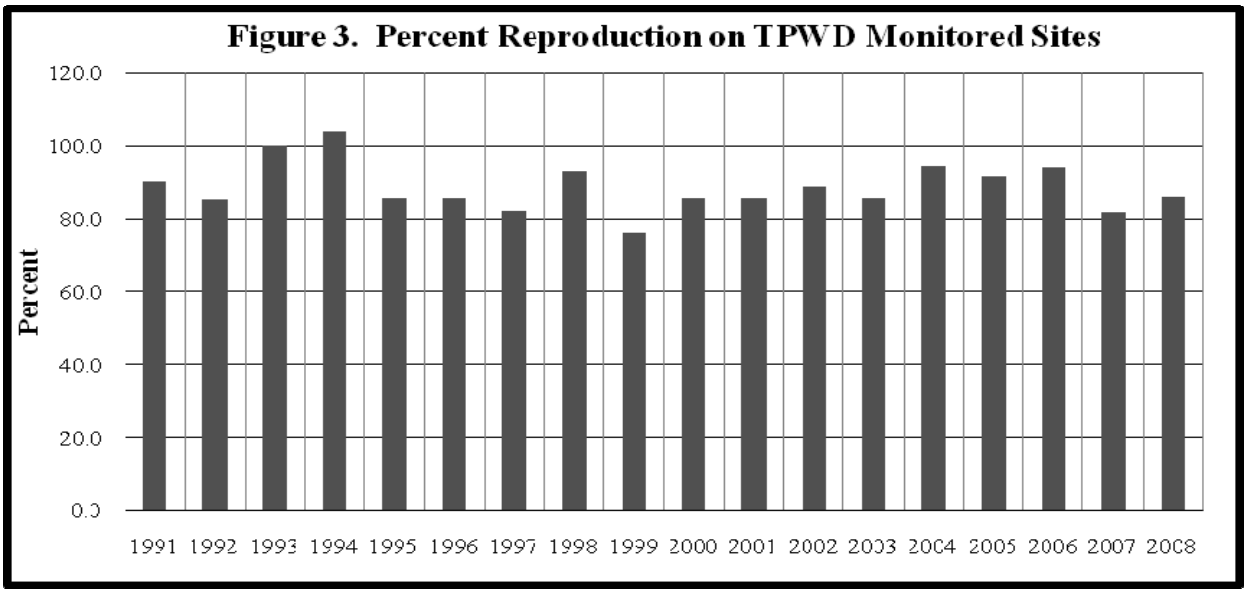


	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Devil's Sinkhole	297	341	334	210	161	81	103	47	28	15	26	24	31	25	32	31	32	34
Buck																158	187	205
Garner SP								2	2	3	2	2	177	693	753	843	778	755
Junction					75	63	112	96	128	176	221	268	276	328	479	512	526	495
Kerr WMA									29	29	79	107	291	320	381	355	914	1090
Lost Maples						403	506	526	509	528	554	551	514	460	369	364	323	299
Pole Hollow					18	16	24	26	30	30	28	29	44	63	56	54	50	44
Kickapoo SP			118	99	95	164	226	223	427	450	554	525	478	435	316	304	279	217
TOTALS:	297	341	452	309	349	727	971	920	1153	1231	1464	1506	1811	2324	2386	2621	3089	3139

Figure 2. Population Fluctuation at Kickapoo Sites



	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Butterfly				18	19	15	31	39	38	38	37	43	35	36	31	27
Dan's Site						3	3	3	5	7	18	3	1	1	2	2
Deep Well									1	2	2	3	1	0	0	0
Goose Chase												5	5	7	8	4
JD-1							10	9	5	7	9	10	8	9	8	9
JD-3							2	3	2	1	1	1	1	1	1	0
JD-4												1	0	1	1	1
Kelly B Mem							1	1	2	2	3	3	3	6	4	3
Kickapoo										13	10	12	11	11	12	10
Linda's Site							21	27	22	23	26	27	21	20	22	21
Mark2										8	8	7	4	4	4	0
NE Corner							2	2	3	8	9	13	12	13	10	9
N Gate							6	8	10	10	18	13	12	15	15	14
Quailtran				1	1	1	1	1	2	6	2	2	3	3	3	3
Ray's Site	118	99	95	106	159	157	232	233	279	208	120	86	71	76	70	51
Sardine											1	1	1	1	1	1
Shag Carpet				8	12	17	16	14	18	20	31	32	10	7	10	7
Stu Cave				17	24	22	26	25	21	19	19	15	12	7	5	4
Tank Hill				10	6	6	5	11	13	13	13	11	6	4	4	3
Vireo Trail				4	5	2	38	40	93	101	98	86	45	31	14	13
Wait Gate							33	34	40	39	53	61	54	51	54	35
TOTAL:	118	99	95	164	226	223	427	450	554	525	478	435	316	304	279	217



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

Powell and Weedin (2001) report a meiotic chromosome count of 2n = 11 II for specimens of SCLTOB collected from Kickapoo SNA in Kinney County. This is equivalent to a diploid chromosome number of 2n = 22.

Butterworth et al. (2002) investigated chloroplast rpl16 intron sequence data to resolve relationships between genera in the Cacteae tribe of the Cactaceae family. Their study included 62 taxa within the tribe, and 4 from outgroups. The results support monophyly within the Cacteae, and they identified nine distinct clades within the tribe. They concluded that the three species of *Sclerocactus* they studied (which included *brevihamatus*) formed a well-supported clade with no affinities to *Pediocactus*, and that *Glandulicactus* should not be included in this clade. They mention *Ancistrocactus* Britton and Rose as a member of the Ferocactus clade, but unfortunately do not indicate the position of this genus in their cladogram nor explain this omission. This study might otherwise have helped explain the relationship, or perhaps synonymy, between *Ancistrocactus* and *Sclerocactus*, and perhaps shed light on the most appropriate classification of SCLTOB.

There are no published investigations focusing on genetic variation between and among the closely related species of *Sclerocactus* (or *Ancistrocactus*) in Texas and adjacent regions. This research need should be promoted to help resolve the lack of consensus among plant systematists regarding the proper classification and taxonomic status of SCLTOB.

Therefore, the genetic studies that have so far been published support the validity of the genus *Sclerocactus* as a taxonomic entity, but have not yet addressed the relationship between *Sclerocactus* and *Ancistrocactus*. Similarly, the genetic

differences between *Sclerocactus brevihamatus* ssp. *brevihamatus* and *S. brevihamatus* ssp. *tobuschii* have not been investigated.

2.3.1.4 Taxonomic classification or changes in nomenclature:

W. T. Marshall described the species as *Mammillaria tobuschii* from a specimen collected by Herman Tobusch in 1951 on the G. W. Henri Ranch, east of Vanderpool in Bandera County, Texas (Marshall 1952). A number of synonyms have been applied to this taxon, including *Ancistrocactus tobuschii* (W.T. Marshall) W.T. Marshall ex Backeb, *Echinocactus tobuschii* (W.T. Marshall) Weniger and *Ferocactus tobuschii* (W.T. Marshall) N.P. Taylor.

Systematics of the Cactaceae has always been controversial. No single treatment is universally accepted, and the steady accumulation of phylogenetic analyses has forced continual revisions. In particular, there is no consensus among cactus authorities regarding the taxa pertaining to the related genera of *Ancistrocactus*, *Sclerocactus*, and *Ferocactus*. The following sources provide a brief review of the prevailing classifications.

The Flora of North America (FNA) (2009) recognizes both *Ancistrocactus* (K. Schumann) Britton & Rose and *Sclerocactus* Britton & Rose as valid genera, and places the species *brevihamatus* in the former genus. With regard to the taxon *tobuschii*, they state:

> "*Ancistrocactus tobuschii* pertains to the north-easternmost populations, from typical *A. brevihamatus* by yellow flowers, rarely with a hint of pink (pinkish, greenish, or brownish in *A. brevihamatus*), smaller stems and fruits, and thinner, more delicate and yellow spines. All of those characteristics, sometimes considered diagnostic for *A. tobuschii*, are unsatisfactory. The oldest plants of *A. tobuschii* are especially similar to *A. brevihamatus*, but *A. tobuschii* occupies marginal habitat and seldom survives long. Varietal status may be warranted for this and at least two other eco-geographical races within the species.

The FNA treatment of *Sclerocactus* was written by K.D. Heil and J.M. Porter. A.D. Zimmerman and B.D. Parfitt are the authors of FNA's *Ancistrocactus* treatment. Zimmerman and Parfitt do not discuss the relationship between these two genera, but Heil and Porter state:

> "There has been considerable controversy concerning generic circumscription of *Sclerocactus*. Some treatments include *Ancistrocactus*, *Echinomastus*, *Glandulicactus*, and *Sclerocactus* as a single genus; whereas others exclude those groups, in addition to *Toumeya*, from *Sclerocactus*. Molecular phylogenetic studies of chloroplast DNA sequences (J. M. Porter et al. 2000; R. Nyffeler 2002) support a close relationship among *Ancistrocactus*, *Echinomastus*, *Toumeya*, and *Sclerocactus*; only *Toumeya* is included with *Sclerocactus* here.…*Ancistrocactus* is sister to

> *Echinomastus* and *Sclerocactus*, providing merit to a broader circumscription of *Sclerocactus*. *Glandulicactus* and *Pediocactus* are only distantly related to this group, bolstering their exclusion from *Sclerocactus*.

It should be noted that Nyffeler (2002) did not investigate either *Sclerocactus* or *Ancistrocactus*, nor discuss their relationship. Porter et al. (2000) investigated the relationship between *Sclerocactus* and *Toumeya*.

Tropicos (2009) appears to follow the FNA treatment by listing *Ancistrocactus brevihamatus* (Engelm.) Britton & Rose as the accepted name for this taxon. Inexplicably, Tropicos lists both *A. brevihamatus* and *Sclerocactus scheeri* (Salm-Dyck) N.P. Taylor as the accepted names for each other.

Powell et al. (2008) stated, "At present it is not clear whether *A. tobuschii* and *A. brevihamatus* should be regarded as distinct species, two intergrading varieties, or merely integrating flower-color morphs of the same taxon."

The Center for Plant Conservation (2009) and Desert Botanical Garden (2009) continue to recognize the name used by USFWS when the species was listed (*Ancistrocactus tobuschii*).

Tobusch fishhook cactus (a.k.a. shorthorn fishhook cactus) is recognized by the United States Department of Agriculture (USDA) PLANTS database (NRCS 2009), Integrated Taxonomic Information Service (IT IS; 2009), NatureServe Explorer (2009), and International Plant Names Index (IPNI; 2008) as *Sclerocactus brevihamatus* ssp. *tobuschii* (W.T. Marsh.) N.P. Taylor.

Rare Plants of Texas (Poole et al. 2007) recognizes the taxon as *Sclerocactus brevihamatus* (Engelm.) D.R. Hunt subsp. *tobuschii* (W.T. Marshall) N.P. Taylor. An excerpt of their description includes these diagnostic features: stems 3–15 cm tall by 1–15 cm wide; tubercles 5–12 mm long, shallowly grooved on the upper surface, roughly aligned into 8–12 ribs; radial spines 7–9 (–12); central spines 3–5, upper 2 forming an erect "V", lower central spine hooked; flowers bright yellow, sometimes pale or greenish; fruit elongate egg-shaped, green, pinkish at maturity; seeds dark brown to black, shiny. Regarding similar species, they state:

> "*Sclerocactus brevihamatus* subsp. *brevihamatus*, which occurs on the southern and western border of the range of *S. brevihamatus* subsp. *tobuschii*, looks almost identical. *Sclerocactus brevihamatus* subsp. *brevihamatus* has more radial spines (12–22), is larger and more cylindrical, and the flowers are dusky rose to yellowish-pink or olivaceous…Also, *S. brevihamatus* subsp. *brevihamatus* is found within south Texas brushland communities, such as cenizo shrubland…"

One of the reasons why the systematics of Cactaceae is so challenging is that many members of the family make very poor herbarium specimens. Diagnostic features, such as flower color, may be difficult to discern in dried specimens.

Nevertheless, sympatric populations of cacti that differ in flower color may attract different pollinators, and therefore be reproductively isolated and following separate phylogenetic paths. We accept the treatment of Poole et al. (2007) and their recognition of the taxon as a subspecies of *Sclerocactus brevihamatus*, because these are the only authors that have observed and studied these cacti as living specimens in the field, and they have done so for at least 20 years.

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.):

In 1979 when the species was federally-listed as endangered, less than 200 individuals had been documented in Bandera and Kerr Counties, Texas. The Tobusch Fishhook Recovery Plan states that the original populations in Bandera and Kerr Counties had been extirpated, but new populations had been found since 1985 in Real, Kimble, and Uvalde Counties (USFWS 1987). The TPWD NDD indicates that by 1999, 3,395 extant individuals had been documented in eight counties of the Edwards Plateau (Bandera, Edwards, Kerr, Kimble, Kinney, Real, Uvalde, and Val Verde).

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

The 1987 recovery plan stated, "The cacti occur in gravelly soils along rivers and plants are periodically disturbed by flooding. Severe floods will destroy plants but some disturbance appears to benefit the species because non-flooded areas become very grassy which tends to crowd out the cacti" (USFWS 1987). Although these observations accurately describe the type locality, Poole and Janssen (2002) noted:

> "When the original status report for Tobusch fishhook cactus (*Ancistrocactus tobuschii*) was written, the species was thought to occur primarily on gravel bars or limestone ledges along floodplains or stream terraces in two counties on the Edwards Plateau of central Texas (Weniger 1979). Thus, it was subject to threat from the inevitable flooding that shapes the Edwards Plateau. In fact, it was such a flood in August 1978 that destroyed two of the four known populations of Tobusch fishhook cactus, and led to the listing (USFWS 1979)…However by the early 1990s many new locations had been discovered, and the species was known from eight counties. Most sites were no longer in the floodplain, but found from lower slopes to ridge tops…"

Emmett (1995b) listed live oak (*Quercus fusiformis* Small), ashe juniper (*Juniperus ashei* Buchh.), Texas persimmon (*Diospyros texana* Scheele), elbowbush (*Forestiera pubescens* Nutt), and agarito (*Mahonia trifoliolata* Moric. Fedde) as the dominant plant species of SCLTOB sites at Walter Buck WMA, Devil's Sinkhole SNA, and Kickapoo Caverns SNA. Mexican piñón (*Pinus*

cembroides v. *remota* Little) was also present at Devil's Sinkhole and Kickapoo Caverns, but not Walter Buck. Although this list includes the most evident species in the general area of populations, these are not the species closely associated with SCLTOB within microsites. Emmett noted, "There was a great deal of apparently suitable habitat at all three sites where no Tobusch fishhook cacti were found during surveys."

Poole and Janssen (2002) provide a more detailed physical description of SCLTOB habitat:

> "Edaphically the habitat consists of discontinuous patches of very shallow, moderately alkaline, rocky loams or clays (primarily of the Tarrant, Ector, or Eckrant series) over massive, fractured limestone bedrock (usually the Edwards formation or an equivalent formation). Typically the sites are on level to slightly sloping hills or ridge tops of no particular aspect. Occasionally plants will be found on steeper slopes, but on level to gently sloping microsites. The sites are open, in full sunlight, with a thin herbaceous cover of grasses and other herbaceous species, but within a matrix of woodland or savanna. This surrounding community is primarily the live oak–juniper woodland community, although pinyon pine–oak is found in the western part of range, and the species is occasionally found in little bluestem grasslands or ceniza shrublands. The plants regularly grow in a thin layer of soil, gravel, rock crack, or spikemoss…associated species vary across the range…"

Emmett (1995b) noted that a wildfire at Devil's Sinkhole SNA in April 1988 burned the entire area where the largest known population of SCLTOB, with over 400 individuals in 2000 m^2, was later discovered. The larger cacti he observed in his study probably were present prior to and survived this fire. This revelation led him to observe, "If occasional disturbance is indeed required by *A. tobuschii* to maintain and/or allow the establishment of populations, human-caused suppression of natural disturbance factors such as fires and floods may be limiting the amount of suitable habitat available for *A. tobuschii* colonization and persistence."

SCLTOB plants were also discovered after prescribed burns were conducted at Lost Maples SNA and Kerr WMA. Poole et al. (2003) observed, "The fire appeared to have little, if any, permanent effect on the plants. Even when all the spines and tubercles are burned off, and the epidermis turns white, red, or purple, the cactus somehow manages to produce new epidermis and eventually tubercles and spines. At Lost Maples only one plant died directly from the fire." However, they noted that the lack of baseline data make it impossible to determine if other SCLTOB plants were burned up.

Sutton et al. (1997) investigated the fine-scale plant associations of the SCLTOB population at Walter Buck WMA in Kimble County. They visually estimated the percent cover of 41 plant species found in 1.0 m^2 plots centered on 291 individual

SCLTOB plants. The median number of associated species per plot was 5 (range of 1 to 12), and the composite plant cover was 33 percent; most quadrats ranged between 10 percent and 39 percent plant cover. The composite percent cover and percent frequency of seven cover classes were as follows:

Table 5. Cover classes in 1-m^2 plots centered on Tobusch fishhook cactus plants at Walter Buck WMA.

Cover Class	**Composite % Cover**	**% Frequency**
Coarse rock fragments	44	93
Grasses	26	n/r
Bedrock	19	69
Bare ground	4	13
Forbs	3	n/r
Pteridophytes	2	20
Woody and succulent plants	2	n/r

n/r = not reported.

These authors conclude that SCLTOB was most closely associated with coarse rock fragments and limestone bedrock. Table 6 lists the composite cover and frequency of all associated plant species detected on the plots, together with associated plant species reported by Lockwood (1995), Emmett (1995b), and the recovery plan (USFWS 1987).

Sutton (1997) investigated the initial effects of livestock grazing, prescribed burning, Ashe juniper removal, and combinations of these treatments on stem diameter, flower and fruit production, and mortality of SCLTOB at Walter Buck WMA. The livestock grazing treatment had a stocking rate of 1 animal unit per 16.2 ha (40 ac). The prescribed burns were conducted on January 29, January 30, and February 4, 1996. Ashe juniper trees were cut by hand, or with a Bobcat broadax; the cut stems were left un-piled on the ground. The author concluded that the mortality rates for grazing (18.1 percent), combined juniper removal and grazing (37 percent), and combined juniper removal, grazing, and prescribed burning (22.2 percent) were significantly higher than mortality rates in the control (6.7 percent). No significant differences were evident between the control and burning, juniper removal, burning combined with juniper removal, and burning combined with grazing. However, the treatments compared here were not replicated. It is unfortunate that it is often impractical or impossible to replicate treatments when ecological data are collected to compare land management practices. Furthermore, the sample sizes of several treatments were too small to meet the minimum sample size requirements for chi-square or G-tests of contingency tables; all expected cell values should be greater than five (Norma Fowler, University of Texas, pers. comm. 2009). Therefore, while these data do suggest that SCLTOB mortality was higher in grazed areas, it is difficult to draw inferences from the results or to attribute the higher mortality directly to grazing. Finally, the observed mortality in burned (2 of 10 SCLTOB), burned and juniper removal (1 of 8 SCLTOB), and burned and grazed (1 of 5 SCLTOB) treatments

might have been lower if the prescribed burning had not been done when the cactus was entering its peak flowering season (from late January to early April).

Baccus (1999) continued through 1998 the demographic study begun by Sutton in 1996. During this time, the population declined from 463 to 276 individual SCLTOB.

Table 6. Plants associated with Tobusch Fishhook Cactus

		Sutton et al. 1997		Lockwood 1995	Emmett 1995b	Recovery Plan
Genus	**Species**	**% Cover**	**% Freq.**	**Present**	**Present**	**Present**
I. Grasses and sedges						
Aristida	*spp.*	2	44			
Bothriochloa	*laguroides ssp. torreyana*	<1	<25			
Bouteloua	*curtipendula*	6	50			X
Bouteloua	*hirsuta*	4	38			
Bouteloua	*rigidiseta*	<1	<25			
Bouteloua	*trifida*	2	32			
Dichanthelium	*pedicellatum*					X
Digitaria	*cognata*	1	22			
Elymus	*canadensis*					X
Eragrostis	*intermedia*	<1	<25			
Erioneuron	*pilosum*	<1	<25			
Hilaria	*belangeri*	4	27			
Muhlenbergia	*reverchonii*	<1	<25			
Nassella	*leucotricha*	<1	<25			
Panicum	*hallii*	3	46			
Rhynchospora	*nivea*					X
Schizachyrium	*scoparium*	<1	<25			
Sporobolus	*compositus*	<1	<25			
Tridens	*muticus*	<1	<25			
Tripsacum	*dactyloides*					X
II. Forbs						
Acalypha	*phleoides*	<1	13			X
Anemone	*berlandieri*			X		
Aphanostephus	*ramosissimus*	<1	7			
Asclepias	*viridis*					X
Boerhavia	*linearifolia*	<1	<1			
Calylophus	*berlandieri*					X
Centaurium	*calycosum*					X
Chaetopappa	*bellidifolia*					X
Chaetopappa	*effusa*					X
Chamaesyce	*angusta*					X
Chamaesyce	*serpens*	<1	12			
Chasmanthium	*latifolium*					X
Chrysactinia	*mexicana*					X
Croton	*monanthogynus*	<1	2			
Desmanthus	*velutinus*					X
Dryopteris	*filix-mas*					X
Euphorbia	*cyathophora*					X
Euphorbia	*marginata*					X
Evax	*verna*	<1	3			
Fallugia	*paradoxa*					X

		Sutton et al. 1997		Lockwood 1995	Emmett 1995b	Recovery Plan
Genus	**Species**	**% Cover**	**% Freq.**	**Present**	**Present**	**Present**
Gaillardia	*pulchella*					X
Gaillardia	*suavis*					X
Galphimia	*angustifolia*	<1	1			X
Giliastrum	*incisa*					X
Giliastrum	*rigidulum*					X
Glandularia	*binnatifida*	<1	3			
Hedeoma	*drummondii*					X
Lespedeza	*texana*					X
Liatris	*mucronata*					X
Lithospermum	*inicisum*					X
Matelea	*edwardsensis*					X
Melampodium	*leucanthum*					X
Mentzelia	*oligosperma*					X
Nolina	*lindheimeriana*					X
Oxalis	*drummondii*	<1	1			
Paronychia	*jamesii*					X
Phyllanthus	*polygonoides*	<1	14			X
Plantago	*helleri*					X
Polanisia	*dodecandra*					X
Polygala	*lindheimeri v. parvifolia*					X
Portulaca	*pilosa*	<1	5			
Salvia	*farinacea*					X
Salvia	*roemeriana*					X
Scutellaria	*wrightii*					X
Selaginella	*peruviana*	2	20	X		
Sida	*abutifolia*	<1	27			
Stillingia	*texana*					X
Tetraneuris	*scaposa*					X
Teucrium	*canadense*					X
Thelesperma	*curvicarpum*					X
Thymophylla	*pentachaeta*	<1	3			
Tragia	*nigricans*					X
Tragia	*spp.*	<1	39			
Unidentified forbs		<1	24			
Verbena	*canescens*	<1	25			
Verbesina	*microptera*					X
Vernonia	*lindheimeri*					X
Wedelia	*hispida*					X
Yucca	*rupicola*	<1	1			X
III. Cacti						
Coryphantha	*sulcata*				X	X
Cylindropuntia	*leptocaulis*				X	

		Sutton et al. 1997		Lockwood 1995	Emmett 1995b	Recovery Plan
Genus	**Species**	**% Cover**	**% Freq.**	**Present**	**Present**	**Present**
Echinocactus	*texensis*				X	
Echinocereus	*coccineus*			X	X	
Echinocereus	*enneacanthus*			X	X	
Echinocereus	*reichenbachii v. reichenbachii*				X	
Echinocereus	*spp.*	<1	<1			
Epithelantha	*micromeris*			X	X	X
Mammilaria	*heyderi*	<1	<1		X	
Opuntia	*engelmannii v. lindheimeri*				X	
Opuntia	*phaeacantha*				X	
Opuntia	*spp.*	<1	18	X		
Sclerocactus	*brevihamatus ssp. tobuschii*	<1	2			
IV. Trees, shrubs and vines						
Acacia	*spp.*	<1	1			
Baccharis	*texana*					X
Brickellia	*dentata*					X
Cephalanthus	*occidentalis*					X
Diospyros	*texana*				X	X
Eysenhardtia	*texana*					X
Forestiera	*pubescens*				X	
Forestiera	*reticulata*					X
Fraxinus	*texensis*					X
Garrya	*ovata ssp. lindheimeri*					X
Juglans	*microcarpa*					X
Juniperus	*ashei*	<1	7		X	X
Mahonia	*trifoliata*			X	X	X
Pinus	*remota*			X	X	
Platanus	*occidentalis*					X
Quercus	*fusiformis*	<1	2		X	X
Quercus	*laceyi*					X
Quercus	*pungens*			X		
Quercus	*texana*					X
Rhus	*aromatica*					X
Rhus	*virens*	<1	<1			X
Smilax	*bona-nox*					X
Sophora	*secundiflora*					X
Toxicodendron	*radicans*					X
Ungnadia	*speciosa*					X

For consistency, this table employs the taxonomic nomenclature of USDA PLANTS, http://www.plants.usda.gov, accessed August 8, 2009.

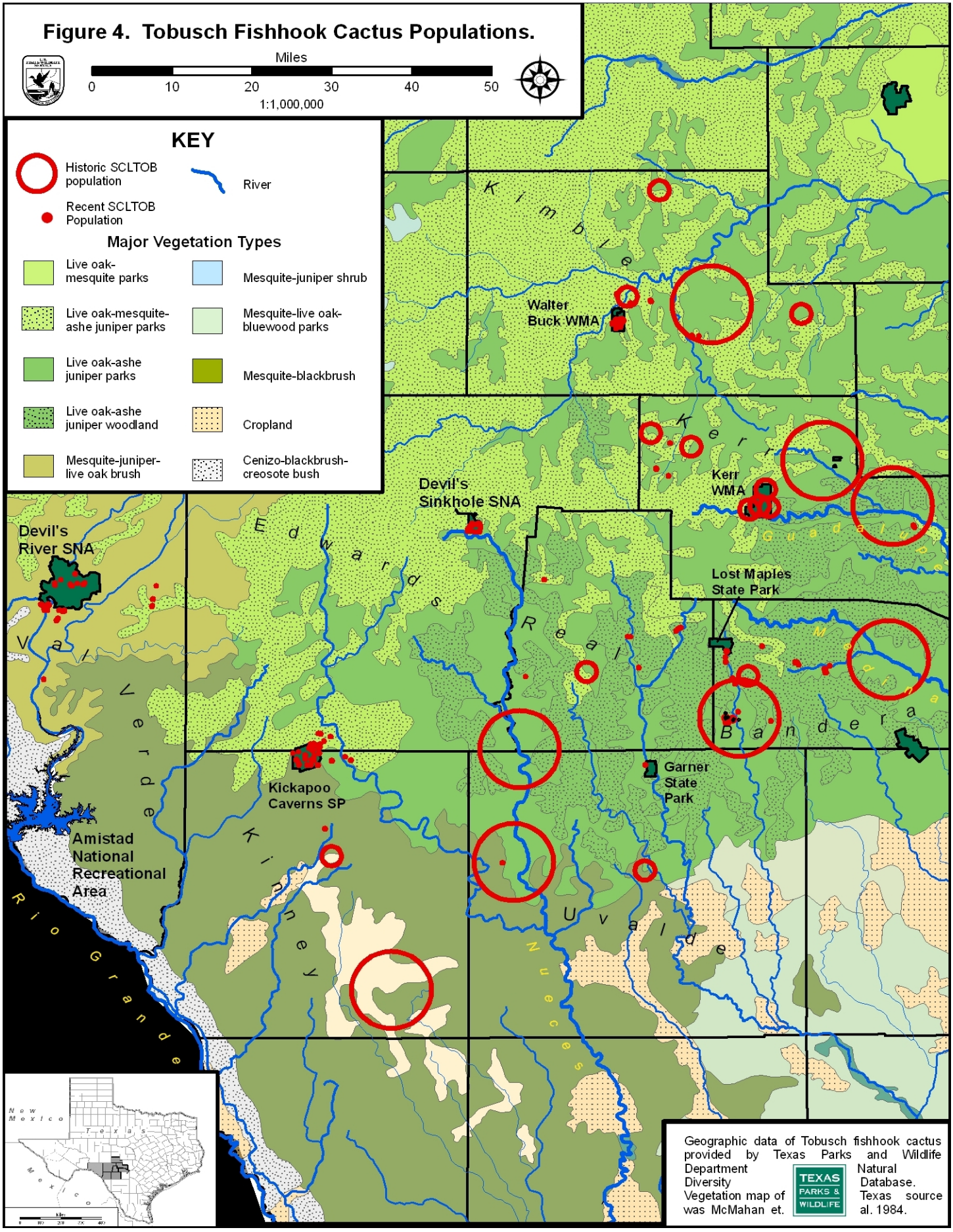
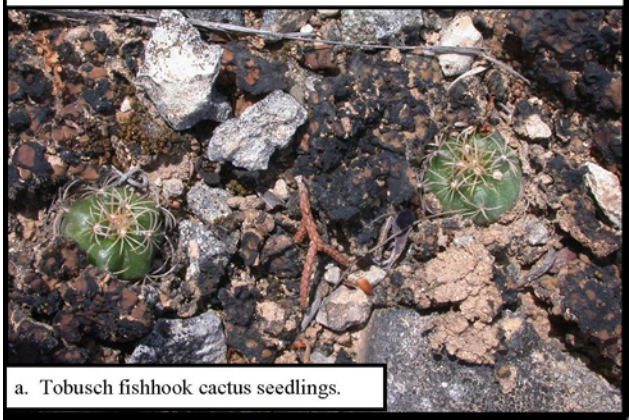


Figure 4. Tobusch Fishhook Cactus Populations.
Miles
0 10 20 30 40 50
1:1,000,000
KEY
Historic SCLTOB population
Recent SCLTOB Population
River
Major Vegetation Types
Live oak-mesquite parks
Live oak-mesquite-ashe juniper parks
Live oak-ashe juniper parks
Live oak-ashe juniper woodland
Mesquite-juniper-live oak brush
Mesquite-juniper shrub
Mesquite-live oak-bluewood parks
Mesquite-blackbrush
Cropland
Cenizo-blackbrush-creosote bush
Kimble
Walter Buck WMA
Kerr
Kerr WMA
Devil's Sinkhole SNA
Devil's River SNA
Edwards
Real
Lost Maples State Park
Medina
Bandera
Val Verde
Kickapoo Caverns SP
Garner State Park
Amistad National Recreational Area
Kinney
Uvalde
Nueces
Rio Grande
New Mexico
Texas
Mexico
Geographic data of Tobusch fishhook cactus provided by Texas Parks and Wildlife Department Natural Diversity Database. Vegetation map of Texas source was McMahan et. al. 1984.
TEXAS PARKS & WILDLIFE

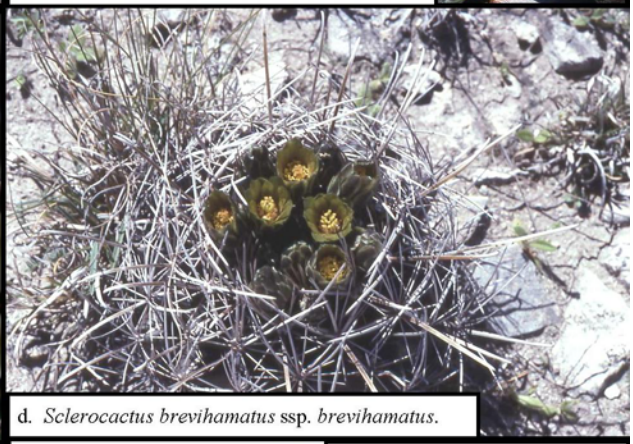
Figure 5. Photographic images.



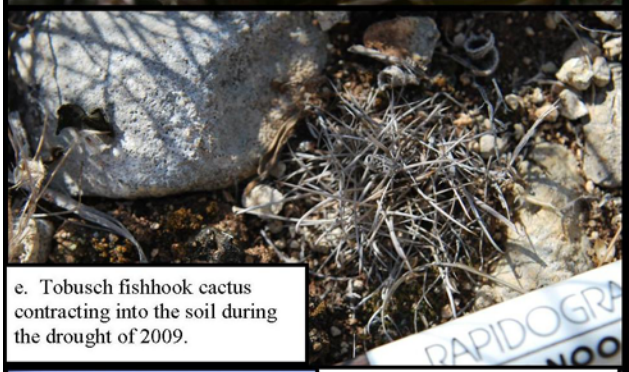
a. Tobusch fishhook cactus seedlings.

b. Mature flowering Tobusch fishhook cactus.

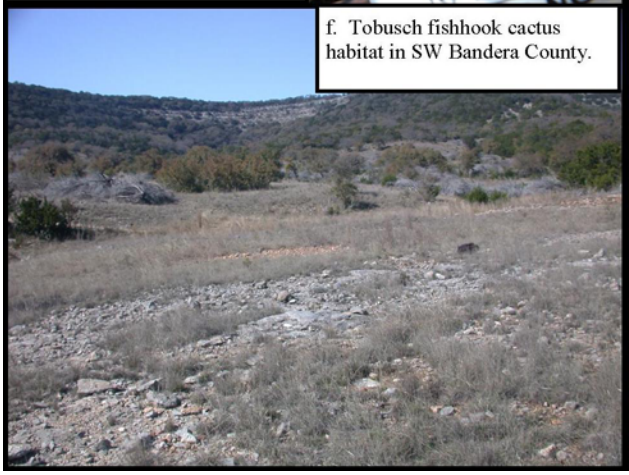
c. Flowers of *Sclerocactus brevihamatus* ssp. *tobuschii*.



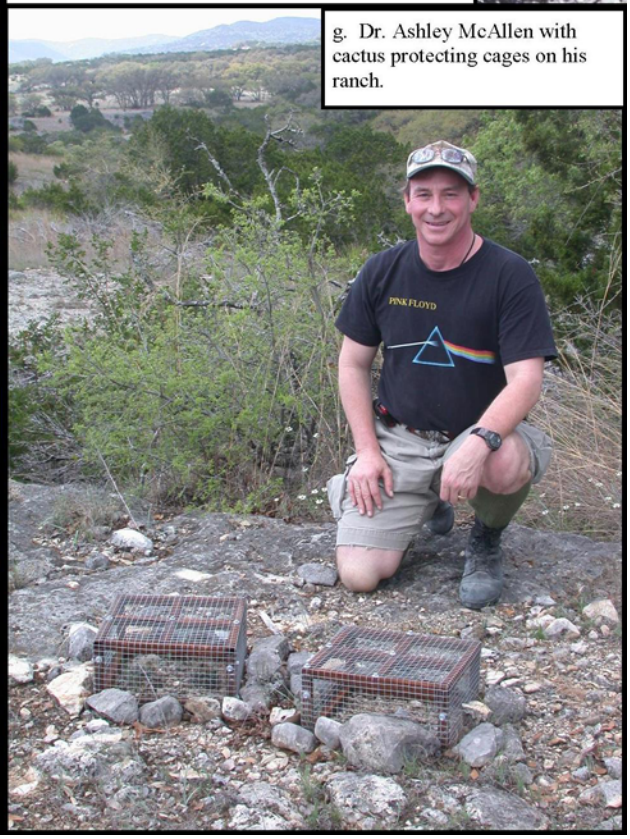
d. *Sclerocactus brevihamatus* ssp. *brevihamatus*.



e. Tobusch fishhook cactus contracting into the soil during the drought of 2009.



f. Tobusch fishhook cactus habitat in SW Bandera County.



g. Dr. Ashley McAllen with cactus protecting cages on his ranch.

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

The recovery plan lists four threats to the continued survival of Tobusch fishhook cactus, but does not apply the five-factor analysis (USFWS 1987). These threats are: 1) real estate development; 2) livestock damage; 3) habitat modification by natural factors; and 4) collection.

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

Relatively little urban and industrial development is occurring within the semi-arid, sparsely populated eight-county range of Tobusch fishhook cactus. However, a significant ongoing trend throughout the species' range is the subdivision of large ranches into many small "ranchettes," leading to a proliferation of roads, fences, power lines, and residential development, all of which contribute incrementally to habitat loss and fragmentation.

Land subdivision also engenders changes in land use and management which may be both beneficial and detrimental to SCLTOB. For example, the predominant, historic land use throughout the Edwards Plateau has been grazing of cattle, sheep, and horses. In many cases, poor rangeland management during the last century has caused the depletion of herbaceous vegetation, cessation of the natural wildfire cycle, proliferation of dense juniper shrublands, soil erosion, and reduced infiltration and storage of rainwater in the soil profile; all of these changes are likely to have harmed SCLTOB populations. The change to a primarily recreational land use usually entails continued grazing, in order to obtain agricultural tax benefits, but at the lowest possible stocking density. Currently, both large and small landowners are more aware of and concerned with conservation issues than during the last century. Prescribed burning may be one of the most important vegetation management tools for sustaining SCLTOB populations; the proliferation of residential development within the species' habitat takes this tool out of the natural resource manager's hands.

The subdivision of privately-owned land and associated threats are likely to continue. These threats can best be mitigated through the following measures:

- appropriate management of the existing protected sites;
- protection of additional SCLTOB habitat through fee-title land acquisition and conservation easements;
- continued public outreach and education regarding the species and the appropriate management of its habitat.

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

Many rare cactus populations have been depleted by overzealous collectors. The recovery plan lists collection by unscrupulous cactus and succulent fanciers as a threat to the species. Poole (1991) found six specimens of SCLTOB, grown legally from seed, for sale in commercial nurseries. Poole and Janssen (2002) noted that one population of SCLTOB was heavily depleted by collection, but concluded that "collection is not currently perceived to be a grave threat." Although illicit collection has not significantly impacted the species, the wild populations openly accessed by the public remain vulnerable to this potential threat. As with other forms of catastrophic loss, this threat can be mitigated through seed or germ-plasm banking of the vulnerable populations, and the development of successful propagation and reintroduction techniques. Furthermore, it is more practical and economical for cactus collectors to obtain SCLTOB plants and seeds propagated from captive versus wild-collected plant material. Therefore, the threat of illicit collection is diminished by the availability of legally-propagated SCLTOB plant material.

2.3.2.3 Disease or predation:

The Tobusch fishhook cactus weevil parasitizes and kills SCLTOB plants, and has contributed significantly to drastic declines in many of the known populations. A species of longhorn beetle (*Moneilema armata*) and an unidentified ant species have also caused mortality at some sites (Poole et al. 2003). Mammals, including deer, javelina, armadillos, feral hogs, and rodents occasionally browse the stems; Poole et al. (2003) believed this accounted for less than two percent of attributable mortality from 1998–2002. If the root systems are not too badly damaged, they may regenerate one or more new stems.

Emmett (1995b) suggested protecting SCLTOB populations from its weevil parasite, but this raises an interesting philosophical question. Considering that the weevil (*Gerstaeckeria* sp. nov.) is a new species, and that it apparently is an obligate parasite of Tobusch fishhook cactus (Poole et al. 2003), the weevil itself can be no less endangered than its host; the weevil species, however, has not been listed or proposed for listing under the ESA.

Periodic outbreaks of weevil parasitism appear to be an unavoidable natural cycle. For this reason, the recovery criterion of 3,000 individuals per population may be unattainable or unsustainable, as such large cactus populations would eventually host very large weevil populations, leading to their collapse. Populations that have been reduced by weevil parasites might be augmented through the reintroduction of plants propagated from material stored in a seed or germ-plasm bank. However, there is a danger that too many SCLTOB plants established over too large an area might only allow the weevil population to persist at high levels or to spread to more populations. The most appropriate conservation strategy

may be to protect larger numbers of small, widely-spaced populations, rather than fewer large populations that are more vulnerable to weevil-induced devastation. Nevertheless, it is important to preserve representative material from each population in seed and germ-plasm banks to prevent the gradual loss of genetic diversity through catastrophic losses caused by weevils or other phenomena.

The recovery plan stated "*Ancistrocactus tobuschii* plants have been observed that were either uprooted or had apical meristem injuries from livestock trampling." Nevertheless, livestock trampling and herbivory have not subsequently been identified as significant causes of mortality or damage to SCLTOB plants. The recurved spines and small size probably protect SCLTOB plants from livestock herbivory. Livestock are not attracted to the sparesely vegetated outcrops where SCLTOB plants typically occur, and the plants are often nestled among larger rocks. While livestock trampling probably occurs in grazed habitats, we have no evidence that it represents a significant threat to the species.

2.3.2.4 Inadequacy of existing regulatory mechanisms:

Federally-listed plants occurring on private lands have limited protection under the ESA, unless also protected by State laws; the State of Texas also provides very little protection to listed plant species on private lands. Approximately 95 percent of Texas land area is privately-owned. It is reasonable to assume that the vast majority of existing Tobusch fishhook cactus habitat, including sites that have not been documented, occurs on private land. Therefore, most of the species' populations and habitats are not subject to Federal or State protection unless there is a Federal nexus, such as provisions of the Clean Water Act or a federally-funded project.

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. Tobusch fishhook cactus was listed as endangered by the State of Texas on April 29, 1983. The State of Texas 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 ESA does provide some protection for listed plants on land under Federal jurisdiction. However, SCLTOB populations have not been documented on Federal land.

International trade of SCLTOB (as *Sclerocactus brevihamatus* ssp. *tobuschii*) is regulated under CITES Appendix I (Convention on International Trade in

Endangered Species of Wild Fauna and Flora 2009).

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).

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 emission 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 southwestern U.S. 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 to30 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 changes that have already occurred have affected Tobusch fishhook cactus 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 Tobusch fishhook cactus occur in eight counties of the Edwards Plateau in central Texas. Rising temperatures might enable the species to survive further north than at present, but might also reduce the southern limit of the range. Similarly, decreasing precipitation could favor an eastward shift in geographic 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 could impede the 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). The species' range in central Texas could experience both

decreased annual precipitation as well as increased storm severity. Changes in temperature and rainfall amounts and patterns could alter the species' competitive advantage in the unique micro-habitats it now inhabits. Regardless of how these changes may affect the autecology of Tobusch fishhook cactus, the altered synecology may be far more significant. For example, higher winter temperatures could increase populations of the parasitic insects that kill this cactus. Conversely, higher temperatures and altered rainfall patterns could increase the frequency or intensity of wildfires, which might benefit Tobusch fishhook cactus by reducing competition from native and introduced grasses and Ashe juniper. The possible effects of climate change on the synecology of the species and its 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.

2.4 Synthesis.

The status of Tobusch fishhook cactus is now known to be significantly more secure than when it was listed. The total known population exceeded 3,000 individuals by 1999, and the combined populations of 8 protected areas that are monitored annually by TPWD totaled 3,129 individuals in 2008. There has also been considerable progress toward meeting the recovery plan objectives. The cactus had been documented at 10 protected sites, and its known range now extends to 8 counties in the Edwards Plateau of central Texas. Nine published research projects have contributed valuable information on the biology, life history, and management of SCLTOB. Demographic investigations, begun in 1991 and now continued annually by TPWD, are tracking the long-term trends of many of the most important populations.

Nevertheless, the species continues to face significant threats of both natural and anthropogenic nature. The Tobusch fishhook cactus weevil, together with other insect parasites, has contributed significantly to dramatic declines in many populations. Poor rangeland management has probably impacted the species throughout its range for at least a century; specifically, increased juniper density, lack of wildfire, and reduced infiltration and storage of rainwater into the soil may all be to the detriment of the species and its habitats. Although the more recent science and practice of rangeland management have improved considerably, the continued subdivision of land and subsequent residential development have augmented the loss and fragmentation of habitats throughout the species' range. Changes in land use from ranching to recreation create new threats and challenges, but may also bring new opportunities for conservation. Although the total known population has steadily increased, this is attributed largely to the continued discovery of new sites and individuals, rather than true recruitment. The species has a high mortality rate in the wild, and many of the monitored populations have declined significantly.

In consideration of the greater known range and larger, currently stable populations of Tobusch fishhook cactus, we believe it is no longer in danger of extinction throughout all or a significant portion of its range. However, it is likely that the species could readily

become endangered, due to the significant threats from parasitic insects. Other threats, including land subdivision and land use changes, could also contribute to a steady decline in habitat quantity and suitability. Therefore, we recommend that the status be changed to threatened even though the downlisting criterion of establishing at least four safe sites that contain at least 3,000 plants each has not been met. The recovery plan was signed in 1987 and needs to be revised to include both downlisting and delisting criteria that address each recovery objective in terms of the threats to the species. The objectives and their criteria should be updated to include new information regarding the species' range, habitat, life history, and threats. Also, the recovery priority number should be changed to 9C (see section 3.2).

3.0 RESULTS

3.1 Recommended Classification:

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

3.2 New Recovery Priority Number: 9C

Brief Rationale:

Tobusch fishhook cactus was listed with a recovery priority number of 2. The discovery of many new sites over a much broader range, including populations in 10 protected areas, reduces the degree of threat from imminent extinction. However, there are still significant threats from insect parasitism, land subdivision and residential development, and land use changes. Much of the potential habitat for the species is privately-owned. All populations are subject to gradual decline in habitat quality due to competition from increased juniper density; this might be ameliorated by periodic juniper cutting, or by prescribed burning, or both. In the aggregate, the degree of threat is moderate. The increased knowledge of the species' range, habitat, life history, and propagation contribute to justify a high potential for recovery. Although systematic botanists do not all agree on the taxonomic status of Tobusch fishhook cactus, we believe it is best classified as a unique subspecies of *Sclerocactus brevihamatus*. Conservation of the species and its habitat may conflict with land subdivision and residential development, construction of new highways, power lines and pipelines, and livestock grazing if the rangeland is not well managed. Therefore, the "C" designation indicates potential conflict with economic activity.

3.3 Reclassification from Endangered to Threatened Priority Number: 6

Brief Rationale:

The determination of priority for species reclassification from "endangered" to "threatened" is described in 48 FR 43103. The management impact is low, since the current classification of "endangered" does not incur an unwarranted management burden nor unnecessarily restrict human activities. The Service did not receive a petition to consider this reclassification.

4.0 RECOMMENDATIONS FOR FUTURE ACTIONS.

The Tobusch fishhook cactus recovery plan should be revised to include both downlisting and delisting criteria that address each recovery objective in terms of the threats to the species. The objectives and their criteria should be updated based on new information regarding the species' range, habitat, life history, and threats. The revised objectives and their criteria must be specific, measurable, achievable, realistic, and time-referenced, in accordance with the revised recovery planning guidance (National Marine Fisheries Service 2007). The existing downlisting criterion calling for 4 protected populations of 3,000 individuals should be modified to a larger number of protected or managed populations, each with a much lower minimum population size. A more appropriate criterion may be to protect larger numbers of relatively small, discontiguous populations. This would very likely involve the support of many private landowners.

Systematic botanists continue to debate the phylogeny and taxonomy of the entire Cactus Family. Not all cactus specialists agree on the taxonomic status of Tobusch fishhook cactus as a unique species or subspecies. The debates will likely rage on as more phylogenetic data continues to emerge. We concur with the treatment adopted by the botanists who are most familiar with this taxon in its wild environment, as expressed in *Rare Plants of Texas* (Poole et al. 2007), and we recommend recognition of Tobusch fishhook cactus as a valid subspecies, *Sclerocactus brevihamatus* ssp. *tobuschii*. We should be prepared to revise this classification if the evidence of peer-reviewed scientific investigations indicates otherwise.

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

1. Continue monitoring and surveying the established protected reserves.
2. Conduct surveys of high-potential habitat within the known range of the species, focusing on sites that have not previously been surveyed.
3. Establish new reserves, using the LBJWC conservation fund and other resources.
4. Conduct public outreach efforts to encourage conservation of the species and its habitat on private lands; establish a private landowner support group, similar to the group now actively working to conserve Texas snowbells (*Styrax platanifolius* ssp. *texanus*).
5. Continue to investigate ecology and management, with special emphasis on woody plant control and prescribed burning; compare effects of prescribed burning conducted at different times of the year.
6. Investigate the factors influencing reproduction and dispersal in the wild, with emphasis on the fate of seeds collected by ants.
7. Apply sound management, as needed, to protected sites.
8. Investigate the phylogenetic and taxonomic relationship between *Sclerocactus brevihamatus* ssp. *brevihamatus*, *S. brevihamatus* ssp. *tobuschii*, *S. scheeri*, and other closely related taxa of *Sclerocactus* and/or *Ancistrocactus*.
9. Collect seeds of representative populations for propagation and seed banking, establish germ-plasm (live plant) refugia, and develop techniques for successful propagation and reintroduction.
10. Revise the 1987 recovery plan.

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PHOTOGRAPHIC AND MAP CREDITS

The photograph of *Sclerocactus brevihamatus* ssp. *brevihamatus* (figure 5, photograph "d") was provided by Jackie M. Poole, TPWD. All other photographs and maps were provided by Chris Best, USFWS.

GLOSSARY OF TECHNICAL TERMS

Autecology	Ecology of individual species.
Chloroplast	A double-membrane organelle found in higher plants in which photosynthesis takes place.
Clade	The scientific classification of living and fossil organisms to describe a monophyletic group, defined as a group consisting of a single common ancestor and all its descendants (Wikipedia 2009).
Cladogram	Graphical representation of one or more clades.
Diploid	Organism possessing two replicate sets of chromosomes.
Edaphic	Adjective referring to soil.
Epidermis	The outer surface (skin) of plants and other higher organisms.
Funiculus	Stalk attaching an ovule to the ovary wall in a flower or fruit (Wikipedia 2009)
Intron	DNA region within a gene that is not translated into protein (Wikipedia 2009).
Meiosis	The division of spore mother cells into gametes with half the original chromosome number.
Monophyly	A group of organisms which consists of all the descendents of a single common ancestor.
Papillate	Possessing a minute nipple-shaped projection (Correll and Johnston 1970).
Phylogeny	The study of evolutionary relatedness among various groups of organisms (e.g., species, populations), which is discovered through molecular sequencing data and morphological data matrices (Wikipedia 2009).
Synecology	Ecology of groups of organisms.
Tubercle	Uniform bulges or protuberances of the surface structure of some members of the Cactus family.

U.S. FISH AND WILDLIFE SERVICE
5-YEAR REVIEW of *SCLEROCACTUS BREVIHAMATUS* ssp *TOBUSCHII*

Current Classification: Endangered.

Recommendation resulting from the 5-Year Review:

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

Appropriate Listing/Reclassification Priority Number, if applicable: 6

Review Conducted By: Chris Best and Sohini Bandy, Austin Ecological Services Field Office.

FIELD OFFICE APPROVAL:

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

Approve _____ Date 9/9/09

REGIONAL OFFICE APPROVAL:

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

Approve _____ Date 01/05/10