REVIEW OF THE LIFE HISTORY AND CONSERVATION OF FEDERALLY ENDANGERED PLANT SPECIES OF THE LOWER RIO GRANDE VALLEY, TEXAS, U.S.A.

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ABSTRACT

This review aims to summarize information critical to the conservation of the federally listed endangered species of South Texas, which occur along the border of Texas and Mexico. This paper describes the characteristics, habitat, population status, distribution, life history, threats, and restoration of endangered plant species of the Lower Rio Grande Valley, Texas, which includes Cameron, Willacy, Hidalgo, and Starr County. Seven federally listed species are considered including *Ambrosia cheiranthifolia*, *Asclepias prostrata*, *Astrophytum asterias*, *Ayenia limitaris*, *Manihot walkerae*, *Lesquerella thamnophila* (syn. *Physaria thamnophila*), and *Thymophylla tephroleuca*. An eighth species, *Physostegia correllii* is under consideration for federal listing by the U.S. Fish and Wildlife Service. This paper assembles information on the background, biological status, major threats, and conservation to aid managers and the scientific community in restoring and managing these species.

RESUMEN

El objetivo de esta revisión es resumir la información crítica para la conservación de las especies en peligro de extinción incluidas en la lista federal del sur de Texas, que se encuentran a lo largo de la frontera entre Texas y México. En este documento se describen las características, el hábitat, el estado de la población, la distribución, el ciclo biológico, las amenazas y la restauración de las especies vegetales en peligro de extinción del Valle Inferior del Río Grande, Texas, que incluye los condados de Cameron, Willacy, Hidalgo y Starr. Se consideran siete especies incluidas en la lista federal, entre ellas *Ambrosia cheiranthifolia, Asclepias prostrata, Astrophytum asterias, Ayenia limitaris, Manihot walkerae, Lesquerella thamnophila* (syn. *Physaria thamnophila*) y *Thymophylla tephroleuca*. Una octava especie, *Physostegia correllii*, está siendo considerada por el Servicio de Pesca y Vida Silvestre de EE.UU. para su inclusión en la lista federal. Este documento reúne información sobre los antecedentes, el estado biológico, las principales amenazas y la conservación para ayudar a los gestores y a la comunidad científica a restaurar y gestionar estas especies.

INTRODUCTION

The objective of this paper is to assemble and review information that is not readily accessible to managers and the scientific community, including the fragmented literature on the ecology and conservation of seven endangered plant species occurring in the Lower Rio Grande Valley National Wildlife Refuge, which includes

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Cameron, Willacy, Hidalgo, and Starr counties, Texas along the Texas-Mexico border. Information on each rare species is organized in sections alphabetized by Latin plant name. Another species is considered, *Physostegia correllii*, which is under consideration for federal listing by the U.S. Fish and Wildlife Service. Delisted species such as *Frankenia johnstonii* are not included in the review (USFWS 2016a,b; Table 1). These rare species have been protected using the process afforded by the U.S. Endangered Species Act of 1973 (UWFWS 1973).

The review includes the morphological characteristics and legal status of each species considered, as well as the habitat, and occurrences of populations in South Texas. Essential aspects of the biology and threats are included to aid regional conservation efforts for these species. Nomenclature follows the USDA Plants Database (USDA 2024). Names from the Missouri Botanical Garden (Stevens 2024) and common names are provided in Table 1.

AMBROSIA CHEIRANTHIFOLIA A. GRAY (ASTERACEAE)

1.1. Characteristics and status

Ambrosia cheiranthifolia (Rio Grande ragweed, South Texas ambrosia; Table 1) is an herbaceous perennial with erect stems and ashy blue-gray, mostly entire leaves (Fig. 1-1) (Correll & Johnston 1979; Lehman et al. 2005; Poole et al. 2007; USFWS 2018). The oblanceolate leaves typically are unlobed and positioned alternately and sometimes oppositely near the base of the stem (Poole et al. 2007; USFWS 2018). Characterized as monecious, the light-yellow male flowers are smaller and more saucer-shaped than the female flowers, which are positioned in the leaf axils in small clusters (Poole et al. 2007; USFWS 2018).

Status.—*Ambrosia cheiranthifolia* was listed as federally endangered in 1994 (USFWS 1994) and has been listed as critically imperiled by the state of Texas (TPWD 2024). NatureServe (2024) ranks the species as G2 (imperiled) (Table 1). A multispecies recovery plan for this species' habitat, the Texas Coastal Bend shortgrass prairie, was finalized and is available from USFWS (2018).

1.2. Habitat and occurrence

Ambrosia cheiranthifolia occurs within the Texas Coastal Bend region, specifically in Nueces and Kleberg counties, Texas in coastal shortgrass prairies (Lehman et al. 2005; USFWS 2018) and grows on unplowed short grass prairie remnants, especially within mowed grassland (e.g., parks, cemeteries, railroads, highway right-of-ways) or eroding banks of creeks (Poole et al. 2007). The species occurs in soils of the Pleistocene Deltas, which were deposited by the San Antonio and Nueces rivers during the Pleistocene or Ice Age (Lehman et al. 2005). These soils are composed of deposits of calcareous clay, silt, and sandy loams mostly in the Beaumont and Victoria Clay soil series (Franki et al. 1965; Poole et al. 2007).

Occurrences.—*Remnant populations occur in drainage systems of fragmented shortgrass prairies watersheds of the Texas Coastal Bend including the Oso, Chiltipin Creek-San Fernando, Alazan Bay-Baffin Bay, and Santa Gertrudis Creek basins (Fig. 1-2; USFWS 2018). As of 2014, there were only seven extant, scattered populations with small numbers of individuals in each population (Fig. 1-2; USFWS 2018).

1.3. Biology

Ambrosia cheiranthifolia reproduces vegetatively through clonal production (Turner 1983 as reported in USFWS 1994) and by sexual reproduction (USFWS 2018). The flowers appear after rainfall events from late summer to fall (A. Hempel 2010, written comm., 13 Jan 2010, as stated in USFWS 2018) and are both wind and insect pollinated (Stebbins 1970). As is the case for all species considered in this review, there is little specific information related to the pollination of the species, particularly the role of pollinators.

Congenerics of *A. cheiranthifolia,* such as *A. artemisiifolia* L., can germinate after forty years of surface soil burial (Darlington 1922; Baskin & Baskin 1998), suggesting that species in this genus have long-lasting seed banks. The seeds of *A. trifida* L. lose dormancy if cold-stratified at 5°C for three months while *A. artemisiifolia* reenters dormancy if air-dried at room temperature (Baskin & Baskin 1998). The seeds *A. artemisiifolia* also enter dormancy when temperatures rise in the summer (Baskin & Baskin 1998), but the exact nature of the longevity of the seed banks of *A. cherianthifolia* is not known.

Table 1. Species conservation statuses for rare species of South Texas by the USFWS under the Endangered Species Act (USFWS 1973), at the state level within Texas (TPWD 2011, 2024), and globally as assessed by NatureServe (2023a,b) by Latin name, and common name. The year for the FWS listing, recovery plan, and 5-year review are referenced in the Literature Cited section by year listed in the column under "USFWS." Multiple citations in a given year are designated by letter. The meanings and interpretations of the statuses shown can be found in Sec.3.6 and Sec.4.a of the U.S. Endangered Species Act of 1973 for the U.S. designation, in TPWD (2011, 2024) for the Texas designations, and in NatureServe (2024a,b) for the global designations. *USFWS (2016) is a post-delisting monitoring plan. N/A is "not available." "+" is an amendment to an earlier recovery plan. Recent updates to nomenclature are denoted as "†" (Stevens 2024).

Latin name	Common name	USFWS listing	USFWS recovery plan	USFWS 5-yr review	United States	Texas	Nature Serve Global
Ambrosia cheiranthifolia A. Gray	Rio Grande ragweed	1994	2018	2022b	Federally endangered	Endangered S1	Imperiled (G2)
Asclepias prostrata Blackwell	Prostrate milkweed	2023	N/A	N/A	Federally endangered	Endangered S1	Critically imperiled (G1)
Astrophytum asterias (Zucc.) Lem.	Sand Dollar, star cactus	1993a	2003	2010	Federally endangered	Endangered S1	Critically imperiled (G1)
Ayenia limitaris Cristobal	Rio Grande ayenia, Texas ayenia	1994	2016	2010, 2022b	Federally endangered	Endangered S1	Imperiled G2
Frankenia johnstonii Correll	Johnston's seaheath, Johnston's Frankenia	1984 (see 1988)	N/A	N/A	Federally delisted (USFWS 2016a,b)	Delisted S3	Vulnerable G3
Lesquerella thamnophila Rollins & Shaw (syn. *Physaria thamnophila* †)	Zapata bladderpod	1999	2004	2015	Federally endangered	Endangered S1S2	Critically imperiled (G1
Manihot walkerae Croizat	Walker's manioc	1991	1993b, 2019+	2009	Federally endangered	Endangered S1	Imperiled (G2)
Physostegia correllii (Lundell) Shinners)	Correll's false dragonhead	NA	NA	NA	Federal listing review (2024)	NA	Imperiled (G2)
Thymophylla tephroleuca (S.F. Blake) Strother (formerly *Dyssodia*)	Ashy pricklyleaf; ashy dogweed	1984	1988	2011a	Federally endangered	Endangered S2	Imperiled (G2)

The seed germination of *A. artemisiifolia* requires soil disturbance during the winter and spring and will not occur if a disturbance occurs during the summer months (Squires 1989) due to seasonal seed dormancy (Baskin & Baskin 1998). However, if the seasonal response of *A. cheiranthifolia* seeds to disturbance is similar to congenerics (Baskin & Baskin 1998), slight disturbance during a non-dormant season could stimulate its germination.

Fifty percent of adult *Ambrosia salsola* (Torr. & A. Gray) Strother & B.G. Baldwin lived after germination during an El Niño event (ENSP/PDO; El Niño/Pacific Decadal Oscillation) for 18 years (Ehleringer & Sandquist 2018). While relatively long lifespans may be the case for certain species in this genus, the lifespan of *A. cheiranthifolia* is not known.

1.4. Threats

While habitat loss is the primary threat to *A. cheiranthifolia,* habitat invasion by nonnative grasses is of additional concern. (USFWS 2018). Shortgrass prairie is susceptible to the spread of nonnative grasses, particularly because vegetation management by fire, mowing and grazing is less common than it once was (USFWS 2018). Also, important from a management perspective, experimental mowing treatments in 2007 were followed by increased population numbers of *A. cheiranthifolia* (USFWS 2018).

Fig. 1-1. *Ambrosia cheiranthifolia*. Photo credit: Chris Best, USFWS (USFWS 2010).

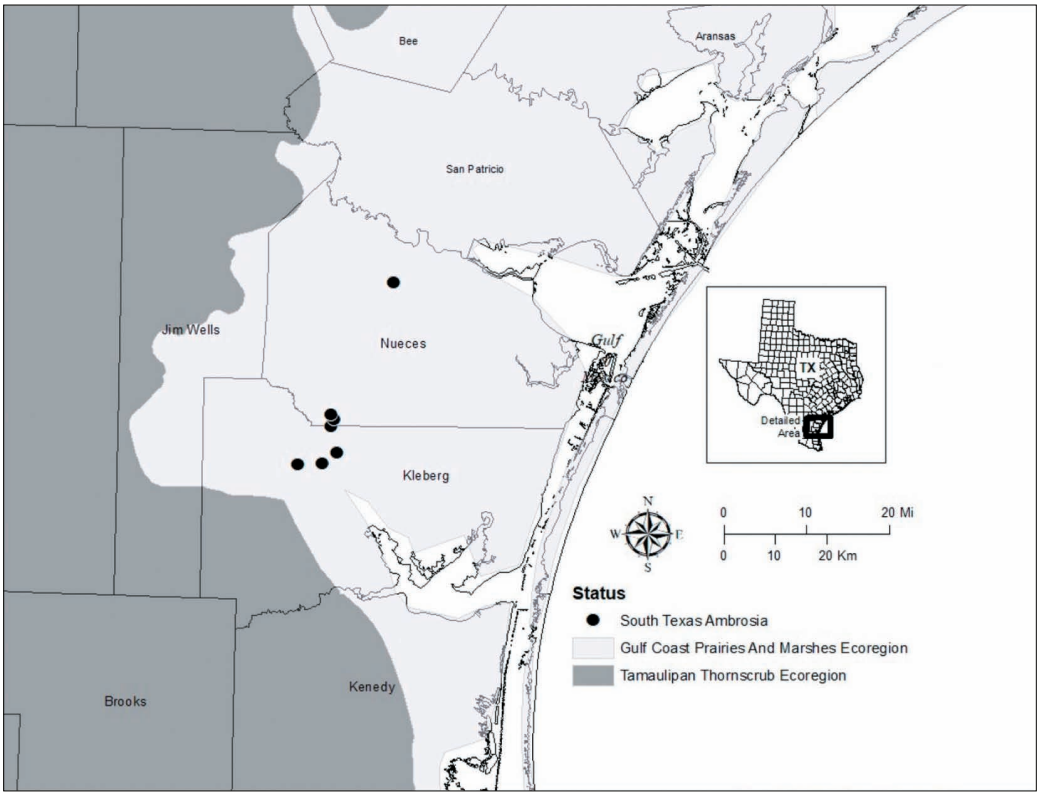

Fig. 1-2. Distribution of *Ambrosia cheiranthifolia* in Texas. Map information provided by the Texas Natural Diversity Database (2013), the Gulf Coast Prairies and Marshes Ecoregion map data online (Gould 1975, Correll & Johnston 1979) as assembled and cited in U.S. Fish and Wildlife Service (USFWS 2018).

Asclepias prostrata W.H. Blackw. (Apocynaceae)

2.1. Characteristics and status

Asclepias prostrata is an herbaceous perennial (Fig. 2-1; Table 1) (Correll & Johnston 1979). The plants grow recumbent on the ground and have leaves that are curly-margined, triangular, and minutely pilose (Poole et al. 2007) attached to a stem emerging from a woody crown (Correll & Johnston 1979; Fishbein 2023). The opposite leaves appear to lie in the same plane on the stem in *Asclepias prostrata* because of the twisting of the milky-sapped stem (pseudo-distichous) (Fig.2-1a; Blackwell 1964) and are branched or simple at the base (Poole et al. 2007). Two milkvine species can be confused with *A. prostrata* including *Matelea brevicoronata* (B.L. Rob.) Woodson and *M. parviflora* (Torr.) Woodson; these two species smell like burned rubber (Richardson & King 2011) with leaves that are white-pubescent or pilose, and the peduncles of the follicle are 7–8 cm long (Poole et al. 2007).

The highly specialized flowers are yellow, cream, greenish, or pink in color and emit a sweet and spicy odor (Fig. 2-1b; Fishbein 2023; USFWS 2020). The fruit is a follicle of about 5.5 cm long and 2 cm thick (Fig. 2-1c; Poole et al. 2007), that is boat-shaped (Fishbein 2023), and contains numerous flat, ovate seeds that are 7–8 mm in size and are wind dispersed (Damude & Poole 1990a; Fishbein 2023).

Status.—*Asclepias prostrata* was listed as federally endangered by the U.S. Fish and Wildlife Service in 2023 (USFWS 2023). NatureServe (2024) ranks the species as G1 (critically imperiled) (Table 1). A USFWS recovery plan for this species was outlined in 2023, but had not been finalized during the development of this article.

Fig. 2-1. Photographs depicting **(a)** leaves, stems, and flowers, **(b)** Monarch butterfly caterpillar and flowers, and **(c)** fruit of *Asclepias prostrata*. Photo credit: Elizabeth Gonzalez, University of Texas Rio Grande Valley, Texas.

2.2. Habitat and occurrences

Asclepias prostrata establish in sparsely vegetated uplands with disturbed soils including sandy loams, gravelly soils, or loose sand (Strong & Williamson 2015). The plants grow in Eocene sandstones and clays of the Jackson, Laredo, and Yegua formations within the Zapata-Maverick, Copita, and Hebbronville soil series, which are well-drained, calcareous upland soils (Strong & Williamson 2015). *Asclepias prostrata* most often grows in openings and occasionally under the shade of Texas scrubthorn dominated by *Acacia rigidula* Benth. (blackbrush) (Strong & Williamson 2015), and individuals grow most readily under open canopy with little to no herbaceous cover (USFWS 2020). *Asclepias prostrata* grows on disturbed dirt roads and right-of-ways (Damude & Poole 1999a; USFWS 2020).

Occurrences.—The known populations of *A. prostrata* occur within 12.9 km (8 mi) of the Texas-Mexico Border (Strong & Williamson 2015; USFWS 2020). As of 2020, there were twenty-four existing populations including sixteen in the U.S. (within the Starr and Zapata counties in South Texas) and eight in Mexico (widely scattered in northern and east-central Tamaulipas and eastern Nuevo León) (Fig. 2-2) (USFWS 2020).

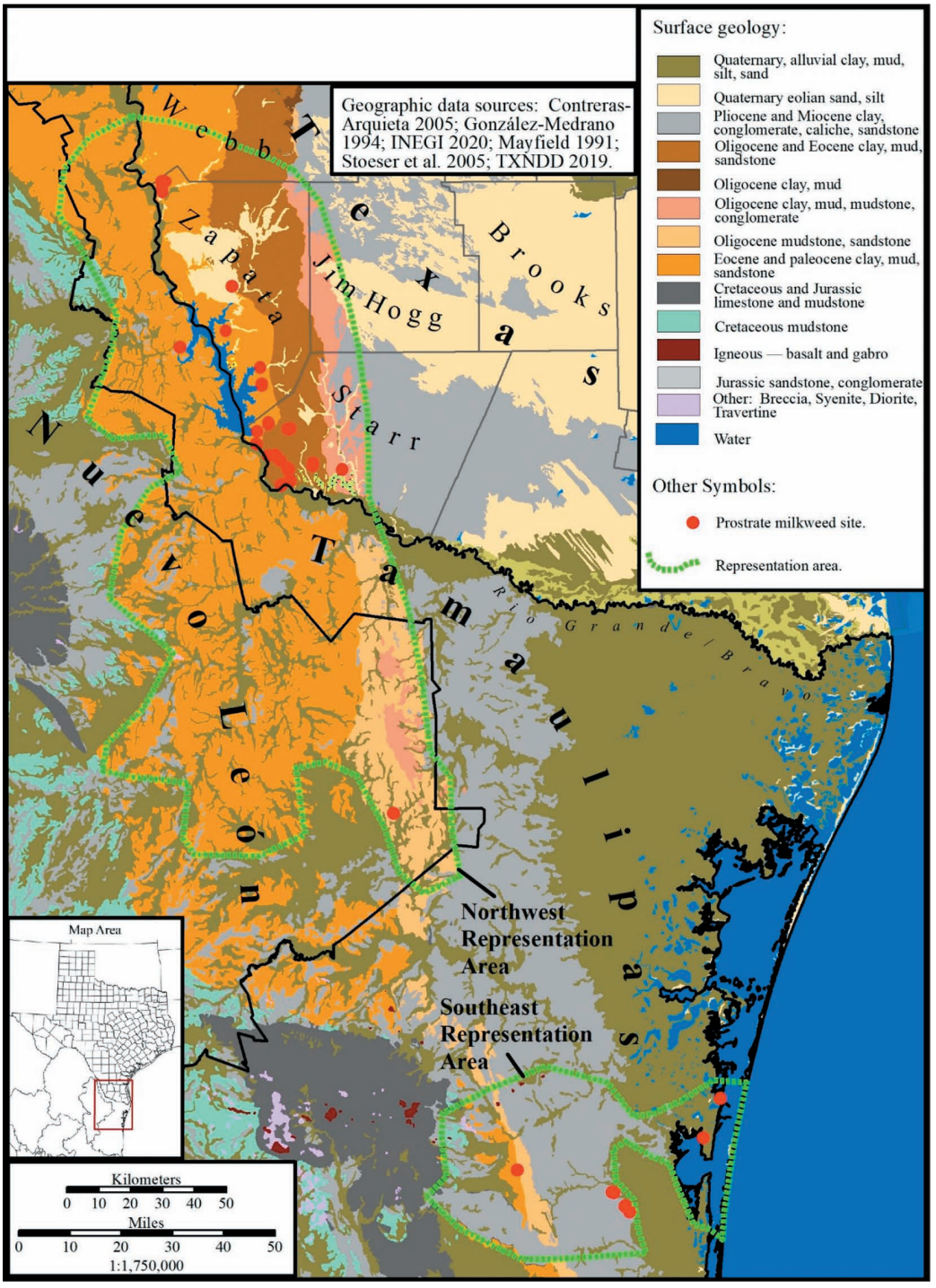

Fig. 2-2. Geological formations associated with *A. prostrata* in Starr and Zapata counties in South Texas and Tamaulipas and Nuevo Leon in Mexico. Map information provided by Contreras-Arquieta (2005), Gonzalez-Medrano (1994), INEGI (2020), Mayfield (1991), Stoeser et al. (2005), TXNDD (2019) and assembled by USFWS (2020). No citation information was included for Gonzalez-Medrano (1994), and Mayfield (1991) in USFWS (2020).

Since 1995, most populations have had fewer than ten individuals emerge, with only one population having over fifty individuals (USFWS 2020). The historical distribution of the species is unidentified, and unknown populations are likely to occur on private lands (Fig. 2-3) (USFWS 2020). Some individuals in Texas (e.g., Dolores in Zapata County) are at least 40 km from the nearest population, with little possibility of genetic exchange. Therefore, the population redundancy of *A. prostrata* is low (USFWS 2020).

2.3. Biology

Asclepias prostrata produces numerous seeds dispersed by wind (Damude & Poole 1991a; Strong & Williamson 2015; USFWS 2020). Sampled populations in Starr and Zapata counties in South Texas, had a mean number of 82 seeds produced per pod (Gonzalez 2023). Seed production has not been studied as extensively in this species as it has for congenerics such as *A. tuberosa* (Fishbein 1996; Fishbein & Venable 1996). *Asclepias syriaca* L. (common milkweed) typically produces more than 220 seeds per follicle (Holdrege 2010) and *A. oenotheroides* Cham. & Schltdl.; zizotes milkweed) produces about 100 seeds per follicle (B. Hardegree 2019; USFWS, written comm., 1 Nov 2019, as stated in USFWS 2020). *Asclepias prostrata* is dependent on rain events to re-emerge, flower, fruit, and germinate (Strong & Williamson 2015; USFWS 2020). Seeds of this species will germinate without cold stratification after wetting (Gonzalez 2023). In seed germination trials, 95% of the seeds that were less than 10 months old germinated when stored at ambient temperatures (Gonzalez 2023).

Flowering and fruiting occur primarily from March through October but can also occur sporadically in February (Strong & Williamson 2015). Physiological seed dormancy is the only type known in the genus *Asclepias* (Baskin & Baskin 1998).

Asclepias prostrata likely has an outcrossing breeding system, like most other milkweed species (Luna & Dumroese 2013; Weitemier 2016). *Asclepias* spp. are pollinated by insects that are big and strong enough to remove the pollinia (bundle of adhering pollen) from the milkweed flower (USFWS 2020). The complex floral structures of milkweeds utilizing pollinia suggest that larger bees and wasps may be successful pollinators for this species (Fishbein 1996; Damude & Poole 1990a; MacIvor et al. 2017). While some *Asclepias* congenerics are pollinated by large Hymenoptera (bees and wasps) and Lepidoptera (butterflies and moths), others are pollinated by a wide variety of types and sizes of insects (Fishbein 1996; Fishbein & Venable 1996; Holdrege 2010; MacIvor et al. 2017). Carpenter bees are substantial in size and can pollinate *Asclepias* spp. (USFWS 2016c).

Zizotes milkweed (*Asclepias oenotheroides*) is pollinated by tarantula hawk wasps, which may also be important pollinators for the closely related prostrate milkweed (C. Best 2020, USFWS, written comm., 11 Mar 2020, as stated in USFWS 2020). Tarantula hawk wasps have been observed visiting *A. prostrata* flowers in the Lower Rio Grande Valley and *Notocyphus dorsalis* (type of spider wasp) has been observed with pollinia on its hind limbs (Gonzalez 2023). Insects with large ranges may be essential to promote outcrossing between populations (USFWS 2020). *Danaus plexippus* (Monarch butterfly) lay their eggs on *A. prostrata*, and caterpillars of this butterfly species consume their leaves (Fig. 2-1b; Gonzalez 2023). Gray hairstreak butterflies (Gonzalez 2023), medium-sized bees and wasp species also visit the flowers of this species (Gonzalez, South Texas College, pers. obs., 2023).

The lifespan of the perennial *A. prostrata* is unknown; however, many related species are long-lived (Bowles et al. 1998). *Asclepias prostrata* often persists but does not reemerge from underground for many years (C. Best 2017 & A. Strong 2020a, written comm. as cited in USFWS 2020). *Asclepias meadii* Torr. ex A. Gray may not flower for twenty to thirty years, and it can remain dormant for 1–5 years (USFWS 2020). In historical locations, plant species with seeds that can persist in the soil for decades should not be considered extirpated for at least 40 years (Hammerson et al. 2008). Therefore, it may be difficult to make an abundance assessment for this species because it tends to remain dormant for many years (USFWS 2020). After suitable rain, *A. prostrata* can re-emerge from tubers with long taproots, which are buried about 0.5 m under the ground (USFWS 2020) and can allow the plant to survive for years in a dormant state (C. Best 2018, USFWS, written comm., 13 Sep 2017, as stated in USFWS 2020). Shoot emergence is assumed to occur about one week after rainfall (A. Strong

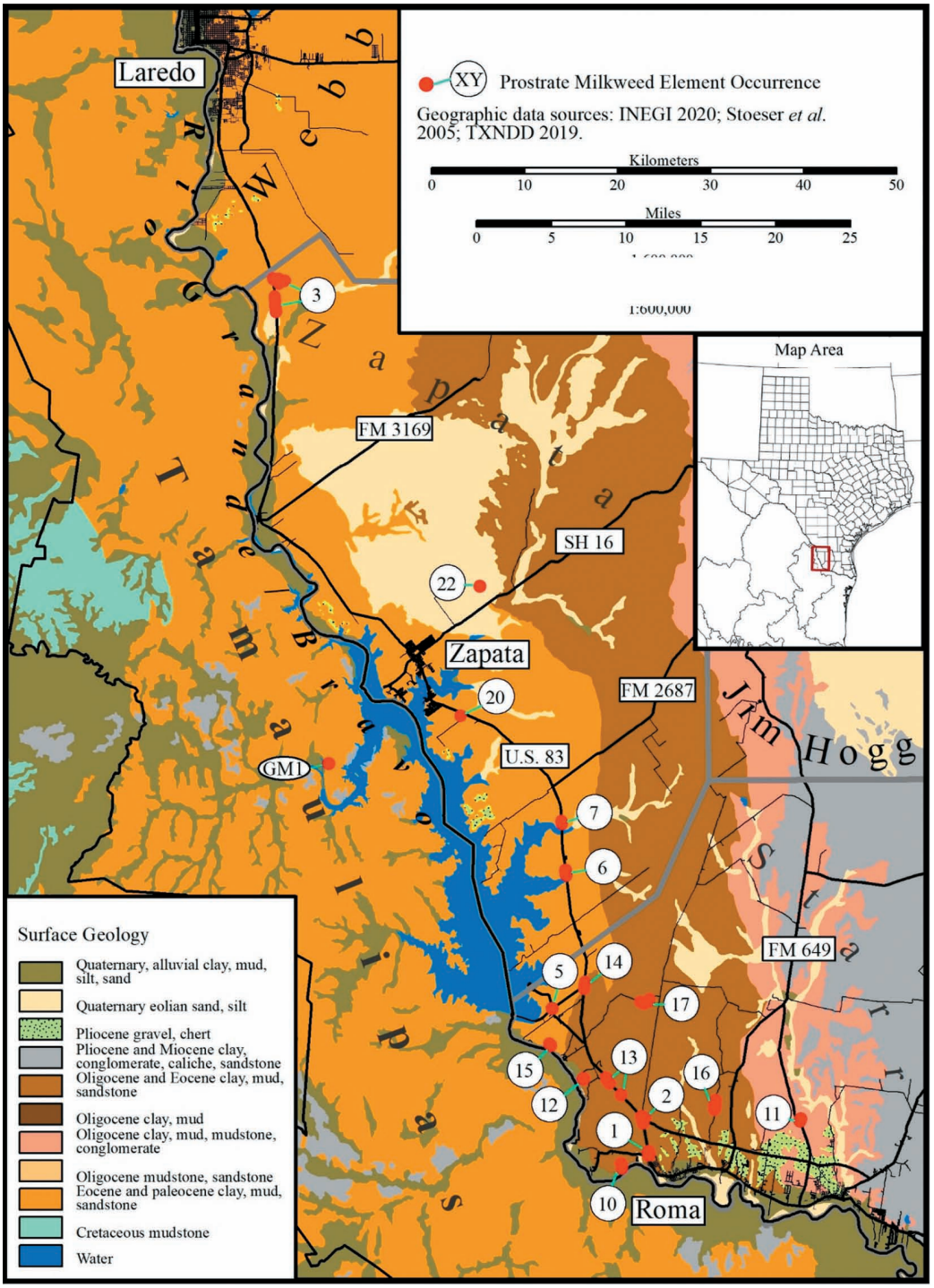

Fig. 2-3. *Asclepias prostrata* populations in South Texas and Mexico. Map information from Stoeser et al. (2005), TXNDD (2019), and INEGI (2020) and assembled by USFWS (2020).

2019, USFWS, written comm., 20 Mar 2019, as stated in USFWS 2020). An important unknown for its conservation is the ability of dormant seeds and underground tubers to provide long-term stability to populations of *A. prostrata*.

Cycles of plant emergence, flower and seed production can be affected by long-term cycles in climate driven by El Niño Southern Oscillations (ENSO) (Chang-Yang et al. 2016), but it is not known how such cycles affect the life cycle of *A. prostrata* in the Tamaulipan thornscrub. In the Sonoran and Mojave Deserts, rain events during El Niño years timed before the flowering season produced 50% and 20% more flowering, respectively (Bowers 2005). For rare annuals and tropical tree species, the changes in the timing of seasonal rains and air temperature may strongly affect population persistence (Numata et al. 2003; Levine et al. 2008). Many species successfully reproduce only after large-scale flowering events, so changes in El Niño cycles with climate shifts could affect the success of the regeneration of plant species (Sakai et al. 2006); this temporal dimension may be a critical consideration for the conservation of *A. prostrata*.

2.4. Threats

Major threats that currently affect *A. prostrata* include overgrazing, soil compaction, land clearing, and nonnative grasses, which are common threats to rare species in South Texas (Strong & Williamson 2015). *Asclepias prostrata* may benefit from mowing and disturbance in right-of-way accesses to maintain open grassland (Strong & Williamson 2015) and is sometimes found adjacent to and on the edge of unpaved roads (Gonzalez 2023); however, it is essential to note that the installation of natural gas pipelines and fiber-optic cables destroyed *A. prostrata* individuals in the Dolores and Arroyo del Tigre Chiquito populations (Fig. 2-2, 2-3) (Damude & Poole 1990a; USFWS 2000). Herbaceous species of open wetland and grassland often require mowing, grazing, fire, or other disturbance to persist (Middleton 2013), and many milkweed species benefit from fire (Baum & Sharber 2012). Notes of past *A. prostrata* occurrences in Arroyo Ramirez in South Texas indicate that individuals sometimes grow in wheel tracks on unmanaged sand or rock roads (USFWS 2020). However, surveys of historic *A. prostrata* locations in Arroyo Ramirez and Arroyo Morteros conducted from January to July of 2023 did not identify any populations or individuals. Defoliated individuals of some species of *Asclepias* produce smaller seeds (Willson & Price 1980).

Astrophytum asterias Lem. (Cactaceae)

3.1. Characteristics and status

Astrophytum asterias (sanddollar, star cactus; Table 1) is a small dome-shaped species in the Cactaceae family (Correll & Johnston 1979; Poole et al. 2007). The plants have eight green or brown-green triangular lobes (Poole et al. 2007; USFWS 2013a) with a single row of small white hair tufts (areoles) down the middle of each lobe (Fig. 3-1; Damude & Poole 1990b). The yellow flowers have orange to red centers. Each fruit is oval and woolly, often producing over 100 seeds (Ken King and Alfred Richardson, Texas A&M, Kingsville, pers. obs.).

Status.—*Astrophytum asterias* was listed as federally endangered by the U.S. Fish and Wildlife Service in 1993 (USFWS 1993a) and endangered by the state of Texas (TPWD 2011, 2024). NatureServe (2024) ranks the species as G1 (critically imperiled) (Table 1). A recovery plan prepared by USFWS was approved in 2003 (Table 1).

3.2. Habitat and occurrences

Astrophytum asterias grows in the flats of shrublands and grasslands of the Tamaulipan thornscrub in semi-protected areas under the shade of nurse plants or rocks (Damude & Poole 1990b: Poole et al. 2007; USFWS 2013). This species grows in saline-sodic gravelly clay and loam soil (Poole et al. 2007; Janssen et al. 2010; USFWS 2013) with a mean pH of 7.5 and maximum values of 8.3 (Janssen et al. 2010). This calcareous soil type ranges in color from deep red to white and is comprised of both coarse and fine gravel (Clover 1933).

Occurrences.—*Thirty-three populations of *A. asterias* are known to occur in south Texas and northeast Mexico (USFWS 2013; Fig. 3-2). Most of the estimated five thousand individuals of this species grow on private property (twelve owners) in Starr County (USFWS 2013). Nine smaller populations are distributed in the states of Nuevo León and Tamaulipas, Mexico (Martinez-Ávalos et al. 2004).

Fig. 3-1. *Astrophytum asterias* grown at Rancho Lomitas Nature Preserve, Rio Grande City, TX. Photo credit: Benito Trevino Jr., Rancho Lomitas Nature Preserve, Rio Grande City, Texas.

3.3. Biology

Flowering usually occurs from March to May with peaks in March and April (Janssen et al. 2010) in response to rainfall (Strong 2005). Each flower is open for only 1–2 days in the morning, but closes in the evening (USFWS 2013). *Astrophytum asterias* does not reproduce vegetatively and can only produce seeds when outcrossed by a pollinator (Strong 2005; Janssen et al. 2010). *Diadasia rinconis* (cactus specialist bee) was the most effective pollinator (Blair 2007; Janssen et al. 2010). Insects from the orders Coleoptera and Hymenoptera visit the flowers of *A. asterias* frequently (Strong 2005) but these species, including *Acmaeodera* spp., *Macrotera lobata* (Janssen et al. 2010), *Carpophilus* sp., and the ant *Forelius mccooki* are not very effective pollinators (Blair 2007). *Macrotera lobata* and *Ashmeadiella maxima* made up 40% of all bee visits in the study conducted by Strong (1995). Beetles settle into the base of the flowers, and rarely fly from flower to flower (Strong 2005). Seed set is much higher in hand-pollinated flowers (Strong 2005), suggesting that limitations in pollinator numbers may constrain the seed set of the species (Janssen et al. 2010).

Seeds of *Opuntia* sp. and other cacti can be dispersed by animals such as jack rabbits (Timmons 1942; Baskin & Baskin 1998). It may be unusual for the seeds of *A. asterias* to be eaten by birds or mammals because seedlings are observed growing only a few centimeters from the mother plant (Blair 2007). However, during

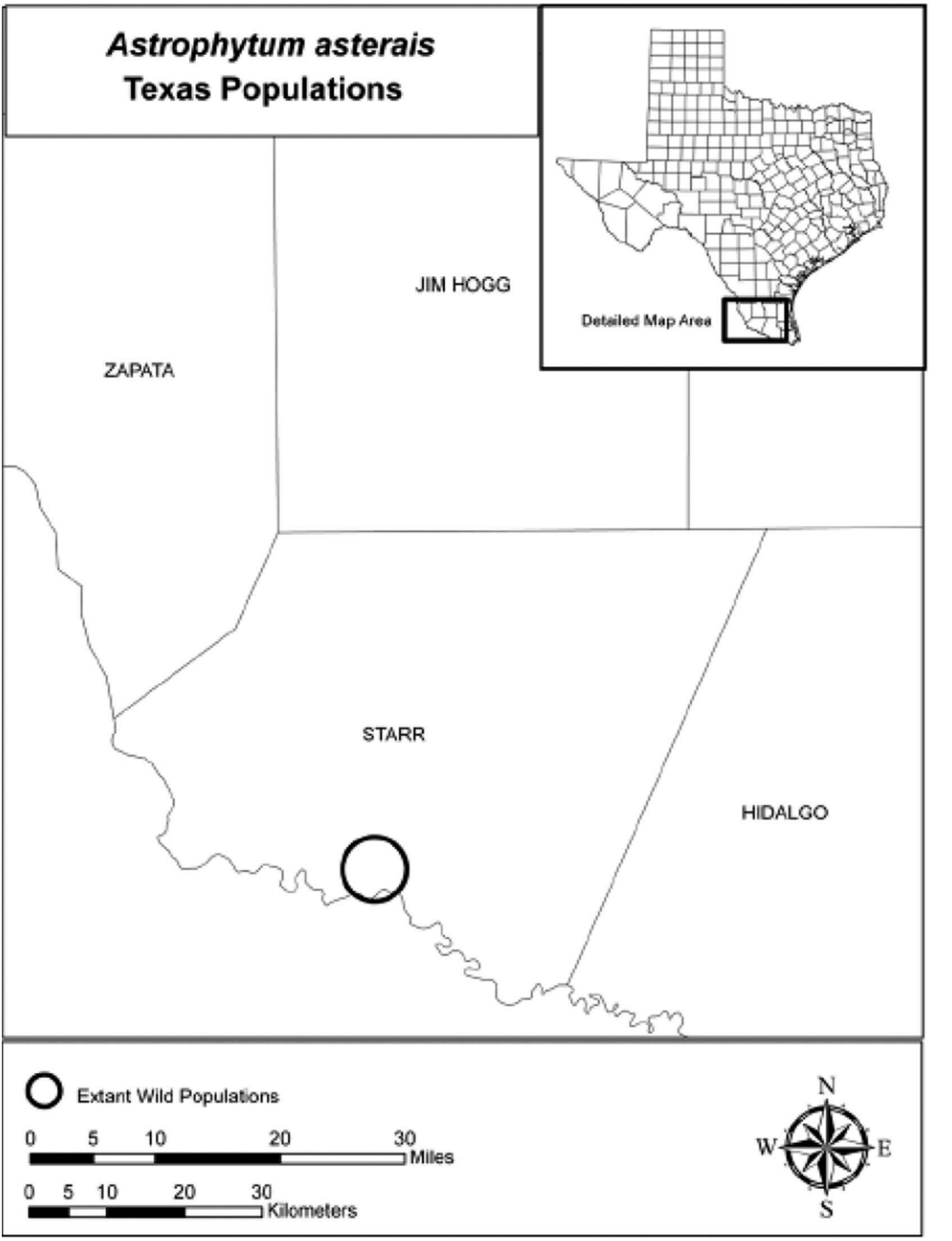

Fig. 3-2. Distribution of *A. asterias* in Starr County, Texas. Map source: USFWS (2013).

drought, this species is eaten by animals, particularly the Mexican ground squirrel (USFWS 2013). Seeds of *Astrophytum* spp. form a flotation cup with an air bubble when wet and may be adapted to dispersal by water (Bregman 1988) so that heavy rainfall may disperse the seeds and therefore increase gene flow (Blair 2007). The optimum temperature for seed germination for congeneric in the genus *Opuntia* spp. is 30°C (Potter et al. 1984; Baskin & Baskin 1998). *Astrophytum asterias* seeds lose viability over time, and it has not been determined whether seeds of this species persist in the seed bank (Birnbaum 2009), which is a critical piece of information for the conservation of this species.

3.4. Threats

Habitat loss may be the largest threat to *A. asterias* and other cacti species, especially by root plowing and converting pastureland to buffelgrass (*Pennisetum ciliare* Link) (Blair 2007, 2008; USFWS 2013). After mechanical disturbance to the land, a former site would no longer support *A. asterias* (USFWS 2013). Heavy grazing and fire suppression may also threaten the habitat of *A. asterias* (Damude & Poole 1990b). The species also has been collected as a rare species with beautiful flowers for private collections (Poole et al. 2007; USFWS 2013).

Burrowing activity by ground squirrels can kill seedlings (Birnbaum 2009). Despite this problem, the reintroduction of *A. asterias* has been more successful via transplanting of seedlings rather than by direct seeding (Birnbaum et al. 2011).

Astrophytum asterias is not known to occur on federal land in the U.S , so the cooperation of private landowners is essential for its protection there (Damude & Poole 1990b). *Astrophytum asterias* occurs in protected areas in central Mexico such as the Tehuacán-Cuicatlán Biosphere Reserve, Mexico, but suitable habitat is predicted to shift outside of this protected reserve in certain future climate change scenarios (Téllez-Valdés & Dávila-Aranda 2003).

Ayenia limitaris Cristóbal (Malvaceae)

4.1. Characteristics and status

Ayenia limitaris (Rio Grande ayenis, Texas ayenia; Table 1) is a small shrub with heart-shaped, alternate, and toothed leaves (Correll & Johnston 1979; USFWS 2016d) with stellate hairs (Poole et al. 2007). The flowers are yellow to cream-colored with distinctive kidney-shaped petals of about 0.8 mm long and 1.6 mm wide and sepals of about 3.1 mm long and 1.6 mm wide (Damude & Poole 1990c; Poole et al. 2007) (Fig. 4.1b) (USFWS 2016d). The fruit is a five-chambered capsule up to 8 mm long, covered with pubescent prickles (Fig. 4.1a) (Poole et al. 2007), which can stick to hair or feathers (Cristóbal 1960 a,b; USFWS 2016d; Dorr 2020). Each capsule produces as many as five brown to black seeds (USFWS 2016d), which are corrugated-tuberculate and 4 to 5 mm wide (Cristóbal 1960 a,b; Dorr 2020). Individuals can grow up to two meters tall; stems of older plants are reddish-brown with cream-colored lenticels (USFWS 2016d).

Status.—*Ayenia limitaris* was listed as federally endangered by the U.S. Fish and Wildlife Service (1994) and as endangered by the state of Texas (TPWD 2011, 2023). NatureServe (2024) ranks the species as G2 (imperiled) (Table 1). A recovery plan for *A. limitaris* was finalized and adopted by USFWS (2016d).

4.2. Habitat and occurrences

The plants grow on the edges of dense shrub and herbaceous thickets in open or shaded areas on dry alluvial clay soils (Ideker 1994 as reported in USFWS 2010) in alluvial soil types including fine sandy loam and heavy clay (USFWS 2016d). One population occurred on a formerly active flood plain comprised of Holocene alluvial deposits (Damude & Poole 1990c).

Occurrences.—*Ayenia limitaris* occurs in southern Texas and northeastern Mexico (USFWS 2016d). Five populations of one hundred to one thousand individuals exist in southernmost Texas including Cameron, Hidalgo, and Willacy counties (Fig. 4-2) (USFWS 2016d). Ten populations, totaling four thousand individuals, are known to exist in Soto la Marina in the state of Tamaulipas, Mexico (Fig. 4.2) with most populations in Mexico (USFWS 2016d).

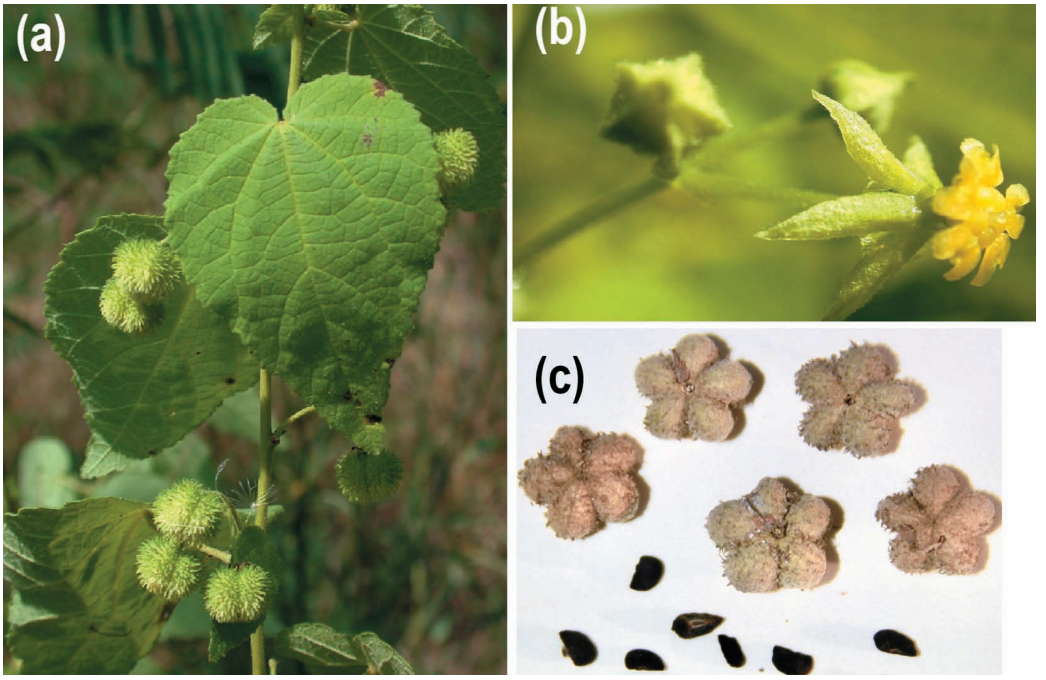

Fig. 4-1 (a–b). Photographs depicting **(a)** leaves, seed capsules, **(b)** inflorescences (Photo credit: Chris Best in USFWS (2022a)), and **(c)** fruits and seeds of *Ayenia limitaris*. Photo credit: Benito Trevino, Rancho Lomitas Nature Preserve, Rio Grande City, TX.

4.3. Biology

Ayenia limitaris blooms predominately from June through November with most flowering/fruiting occurring after heavy rainfall from September to November or occasionally in May (USFWS 2016d). The morphology of the flower may make self-fertilization impossible; the gynoecium is raised above the sessile anthers by an androgynophore of 0.3 mm in length (Cristóbal 1960a, b; Dorr 2020), making it likely that *Ayenia limitaris* is an obligate out-crosser (Cristóbal 1960b). The nature of pollinator success with respect to the morphology of the flower is intriguing and deserves much more study.

Desert and semi-desert shrubs in the Malvaceae have physiological seed dormancy (Baskin & Baskin 1998). Many species in the Malvaceae have persistent seed banks (twelve species in seven genera tested) (Baskin & Baskin 1998). In a restoration garden, seedlings of *A. limitaris* germinated from a seed bank in a landscape island next to a mowed lawn (USFWS 2010).

4.4. Threats

Ayenia limitaris is threatened by agricultural and urban development with little of its original habitat intact (USFWS 2016d). Management changes may have allowed the shade of spreading thornland to hinder the growth of the species following fire suppression and poor range management (USFWS 2016d).

Lesquerella thamnophila Rollins & E.A. Shaw (Brassicaceae)

5.1. Characteristics and status

Lesquerella thamnophila (syn. *Physaria thamnophila*) (Stevens 2024) is a species in the Brassicaceae (Al-Shehbaz 2020) (Fig. 5-1a-c). The plants have yellow flowers with four petals and four sepals in the form of a cross (Fig. 5-1b; Correll & Johnston 1979; Al-Shehbaz 2020). *Lesquerella thamnophila* has silvery-green, oval, elongated rosette leaves, which are irregularly wavy with smooth edges or shallow teeth (Fig. 5-1a) and covered with

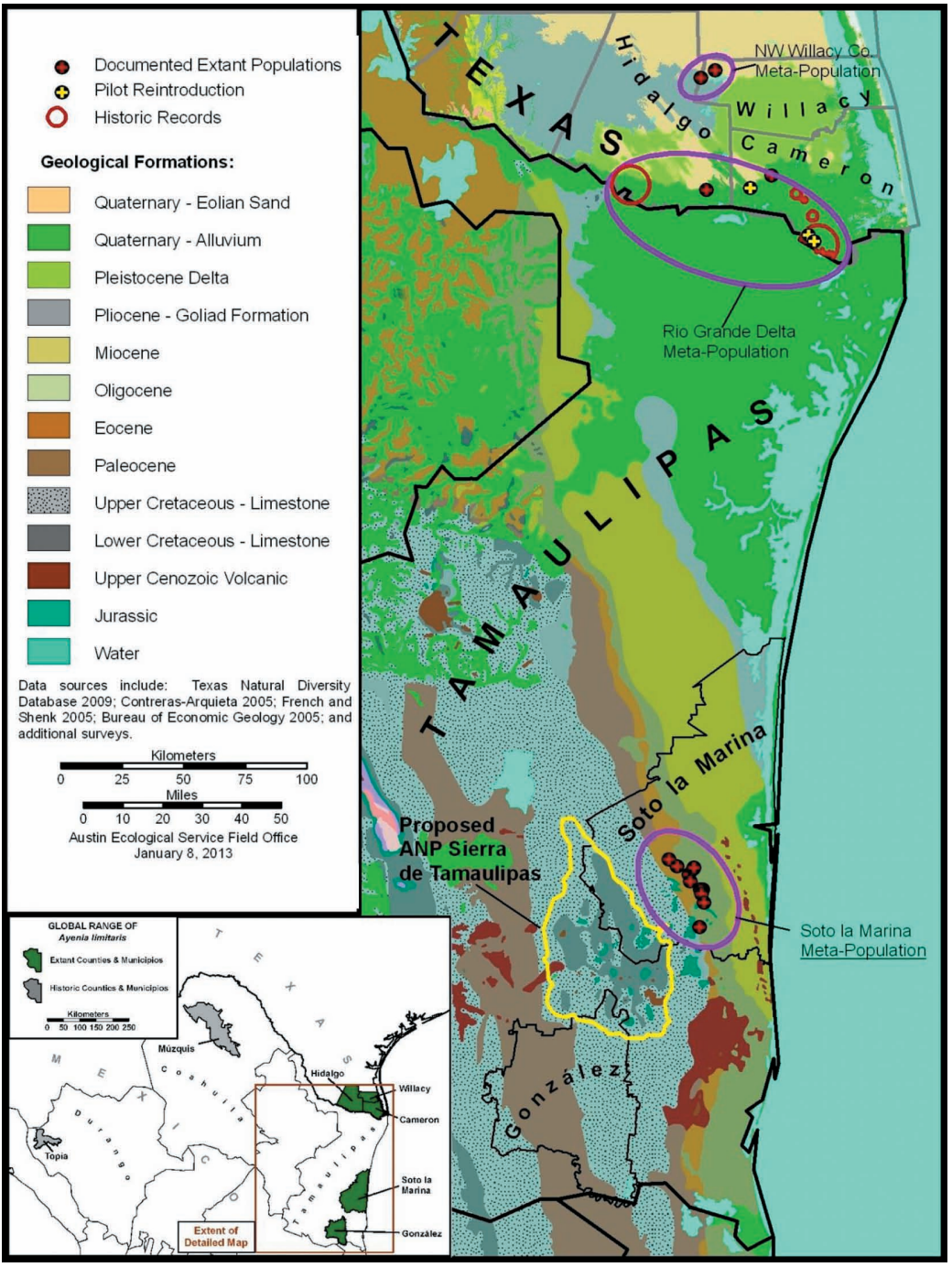

Fig. 4-2. Locations of *A. limitaris* throughout Texas and Mexico and geological formations. Map information from the Texas Natural Diversity Database (2009), Contreras-Arquieta (2005), French & Shenk (2005), Bureau of Economic Geology (2005) and assembled by USFWS (2016d).

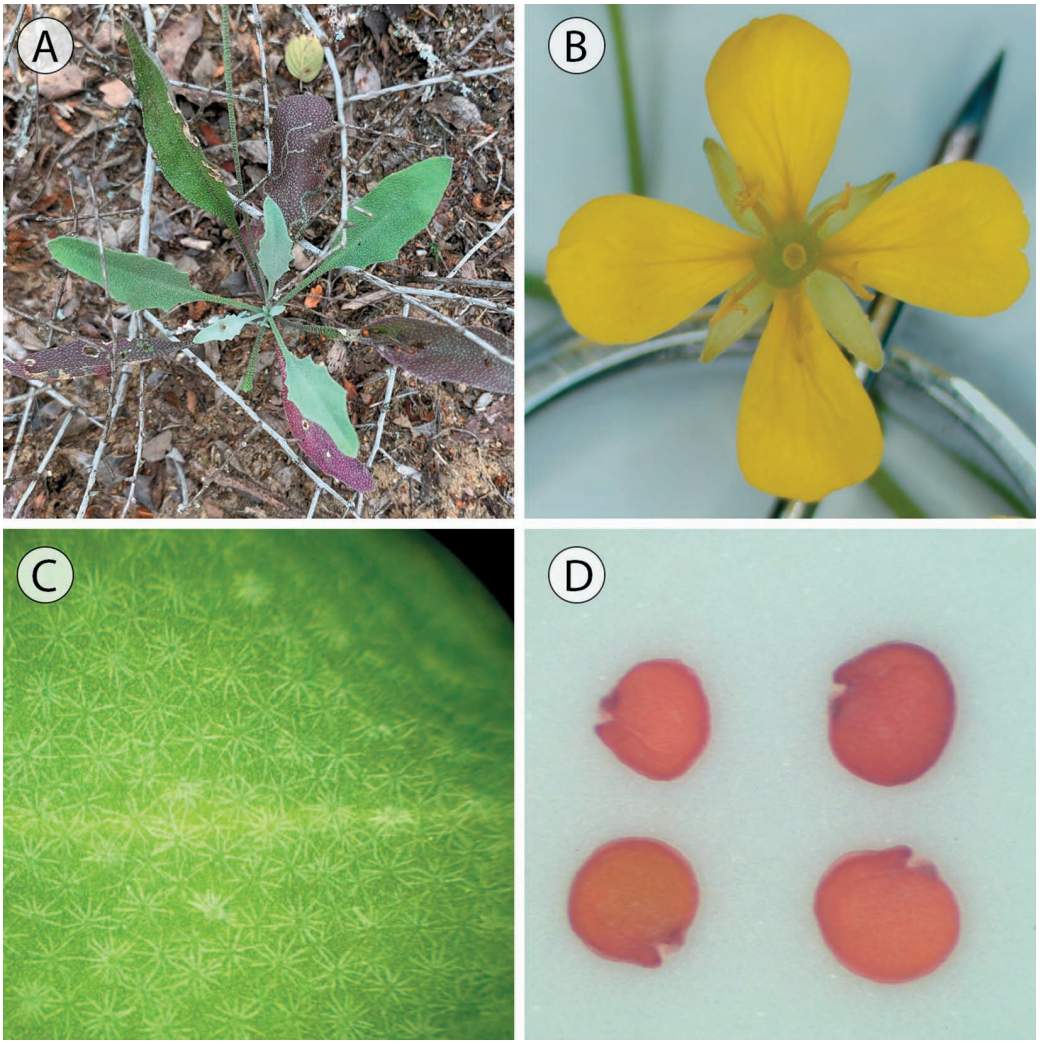

Fig. 5-1. ***Lesquerella thamnophila*** **including rosettes A., and flowers B. Photo credit: Kat Loomis, CNSS (a&b). The microscopic leaf hairs are diagnostic; these split into radiating side branches (4-5), which may divide further into two more branches C. Photo credit: Jerald Garrett, UTRGV. The seeds are flattened D. Photo credit: Benito Trevino Jr., Rancho Lomitas Nature Preserve, Rio Grande City, Texas.**

small silvery hairs (TPWD 2024). The hairs have elaborately stellate trichomes with 4–6 rays sometimes slightly fused and forked near the base (Fig. 5-1c) (Poole et al. 2007). The circular configuration of the hairs collects dew droplets on cool nights during the winter season (Middleton, U.S. Geological Survey, pers. obs.) but their overall function is not known.

Lesquerella thamnophila has sprawling stems from a basal rosette of leaves (Poole et al. 2007) with pendent, silique fruits hanging from downward curving pedicels (Correll & Johnston 1979; Al-Shehbaz 2020). The fruit is sub-globose are 4.5–6.5 mm long, and the flattened, brown seeds (Fig. 5-1d) (Al-Shehbaz 2020) are about 3–5 mm in diameter (Trevino, written corr., March 30, 2023). Usually, there are four seeds in each of the two chambers (8 seeds per capsule; Poole et al. 2007) but there are sometimes as many as 10–11 seeds per

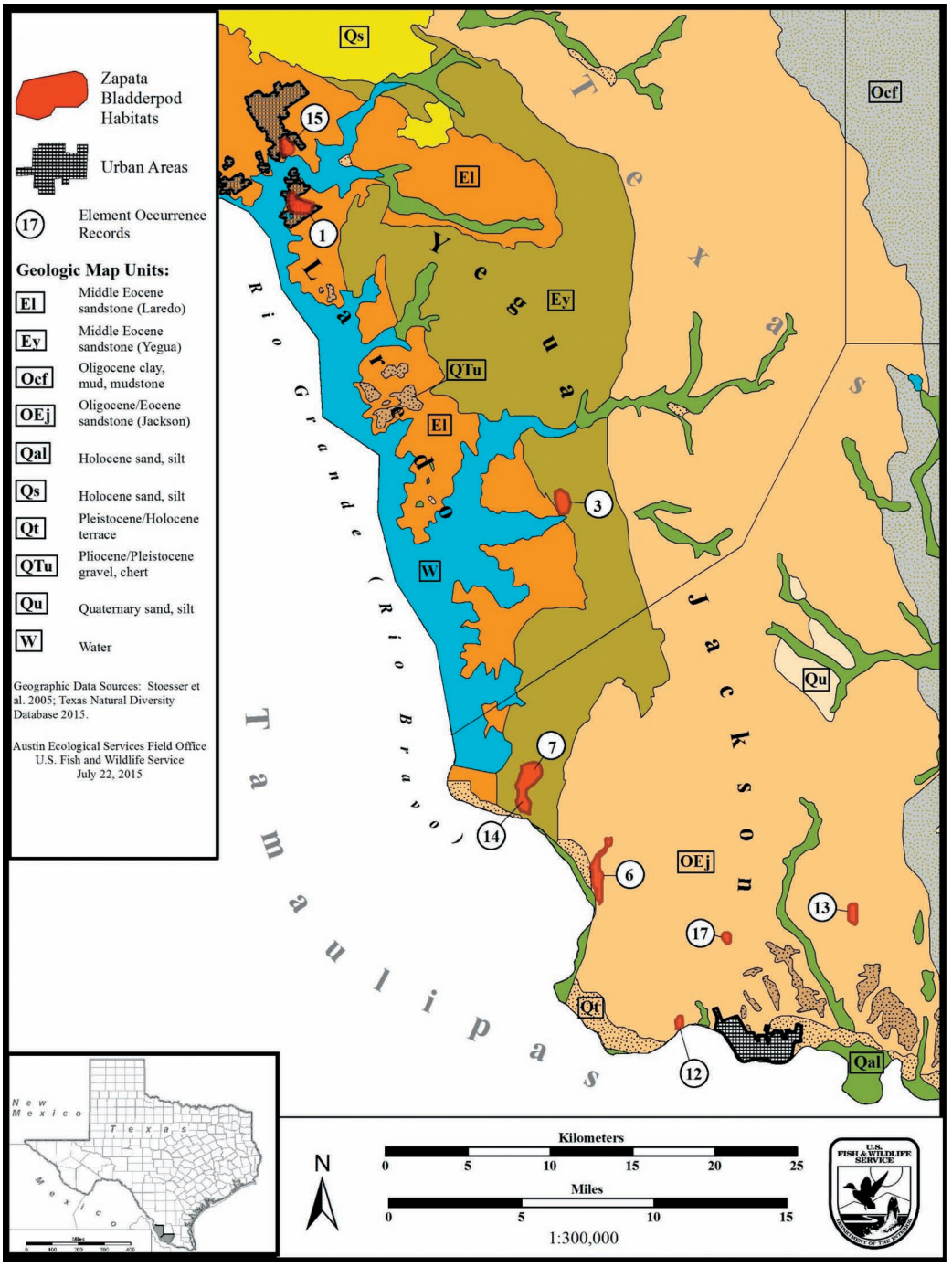

Fig. 5-2. Geological map units of *L. thamnophila* populations in the Lower Rio Grande Valley National Wildlife Refuge (LRGV NWR). Map information from the Texas Natural Diversity Database (2015) as assembled by USFWS (2015).

capsule (Brenda Molano-Flores and Janice Coons, and Chris Gabler and Jerald Garret, respectively, 2022–2023, pers. obs.).

Status.—The U.S. Fish and Wildlife Service (1999) listed *Lesquerella thamnophila* as federally endangered, and the state of Texas (2011) listed it as critically imperiled/imperiled (S1S2) (Table 1). A recovery plan for *L. thamnophila* was adopted in 2004 (USFWS 2004) (Table 1).

5.2. Habitat and occurrences

Lesquerella thamnophila is associated with shrub-thorn shrubland most often under a canopy (Fowler et al. 2011; Price et al. 2012). The dominant canopy species in this shrubland include *Acacia rigidula* (blackbrush) and *Leucophyllum frutescens* I.M. Johnst. (cenizo), which can grow up to 3.6 m and 2.4 m tall, respectively, on calcareous soils and limestone caliche slopes or ridges (Fowler et al. 2011; Texas A&M 2023; TNPD 2024). *Lesquerella thamnophila* is often found in shorter blackbrush habitats with a height of shrubs of 1–2 m (Middleton and Lain, and Gabler and Garrett, 2023 U.S. Geological Survey and UTRGV, respectively, pers. obs.). Shrub roots anchor the soil to some extent (Middleton, 2023 pers. obs.) and act as nursery plants because these facilitate seed germination by trapping soil, seeds, and moisture (Fowler et al. 2011; Price et al. 2012).

Lesquerella thamnophila grows in well-drained, shallow, sandy loam soils of the Maverick, Catarina, Zapata, and Copita series (NRCS 2019) including calcareous sandstone of the Jackson, Yegua, and Laredo formations formed during the Eocene (Price et al. 2012) (Fig. 5-2). Soils of the Catarina, Copita, and Maverick series all consist of deep, undulating upland soils and Zapata series (Fig. 5-2) (NRCS 2019) of very shallow soils over caliche (Sedio et al. 2023). Most of the soils found in Starr County are calcareous and alkaline with pH ranging from 7.5 to 8.5 or higher (Fig. 5-2) (Loeppert & Suarez 1996). Gypseous soils are susceptible to erosion during sheet flow during heavy rain due to their poor aggregation (FAO 1990). Gypsum crystals, composed of hydrated calcium sulfate, can whiten the soil surface at *L. thamnophila* sites (NRCS 2019). Maverick and Catarina vs. Copita soils have 15% vs. 2% gypsum content (NRCS 2019).

Occurrences.—*Lesquerella thamnophila* historically occurred in southern Texas and Tamaulipas, Mexico (Fig. 5-3) (Johnston 1963; USFWS 2015). However, a recent population genetic study suggests that a population in Mexico is a different subspecies (Sedio et al. 2023). In the U.S., eight populations were recorded in 2007 in Starr and Zapata County, Texas, with two more populations presently unknown that were observed in Starr County in 1986 and 1994 (USFWS 2015). Two additional populations have been observed in the region (Coons & Molano-Flores, Illinois Natural History Survey, pers. obs., 2023). Herbarium specimens can provide vital documentation of occurrences that are important in the federal listing process. This information has been used to develop a Species Distribution Model that could assist with the scouting of additional populations for the species (Molano-Flores et al. 2023).

5.3. Biology

Leaf emergence from the dormant caudices probably occurs in the fall to early winter after rain (USFWS 2015), but individuals can emerge at other times of year (e.g., January, June, July; Middleton, 2023, U.S. Geological Survey, pers. obs.). The caudices may survive in a dormant state for long periods of time, with old leaf scars present on the apex of the woody caudex (USFWS 2015).

Flowering in *L. thamnophila* occurs sporadically after rain events usually from February through April but also as late as October (USFWS 2015) or as early as January (Middleton, USGS 2023, pers. obs.). Fruiting occurs mostly in March and April (USFWS 2015), although it has been observed at other times (Coons & Molano-Flores, Illinois Natural History Survey, pers. obs., 2023). *Lesquerella thamnophila* is visited by metallic sweat bees and other species (Fig. 5-4; Trevino, written comm. to Middleton, March 30, 2023). Many *Lesquerella* species are obligate outcrossers pollinated by bees and flies (Rollins & Shaw 1973; Molano-Flores & Coons 2020).

A comparative study of seed germination constraints in *Lesquerella* suggested that optimal germination occurs after 12 weeks of storage in warm temperatures for species such as *L. thamnophila*, *P. fendleri* (A. Gray) O'Kane & Al-Shehbaz, and *P. recurvata* (Engelm. ex A. Gray) O'Kane & Al-Shehbaz, which indicates some

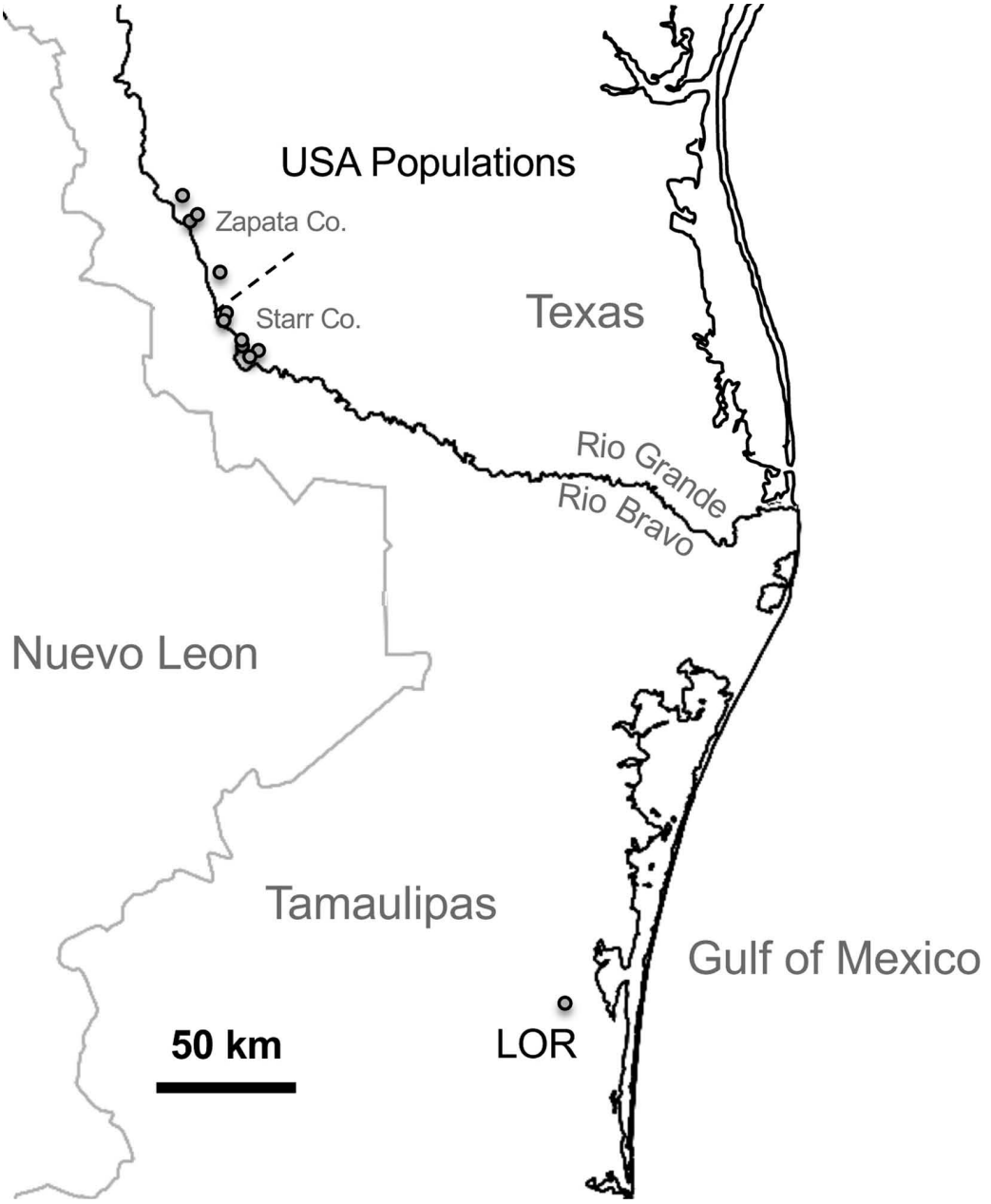

Fig. 5-3. Locations of *L. thamnophila* populations in the U.S. and Mexico (with permission of Sedio et al. 2023; J. Bot. Res. Inst. Texas).

Fig. 5-4. Metallic sweat bee from genus *Lasioglossum* visiting *P. thamnophila* flowers. Photo credit: Benito Trevino Jr., Rancho Lomitas Nature Preserve, Rio Grande City, TX.

level of dormancy, and that after-ripening is important (Cruz et al. 2012). Also, *L. thamnophila* seeds varied in germination levels in GA_3 with and without light (75.8% ± 1.7% vs. 56.9% ± 3.4%, respectively) and without GA_3 with and without light (63.6% ± 2.6% vs. 46.4% ± 3.5%) (Cruz et al. 2012).

Little is known regarding the longevity of seed banks and their role in supporting populations of *L. thamnophila* (USFWS 2019a). While persistent seed banks are common in many Brassicaceae (Baskin & Baskin 1998), *Lesquerella ludoviciana* (Nutt.) O'Kane & Al-Shehbaz lacks a persistent seed bank (Grant et al. 2012). Members of Brassicaceae from the salt deserts often have seeds with physiological dormancy that disappears during dry storage so seeds do not require special pretreatment for germination (Baskin & Baskin 1998).

Seedlings or juvenile plants are observed after rains, but may not survive long enough to establish caudices, flowers, or seeds (Sternberg 2005; Fowler et al. 2011; Price et al. 2012). The population numbers of *L. thamnophila* fluctuate greatly in response to rainfall, so that the true sizes of the viable seed bank and potentially perennating caudices are difficult to estimate (USFWS 2015). Many seeds germinate and produce large numbers of seedlings after rains, but few of these reach a reproductive age (USFWS 2019a). The lifespan of the

Lesquerella thamnophila is the subject of debate because it is unclear if the species is perennial, semi-perennial or annual (Rollins & Shaw 1973; USFWS 2004; Sternberg 2005; Poole et al. 2007; O'Kane 2015) and lifespan is important in the conservation of the species. Some consider it a short-lived perennial (Fowler et al. 2011; Price et al. 2012). In three experimental trials, plants grown from seed in an outdoor setting did not regrow after flowering (B. Trevino, 2023, pers. obs.). However, the species is likely a perennial; the FWS 5-year review of *L. thamnophila* states that it is a perennial with an unknown lifespan (USFWS 2019a), citing leaf scars on the caudex as evidence (USFWS 2015).

5.4. Threats

Lesquerella thamnophila may be threatened by soil disturbance from border wall construction, economic development, erosion, oil and gas exploration, overgrazing, traffic, and root-plowing (USFWS 2015). Nevertheless, certain shade-intolerant species benefit from low levels of natural disturbance (Sternberg 2005). *Lesquerella thamnophila* often has more flowers, fruit, and higher growth rates on soil and rocks disturbed by clearance, rock piles, or infrequently maintained utility areas, and is likely shade-intolerant (Sternberg 2005; Fowler et al. 2011).

Brush removal, low levels of cattle, or deer grazing may be useful to mimic fire that creates open habitats for *L. thamnophila* (USFWS 2015). *Lesquerella thamnophila* numbers increase after the removal of shrubs (Poole et al. 2007; Fowler et al. 2011).

Manihot walkerae Croizat (Euphorbiaceae)

6.1. Characteristics and status

Manihot walkerae is a perennial herb or weak shrub (Correll & Johnston 1979; USFWS 2009; Table 1), which smells like cyanide (Poole et al. 2007). The plant has three to five deeply palmate-lobed, alternate leaves (Fig. 5-1a) (Correll & Johnston 1979), which are halbert-shaped (Fig. 6-1a) (Poole et al. 2007). The plants have white flowers with 5 petals (Fig. 6-1a) (Correll & Johnston 1979; Poole et al. 2007). The flowers are in 5–10 cm long racemes. The pistillate flowers (Fig. 6-1b) mature before the staminate flowers; the stamens are 6–10 mm long in two whorls (Fig. 6-1c) (Poole et al. 2007). The fruit is globular, dry, and dehiscent (Poole et al. 2007; Fig. 6-1d). Mature capsules can produce up to three seeds, which can be ejected several meters from the parent plant (Best 2008 as cited in USFWS 2009). The roots are carrot-shaped (Fig. 6-1e) (Poole et al. 2007).

Status.—*Manihot walkerae* was listed as federally endangered by the U.S. Fish and Wildlife Service (USFWS 1991) and listed as endangered by the state of Texas (TPWD 2024). NatureServe (2024a,b) ranks the species as G2 (imperiled) (Table 1). Recovery plans were adopted by USFWS in 1993 (USFWS 1993b) and amended in 2019 (Table 1) (USFWS 2019b).

6.2. Habitat and occurrences

Manihot walkerae occurs in thorn shrublands on shallow, calcareous, sandy soils overlying whitish mineral deposits associated with the Goliad geological formation (Bureau of Economic Geology 1975–1976 as cited in USFWS 2009).

Occurrences.—In 2019, there were thirty-five populations of *M. walkerae* documented (USFWS 2009). There are eleven populations in southern Texas, mostly in Hidalgo and Starr County, and twenty-four populations in Tamaulipas, Mexico (Fig. 6-2; USFWS 2009). The three largest populations in the U.S. are protected within the Lower Rio Grande Valley (LRGV) National Wildlife Refuge, while the other populations have thirty or fewer individuals (USFWS 2009).

6.3. Biology

The LRGV National Wildlife Refuge and the San Antonio Botanical Garden suggest that *M. walkerae* is self-fertile and lacks a specialized pollinator (Best 2008 as cited in USFWS 2009) although bees, butterflies, and wasps visit the flowers (Garza 2021). Flowering usually occurs from April to September following rainfall (USFWS 2009). Seed can be ejected several meters from the capsules of the parent plant (Best 2008 as cited in USFWS 2009). Seeds are also dispersed by ants (myrmecochory) (Best 2008 as cited in USFWS 2009). The ant

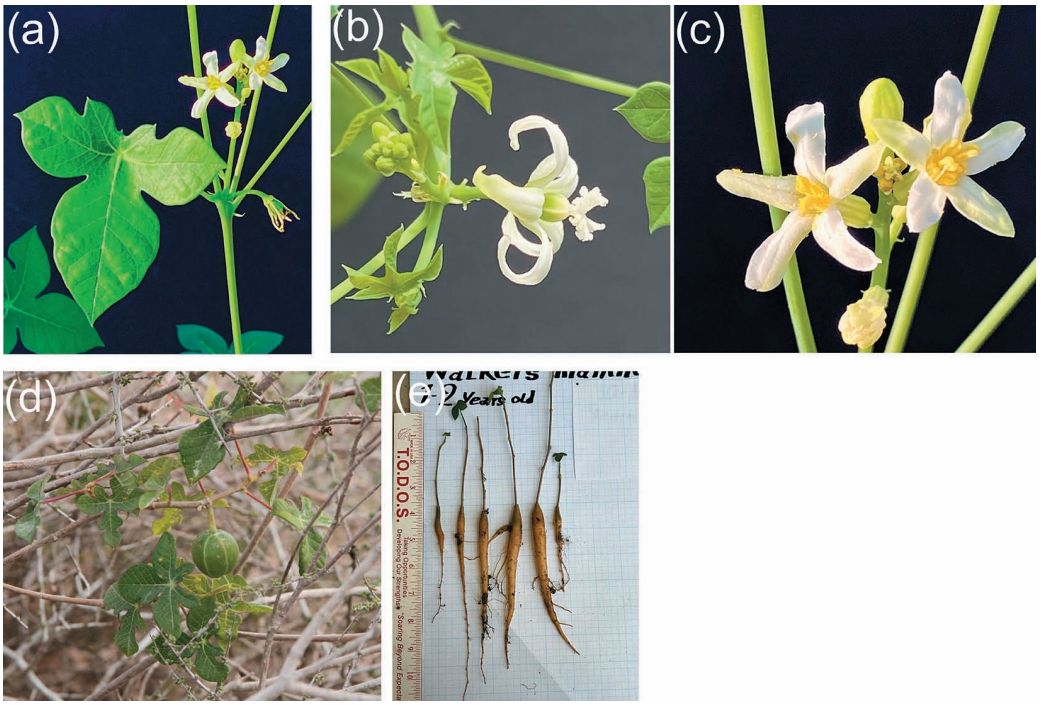

Fig. 6-1. *Manihot walkerae* **(a)** flower and leaf, **(b)** female flower with pistil, style and ovary, **(c)** male flower with stamens, **(d)** fruit, and **(e)** carrot-shaped root. Photo credit: USGS volunteer, and Rancho Lomitas Nature Preserve, Rio Grande City, TX.

grasps an appendage (caruncle) on the seed (Garza 2021), which may be used as food by the ants (Best 2008). Seeds of related species such as *Euphorbia prostrata* Aiton are dispersed by animals after ingestion in savanna ecosystems in Rajasthan, India (Middleton & Mason 1993). Still, it is not known if mammals ingest *M. walkerae* seeds in this system.

Another congeneric *Manihot esculenta* Crantz has orthodox seeds, which means that the seeds can tolerate low levels of internal seed moisture (<5% moisture) without losing viability (Ellis 1991; Baskin & Baskin 1998). Physiological seed dormancy is the only type known in the Euphorbiaceae family (Baskin & Baskin 1998). The seeds of *M. walkerae* can remain dormant for one year or longer with germination induced by heat, moisture (Simpson 1995 as cited in USFWS 2009), or gibberellic acid (Best 2008 as cited in USFWS 2009). Seedlings indicate sexual reproduction and occur in several populations (TRC 2009 and STPRT 2018, as cited in USFWS 2019b), but seedling survival can be low (Best 2008 as cited in USFWS 2009).

Tuberous roots produce new stems annually, which support themselves on other vegetation (USFWS 2009). The tubers allow the plants to remain dormant underground during non-growing seasons (Best 2008; USWFS 2009).

6.4. Threats

Manihot walkerae is threatened by habitat loss due to land clearance for commercial development and other purposes (USFWS 2009). Many of the remaining populations of the species occur on abandoned cattle pastures (USFWS 2009). The species occurs along rights-of-way (Benito Trevino, pers. comm. as cited in USFWS 2009), and in cemeteries (Best 2000 as reported in USFWS 2009). The species may benefit from occasional fire or other disturbance (USFWS 2009), since the spread of dense thornland may be due to fire suppression (Johnston 1963). Some rangeland management practices may benefit the species (USFWS 2009). Some relict

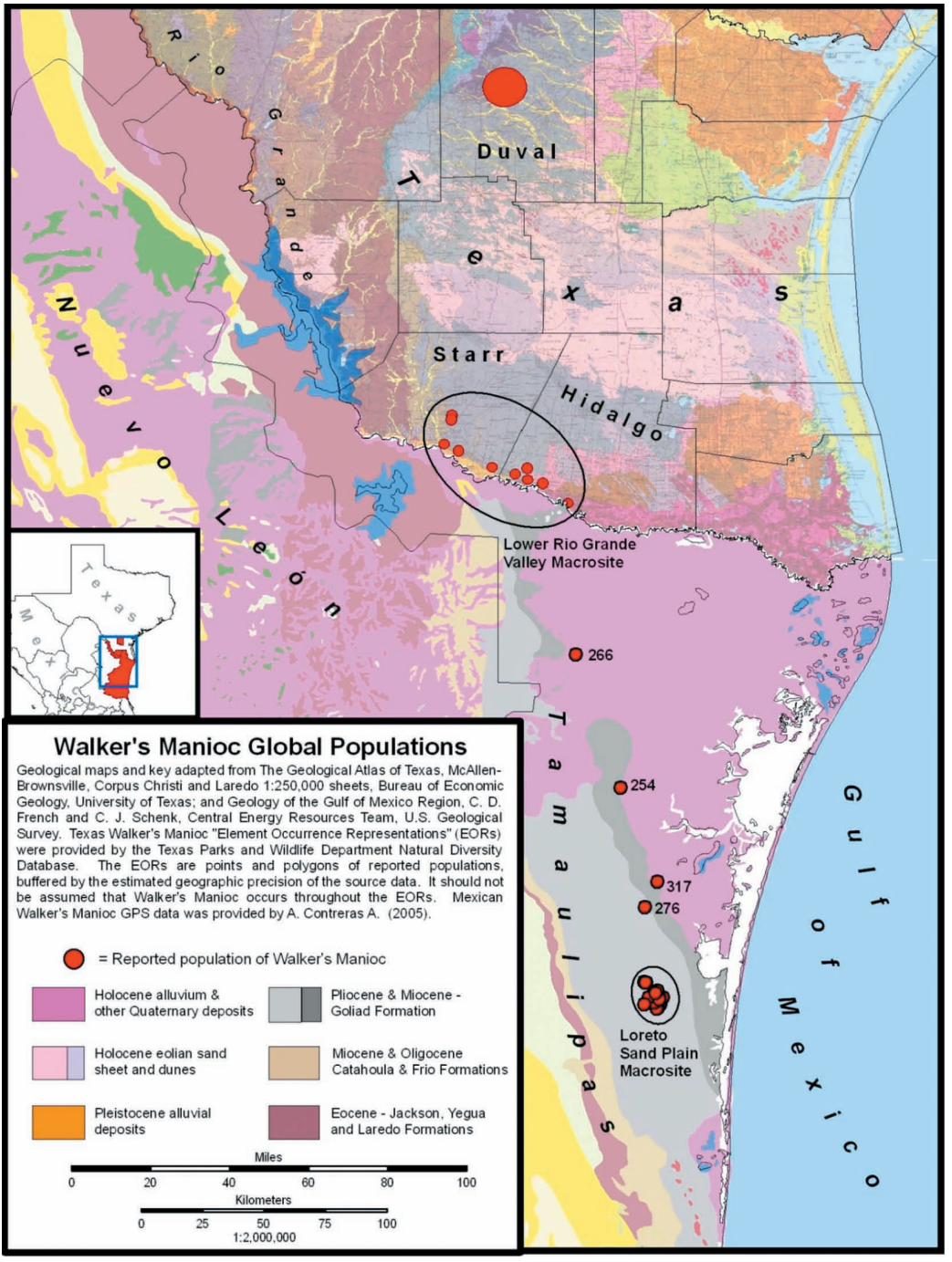

Fig. 6-2. Distribution of *Manihot walkerae* in Texas and Mexico. Map source: USFWS (2009).

species benefit from traditional grazing, mowing, and fire management (Middleton 2013). *Manihot walkerae* was discovered in a cultivated maize field that had been cleared a few years before, with no herbicides applied; it is likely that tubers of the plant were spread by farm equipment (USFWS 2009).

The spread of dense thornland may be due to fire suppression (Johnston 1963), and the species may benefit from occasional fire or other disturbance (USFWS 2009). Along the state-owned FM 2221 right-of-way, a no-mow zone has been established to protect a population of *M. walkerae* (USFWS 2009). Only a few of the protected areas in the U.S. might be utilized for reintroduction and restoration of habitat to support the species because much of current protected land may not have the right environment in future projected climate scenarios. In Mexico, the projected future habitat for the *M. walkerae* lies outside of public lands, so restoration and management efforts might benefit from cooperation with local landowners (Garza et al. 2020).

Physostegia correllii (Lundell) Shinners (Lamiaceae)

7.1. Characteristics and status

Physostegia correllii is a rare perennial in the Lamiaceae (Fig. 7-1; Table 1) (Cantino 1982). The plants can grow to a height of one meter or more (Poole et al. 2007; Williams & Manning 2020; USFWS 2024). The oblong-elliptic or obovate leaves are opposite, sessile, sharply serrate, glabrous, and leathery (Poole et al. 2007). The stems have dense spikes of tubular purple-pink, speckled flowers with finely pubescent calyces (Poole et al. 2007). The leaves are dark green, opposite, sessile, and toothed (Cantino 1982). The inflated flowers have nectar guides (Fig. 7-1; Middleton et al. 2024). Flowering is from May through September (Poole et al. 2007). Each fruit has four sharply-angled nutlets, which are 2–3 mm long (Poole et al. 2007). The plant is rhizomatous and produces extensive secondary and tertiary horizontal rhizomes with perennating buds of up to 50 cm in length (Cantino 1982).

Status.—*Physostegia correllii* is under review for listing under the Endangered Species Act (USFWS 2024). The species is not listed in Texas (TXNDD 2024a,b), and is globally ranked as imperiled (G2) by NatureServe (2011, 2024) (Table 1).

7.2. Habitat & occurrences

Originally, the species grew along large rivers such as the Rio Grande (e.g., near Moody Ranch), the Colorado (Lady Bird Lake, Austin TX), and the lower Mississippi River (Middleton et al. 2022; Middleton & Williams 2023). It most commonly occurs along the eroding edges of rivers or in mudflats deposited in creek mouths or islands in rivers (Middleton et al. 2022), and especially along the sunny edges of riparian and forested wetlands including cypress swamps, roadsides, and irrigation ditches (Cantino 1980, 1982). The plants can grow in deposits of silty sediment, gravel, bedrock, sand, concrete, or decomposed organic compounds (Cantino 1980, 1982).

Occurrences.—*Physostegia correllii* currently occurs in southern Louisiana, central Texas, and Coahuila and Nuevo León, Mexico with the most frequent observations in Travis County, Texas (Cantino 1982; Williams & Manning 2020), and Lady Bird Lake (Middleton et al. 2022; Middleton & Williams 2023). Historically, the species also occurred in eastern and southern Texas with fewer than fifteen reported occurrences (USFWS 2024). Most historic populations have not been relocated (USFWS 2024; C. Williams, written comm., June 28, 2022; B. Middleton 2023, U.S. Geological Survey, pers. obs.).

7.3. Biology

Physostegia correllii is a self-compatible, seed-producing species that usually flowers from June through the end of September (Cantino 1982). The flowers mature from the base toward the tip of the spike, as a part of its indeterminate growth strategy (Middleton et al. 2022). As is true of other *Physostegia* species, *P. correllii* can spread by seed dispersal and rhizomes (Cantino 1980, 1982). Seed dispersal of congenerics in the Lamiaceae disperse via water (Cook 1990; Middleton 1999).

This species is pollinated by native bees and hummingbirds, with bumblebees being the most effective pollinators (Cantino 1982). Carpenter bees both pollinate and nectar rob by drilling holes in the base of the

Fig. 7-1. *Physostegia correllii*. Photo credit: Beth Middleton, U.S. Geological Survey, Wetland and Aquatic Research Center, Lafayette, Louisiana, USA.

corolla (Cantino 1982; B. Middleton, U.S. Geological Survey, 2022, pers. obs.). The seeds of *P. correllii* may take as long as long as two years to germinate after their production (Middleton et al. 2022), and were maintained in the soil of Lady Bird Lake in Austin for at least four years after adult plants disappeared (Middleton & Williams 2023).

7.4. Threats

Physostegia correllii is shade intolerant and may be threatened by the expansion of woody species along rivers (Middleton & Williams 2023). In an experiment, 30% shading reduced the height and seed production of *P. correllii* indicating that the spread of overhanging branches along rivers may reduce its growth (Middleton et al. 2022).

A critical unknown related to the conservation of this species is the amount of natural disturbance required to maintain populations in relatively open riverbank shrublands and forests. This rare species is a disturbance fugitive (species of early successional habitats that depends on natural disturbance; Mettler et al. 2001) found along the edges of large rivers such as the Rio Grande, Colorado, and Mississippi (Middleton & Williams 2023) and similar to certain other species in its habitat and need for natural disturbance. After large floods on the Illinois River, the population of the federally threatened species, false decurrent aster (*Boltonia decurrens* (Torr. & A. Gray) Wood) increases because the floods remove old vegetation and allows the temporary recruitment of seedlings (Mettler et al. 2001; Middleton 1999). *Pedicularis furbishiae* S. Watson (Furbish's lousewort) is a federally threatened species of the northeastern U.S. that requires hillside river erosion or active management to remove shrubs to persist (Day 1983). *Physostegia correllii* may benefit from pruning overhanging vegetation or the re-establishment of flood-pulsed conditions along modified rivers (Middleton & Williams 2023).

Thymophylla tephroleuca (S.F. Blake) Strother (Asteraceae)

8.1 Characteristics and status

Thymophylla tephroleuca is a short perennial sub-shrub with a woody base of 10–30 cm tall (Fig. 8-1) (USFWS 1987, 2011; Poole et al. 2007; Table 1). The plants have yellow flowers with ashy-white pubescent leaves, which are linear and arranged alternately along the stem (USFWS 1987, 2011; Strother 2020), and these have a pungent smell (Poole et al. 2007). The narrow leaves are simple and glandular-pubescent (Poole et al. 2007). The yellow flower heads have peduncles with white pubescence (Poole et al. 2007). As a member of the Asteraceae, the single-seeded fruit (achenes) are multi-striate and have apical appendages of two types: awns (bristles) and (pappi) of 10–11 scales (Poole et al. 2007).

Status.—*Thymophylla tephroleuca* was listed as federally endangered by the U.S. Fish and Wildlife Service in 1984 (USFWS 1984) and as endangered (S2) by the state of Texas (TWPD 2011b, 2024). Nature Serve (2024 a,b) ranks the species as G2 (imperiled) (Table 1). A federal recovery plan was adopted for *T. tephroleuca* in 1988 (Table 1) (USFWS 1987).

8.2 Habitat and occurrences

Thymophylla tephroleuca occurs in grasslands and scattered shrub-dominated habitats with sandy loam soils, mainly of the Hebbronville series (Turner 1980; USFWS 1987; Poole et al. 1990). The plants grow on several different soils including the Maverick-Catarina, Copita-Zapata, Nueces-Comita, and Aguilares soils (USFWS 1987).

Occurrences.—*Thymophylla tephroleuca* occurs mainly on private lands in Zapata County and Webb County in southern Texas (USFWS 1987). Historically, it was also observed eight miles north of Rio Grande City in Starr County, but this population has not been verified since 1932 (Fig. 8-2; USFWS 1987). As of 2011, there were six populations mostly within 10 miles of the U.S. Highway 83 right-of-way (Fig. 8-2; USFWS 2011). The largest meta-population was last observed in 2007, on managed land, disturbed private lands, and state-owned rights-of-way near the Webb and Zapata county lines (USFWS 2011). The population has increased to hundreds of thousands of individuals since its listing in 1984 (Turner 1980 as cited in USFWS 2011).

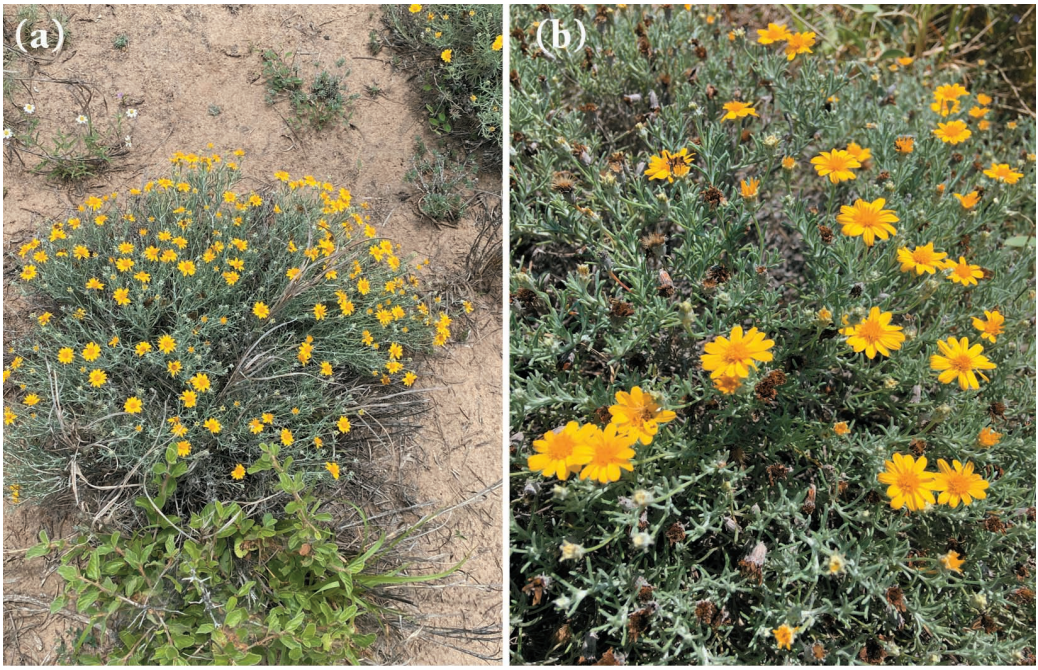

Fig. 8-1. *Thymophylla tephroleuca* **(a)** clump, and, **(b)** flower/leaf habit. Photo credit: Benito Trevino, Rancho Lomitas Nature Preserve, Rio Grande City, Texas.

8.3 Biology

Thymophylla tephroleuca is an obligate out-crosser, requiring cross-pollination to set seed (Dodson 2001; Williamson 2002; Poole et al. 2007). Flowers occur after rainfall between March and May (Correll & Johnston 1979). Flowers are visited by non-specialist beetles, bee flies, and bees in the Buprestidae, Bombyliidae, Megachilidae, and other families (Dodson 2001; Williamson 2002).

Heat increases the seed germination rate of *T. tephroleuca* by about two times (Poole 1992 as cited in USFWS 2011). Physiological seed dormancy is the only type of dormancy known in Asteraceae (Baskin & Baskin 1998). Persistent soil seed banks are common in the Asteraceae (Baskin & Baskin 1998) but the details of seed longevity of *T. tephroleuca* are unknown.

8.4. Threats

Cattle avoid eating *T. tephroleuca* because of its bitterness (USFWS 1987), but seedling success may be decreased in areas with high cattle grazing pressure (Williamson 2002) because of soil compaction (USFWS 1988). Plants along unplowed fence rows are subject to herbicide drift from adjacent fields, which could negatively affect this species (USFWS 2011). Nonetheless, certain disturbance levels may enhance this species' establishment (USFWS 2011). In an experiment, the density of seedling emergence of *T. tephroleuca* was higher in plots after root plowing in the absence of buffelgrass than in the control plots with buffelgrass (Dodson 2001). Individuals can be common on highway rights-of-way (USFWS 2011), which is the case along multiple roads near Dolores, San Ygnacio, and Las Canterras in Zapata County (Trevino 2020). Mowing may help manage of this species, especially if the mowing is infrequent or higher than 10 cm from the ground (B. and T. Trevino, Rancho Lomitas Nature Preserve, pers. obs., 2020). Mowing after seed set can also help to support the regeneration of this species (Poole et al. 2007).

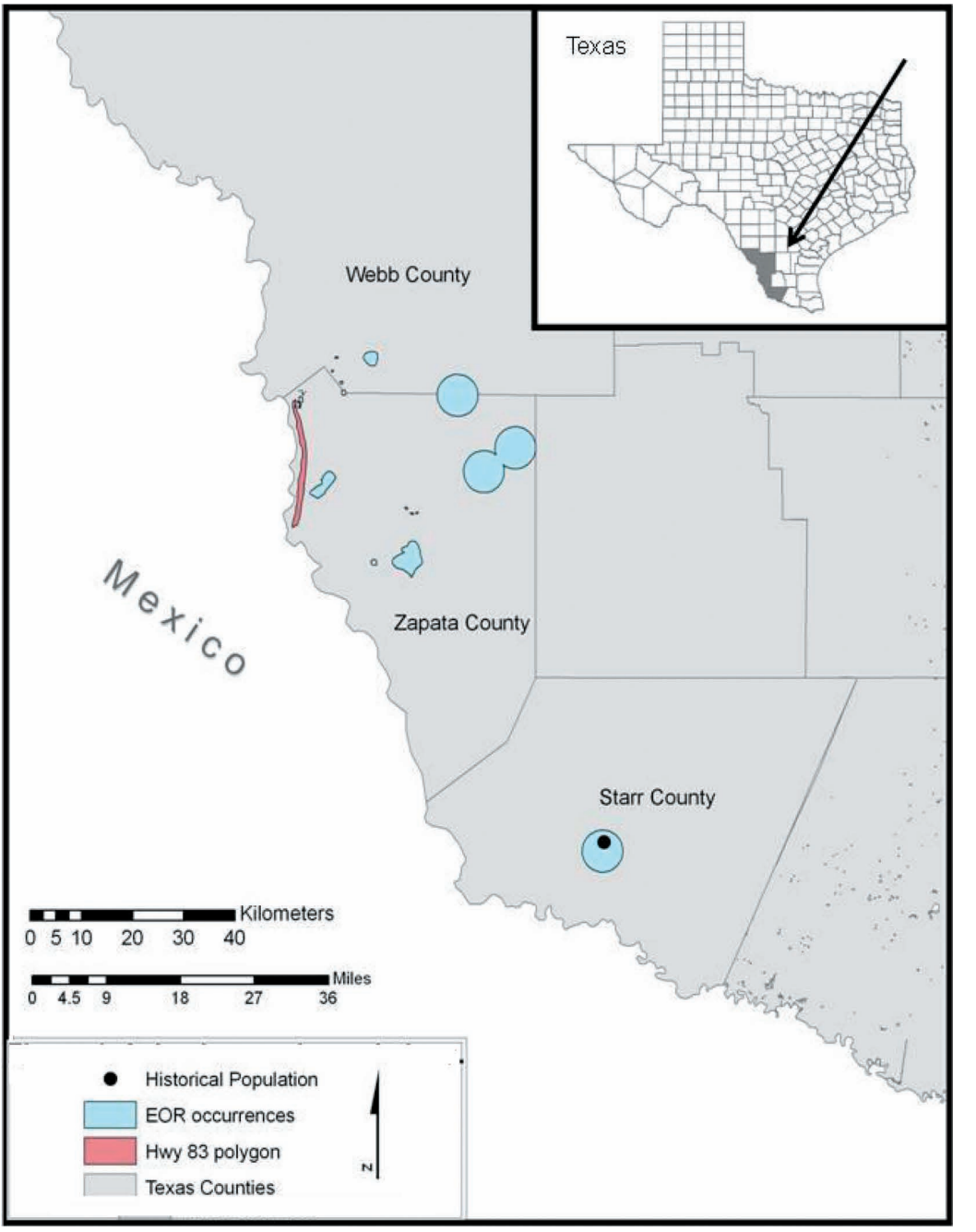

Fig. 8-2. Locations of *T. tephroleuca* populations in Web, Zapata and Star County, Texas. Map source: USFWS (2011a).

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