Central Texas Mussels Recovery Outline

June 2024

Species Names (from the top left, moving clockwise and then the middle):
Guadalupe Fatmucket (*Lampsilis bergmanni*), Texas Fatmucket (*Lampsilis bracteata*), Guadalupe Orb (*Cyclonaias necki*), Texas Pimpleback (*Cyclonaias petrina*), False Spike (*Fusconaia mitchelli*), Balcones Spike (*Fusconaia iheringi*), and Texas Fawnsfoot (*Truncilla macrodon*)

Species Range:
All seven species occur in the state of Texas, USA.

Recovery Priority Number:
5 for Guadalupe Fatmucket, Guadalupe Orb, Texas Pimpleback, False Spike, and Balcones Spike and 8 for Texas Fatmucket, Texas Pimpleback, and Texas Fawnsfoot; explanation provided below.

Listing Status:
The Guadalupe Fatmucket, Texas Fatmucket, Guadalupe Orb, Texas Pimpleback, False Spike, and Balcones Spike are listed as endangered, and the Texas Fawnsfoot is listed as Threatened with a Section 4(d) rule, 89 FR 48034, 2024.

Lead Regional Office/Cooperating RO(s):
Southwest / Region 2

Lead Field Office/Cooperating FO(s):
Austin Texas ESFO (lead); Texas Coastal and Central Plains ESFO (cooperating)

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PURPOSE

The recovery outline is a succinct document that presents a preliminary recovery strategy and actions to direct a newly listed species' recovery efforts until a recovery plan is completed. Recommendations in the recovery outline are non-binding and are intended to guide (not require) regulatory (e.g., section 7 consultations and section 10 permitting) and conservation actions to be implemented by the U.S. Fish and Wildlife Service (USFWS) and our external partners.

This document lays out a preliminary course of action for the survival and recovery of the Central Texas mussels. Formal public participation for recovery planning will be invited upon the release of the draft recovery plan. However, we will consider any new information or comments that members of the public offer in response to this outline during the recovery planning process. For more information on Federal recovery efforts for the Central Texas mussels, or to provide additional comments, interested parties may contact the lead field office for the species at the above e-mail addresses and telephone numbers.

BACKGROUND

The Service listed the Guadalupe Fatmucket, Texas Fatmucket, Guadalupe Orb, Texas Pimpleback, Balcones Spike, and False Spike as endangered with critical habitat and the Texas Fawnsfoot as threatened with a Section 4(d) rule and critical habitat under the Endangered Species Act (ESA) of 1973, as amended, on June 4, 2024 (89 FR 48034). The following includes a summary of the biology, life history, and ecology of each of the Central Texas mussels. A complete discussion of the species' morphologies, phenologies, reproduction, lifespans, demographic trends, and habitat needs can be found in Chapters 2 and 3 of the Species Status Assessment (SSA) for the Central Texas Mussels (USFWS 2022, entire). An electronic copy of the SSA report is available on the species' ECOS pages or the Austin ESFO website at https://www.fws.gov/library/collections/central-texas-freshwater-mussels-final-rule-and-supporting-documents.

Type and Quality of Available Information to Date

Important information gaps on the Central Texas mussels include the following:

- **Distribution -** We constructed a current and historical range for each mussel species based on surveys and documented observations. Regular surveys are conducted within the occupied ranges and across portions of the unoccupied ranges for each of the Central Texas mussels. However, there are gaps in our knowledge of species' distributions. For example, existing survey data may be old or incomplete or there may be gaps in survey coverage. Lastly, it is possible that in some locations Central Texas mussels exist but have not been detected in surveys; this is especially true for small-bodied species and smaller individuals (i.e., early life stages). Long-term population trend data are lacking as well, with most surveys restricted to the last few decades.
- **Climatic Effects -** While we have high certainty that climatic changes have occurred and will continue to occur across the range of the species, some uncertainty remains in the relative magnitude of these changes (i.e., intermediate versus severe) and the ways in which climatic changes will impact mussels. Though enhanced evaporative demand (i.e., overall

drying) and more extreme precipitation patterns (Jiang and Yang 2012, pp. 238-242; Mullens and McPherson 2017, pp. 15-21) are consistent across climate change predictions, additional information on how climate change may affect hydrology and habitat quality could improve our understanding of how climate change will impact the current populations of Central Texas mussels and unoccupied critical habitat. This additional information would also improve our understanding of how natural resource managers might mitigate or minimize stressors associated with climate change.

- **Physiological Tolerances -** Species-specific physiological tolerances, including thermal limits and tolerance of various waterborne pollutants, and tolerance of other water quality degradations (e.g., low dissolved oxygen) are not well defined for the Central Texas mussels. Even less is known about the impact of exposure to multiple pollutants simultaneously, which is common in natural systems, or the synergistic effects of multiple stressors at a time (e.g., chemical exposures during hotter than normal temperatures).
- **Biological Data -** We have limited information on biological data for most of the Central Texas mussel species (e.g., data on diet, reproduction, and metabolism). Much of our understanding is based on congener species. Among other benefits, additional biological information could facilitate identification of broodstock and captive propagation.
- Though some information on habitat parameters exists (e.g., Bonner et al. 2018, pp. 77-119), additional information on habitat associations and habitat evaluations would improve our understanding of how key abiotic factors influence at-risk mussel species' presence, absence, and survival at a reach and site-level scale. This information would also help the USFWS prioritize areas or populations for various protection and recovery activities.
- Additional uncertainties include upper and lower thresholds for flow (e.g., tolerances for shear stress), erosion and sediment dynamics associated with development patterns, human responses to a future with less water availability and more demand for limited water supplies, the potential for future construction of reservoirs and wastewater treatment plants, future changes to return flows and reuse, development of alternative water supplies, and effects of invasive species.

Brief Life History

Each of the seven species of Central Texas mussels belong to the Family Unionidae—also known as the naiads and pearly mussels—and the subfamily Ambleminae. Apart from Texas Fatmucket and Guadalupe Fatmucket, the Central Texas mussels are typically slow-growing and commonly live for more than twenty years (Howells et al. 1996, p. 17). Members of the genus *Lampsilis*, including Texas Fatmucket and Guadalupe Fatmucket, tend to have faster growth rates and an estimated maximum age of 13 to 25 years (Haag and Rypel 2010, p.5).

The Central Texas mussels are broadcast spawners. Males release sperm into the water column, which is taken in by females through their incurrent siphons. The sperm fertilizes the eggs, which remain in the gills of the female mussel until they mature and are ready for release as glochidia (i.e., parasitic larvae). The female releases the glochidia, which attach to the gills, head, or fins of species-specific host fishes (Vaughn and Taylor 1999, p. 913; Barnhart et al. 2008, pp. 371-373). Glochidia encyst on a host fish's tissues, draw nutrients from the fish, and develop into juvenile mussels over a period of weeks or months (Arey 1932, pp. 214-215).

Appropriate host fish are necessary for metamorphosis from glochidia to juvenile mussels. Juveniles excyst (i.e., drop off) from the host fish and must land on suitable habitat (substrate) to survive. The juvenile mussels burrow into interstitial substrates and grow to a size that is less susceptible to predation and to displacement from high-flow events (Yeager et al. 1994, p. 220). Adult mussels typically remain within the same general location where they dropped from their host fish as juveniles.

The Central Texas mussels generally occur in medium to large streams and rivers with adequate amounts of flowing water, free of contaminants and water quality degradations, with adequate food supply and refugia from both high- and low-flow events, appropriate substrate that is generally characterized as stable and free of excessive fine sediment, access to appropriate fish hosts, and habitat connectivity (i.e., lack of excessive impoundments and barriers to fish passage; **Table *1***USFWS 2022, p. 6). General life history traits and resource needs for the Central Texas mussels are shown in Table 1.

Limiting Life History Characteristics

The Central Texas mussels are generally immobile and subject to their immediate environments. However, variation in host fish specificity, life history strategy, and physiological tolerances can impact the species' ability to respond to or tolerate changing environmental conditions. For example, the Central Texas mussels differ in their behavioral responses to dewatering, likely due to differences in life history strategies and habitat adaptations (Mitchell et al. 2018, pp. 14). Mussels tolerant of exposure (i.e., drying conditions), like Texas Pimpleback (which is often found in shallow runs and riffle habitats), show little horizontal movement in response to dewatering. Conversely, mussels that are intolerant to exposure, like Texas Fatmucket (which is often found in run-of-the-river pools), show horizontal movement and are able to avoid stranding during slow dewatering events (Mitchell et al. 2018, pp. 14-16).

Table 1. Generalized life history and resource needs of the Central Texas mussels.

Life Stage	Resource Need(s)	Reference(s)
Gamete Broadcast sperm and egg development to fertilization	• High-quality water free of harmful toxicants and with basic water chemistry within tolerance limits (e.g., low total suspended solids and low sediment loads) • Appropriate water temperature and food availability (for gravid adult mussels) • Appropriate water temperatures for brooding (high temperatures can lead to premature expulsion of glochidia)	Gascho-Landis and Stoeckel 2015, p. 8 Gascho-Landis et al. 2013, pp. 76, 79 Cope et al. 2008, p. 454 Galbraith and Vaughn 2009, p. 12
Glochidium Attachment through excystment	• Presence of host fish (for attachment, encystment, and upstream dispersal) • Good water quality free of harmful toxicants, with contaminant levels below toxicity thresholds of mussels and their host fishes (thresholds can differ). Glochidia can be up to four times more sensitive than juvenile mussels. • Water temperature < 27.9 ^{o}C (82 ^{o}F)	Barnhart et al. 2008, p. 372 Augspurger et al. 2003, p. 2571 Wang et al. 2018, p. 3041 Khan et al. 2019, p. 1207
Juvenile Excystment through maturity	• Flow refugia • Appropriate substrate for burrowing • Low salinity • Low ammonia levels (below 0.7 mg/L NH_3-N at pH 8 and 25°C) • Low levels of heavy metals and other contaminants (pollutants below toxicity thresholds) • Dissolved oxygen (DO) > 2 mg/L • Flowing water within tolerance limits • Dissolved minerals (Ca) to support shell growth	Augspurger et al. 2003, pp. 2571, 2574 Augspurger et al. 2003, p. 2569 Cope et al. 2008, p. 456 Wang et al. 2007, p. 2055 Wang et al. 2017, p. 791, 795
Adult Maturity	• Flow refugia • Appropriate substrate for burrowing • Low salinity (< 2 parts per thousand; ppt) • DO > 2 mg/L • Adequate water quality (pollutants below toxicity thresholds) • Appropriate food source(s) • Water temperature < 29 ^{o}C (84 ^{o}F) • Flowing water within tolerance limits • Dissolved minerals (Ca) to support shell growth	Bonner et al. 2018, pp. 6, 7, 130-131, 140, 161-162, 164

Primary Threats

The primary threats to the current and future condition of the Central Texas mussels are related to habitat loss and modification. Threats include (1) increased fine sediment, (2) changes in water quality, (3) altered hydrology in the form of inundation, (4) altered hydrology in the form

of loss of flow and scour of substrate, (5) predation and collection, and (6) barriers to fish movement (USFWS 2022, pp. 132-140). Climate change, which is also a form of habitat modification and loss, is considered an exacerbating factor, contributing to the increase of fine sediments, changes in water quality, altered hydrology, and predation.

Current Biological Status of the Species

The seven species of Central Texas mussels have declined significantly in terms of overall distribution and abundance, relative to historical conditions. Most of the known populations currently exist in very low abundances, with limited evidence of recruitment, and occupy significantly reduced ranges. Furthermore, existing available habitats are reduced in terms of quality and quantity, relative to historical conditions.

We define the Central Texas mussels' viability as the ability of the species to sustain populations in the wild over time. Using the SSA framework, we describe the species' viability in terms of its resiliency, redundancy, and representation (collectively, the 3Rs). Resiliency is the ability of a species or population to withstand environmental and demographic stochasticity and disturbances (Redford et al. 2011, p. 40), redundancy is the ability of a species to withstand catastrophes via the number and distribution of populations, and representation is the ability of a species to adapt to changes in the biological and physical environment. The following passages provide a summary of our assessment of the current condition of the Central Texas mussels, by species, from the SSA Report (USFWS 2022, entire).

Guadalupe Fatmucket

Historically, Guadalupe Fatmucket occurred throughout the Guadalupe River basin and occupied approximately 150 river miles (rmi) or 240 river kilometers (rkm) of the Guadalupe River from Gonzalez County to Kerr County, including the North Guadalupe River, Johnson Creek, and the Blanco River (Howells 2014, pp. 41-42; Figure 1). Now, the species occurs in one population in the upper Guadalupe River (USFWS 2022, p. 117; Figure 1). The total current distribution of Guadalupe Fatmucket summed across the Upper Guadalupe River population is about 53 rmi or 85 rkm.

The one remaining population of Guadalupe Fatmucket is considered unhealthy (i.e., having low resiliency) due to low abundance, reproduction, and recruitment. Very few individuals have been found in recent years, and the upper Guadalupe River in this reach already experiences very low water levels. These low water events are expected to continue, and the population is unlikely to rebound from any degraded habitat conditions (USFWS 2022, p. D-16). Given that there is only one remaining population, representation and redundancy of the species is limited, reducing the overall viability of the species.

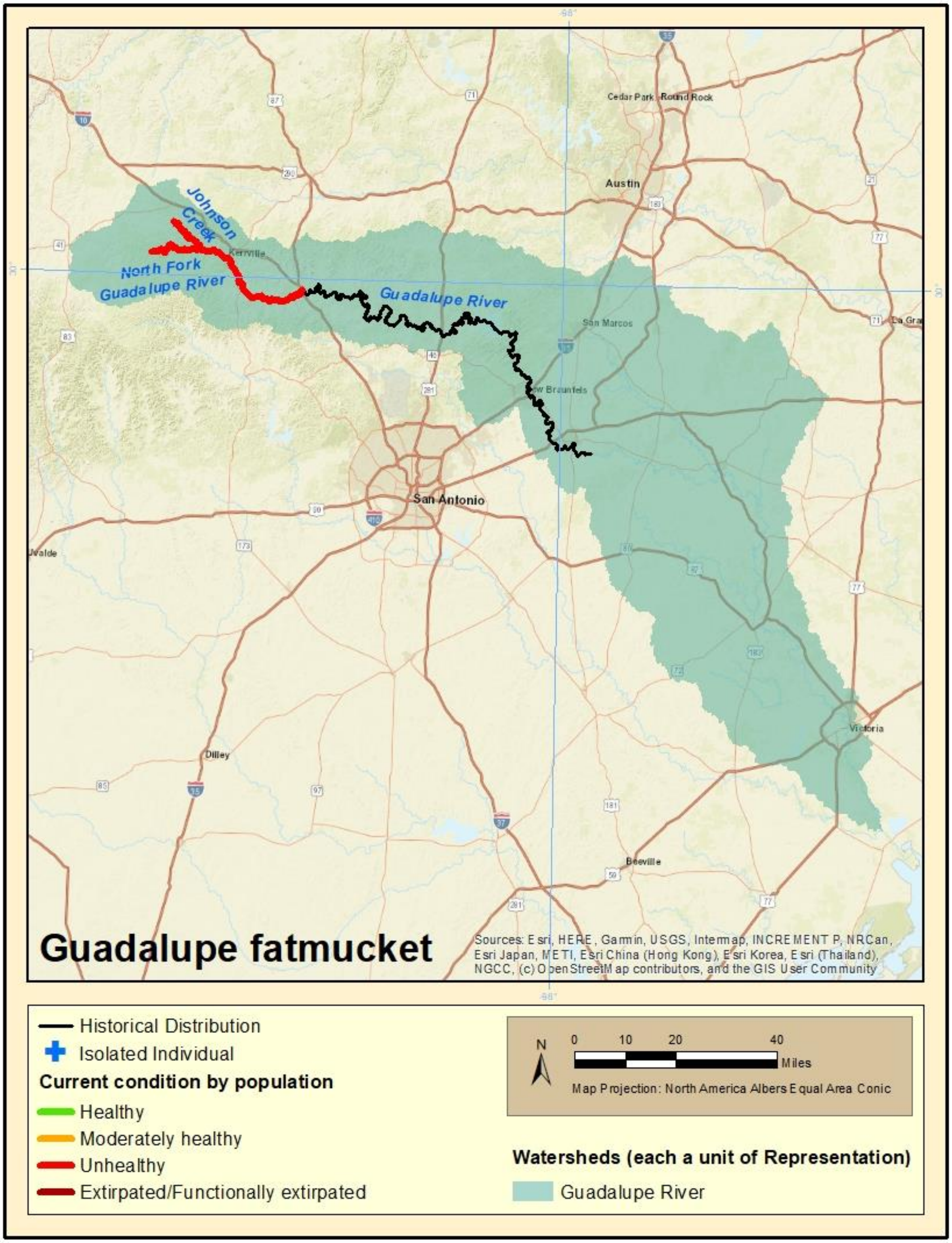

Figure 1. Location and current population condition of Guadalupe Fatmucket in the Guadalupe River basin.

Texas Fatmucket

Texas Fatmucket once existed in at least 14 rivers in the upper Colorado River basin in Texas (USFWS 2022, pp. 35-36; Figure 2). The species ranged from Travis County upstream approximately 200 rmi or 320 rkm to Runnels County. The species was also found in many tributaries of the Colorado River, including the Pedernales, Llano, San Saba, and Concho Rivers, and Jim Ned, Elm, and Onion Creeks (Howells et al. 1996, p. 61).

Currently, there are five remaining populations of Texas Fatmucket, all limited to the upper reaches of major tributaries within the Colorado River basin (Randklev et al. 2017, p. 4; USFWS 2022, p. 90; Figure 2). The total current distribution of Texas Fatmucket, summed across the five populations from the Colorado River basin, is a combined stream length of approximately 295 rmi or 475 rkm (USFWS 2022, p. 90). Historically, these populations were likely connected by fish migration, but due to impoundments and low water conditions in the Colorado River and its tributaries, the remaining populations are isolated from one another, and repopulation of extirpated locations is unlikely to occur without human assistance.

Of the remaining populations of Texas Fatmucket, two are considered moderately healthy, two are unhealthy, and one is functionally extirpated (USFWS 2022, pp. 98-100).

The population in Lower Elm Creek is extremely small and isolated. This population is threatened by excessive sedimentation, deterioration of substrate, altered hydrology associated with anthropogenic activities and the effects of climate change, and water quality degradation (USFWS 2022, p. D-5). The poor habitat conditions and only a single individual found at this site more than a decade ago indicate a population that is unlikely to persist and may already be extirpated (Burlakova and Karatayev 2010, p .12; USFWS 2022, p. D-5).

The population in the Upper/Middle San Saba River is currently considered to be moderately healthy (USFWS 2022, pp. 98-100). Low flows in the San Saba River have resulted in significant stream drying, and stranded Texas Fatmucket and Texas Pimpleback have been identified following dewatering as recently as 2015 (Texas Parks and Wildlife Department 2015, p. 3). During the 2011–2013 drought, stream flows in the San Saba River were critically low, such that several water rights in Schleicher, Menard, and McCulloch Counties were suspended by the Texas Commission on Environmental Quality. These very low flow events are expected to continue and put the upper/middle San Saba River population of Texas Fatmucket at risk of extirpation (USFWS 2022, p. D-5). Even if the stream habitats at the locations of Texas Fatmucket do not become dry, water quality degradation and increased sedimentation associated with low flows is expected.

The Llano River population is currently considered moderately healthy, although there has been limited evidence that the population is successfully reproducing (USFWS 2022, pp. 98-100). We expect base flows to continue to decline and the frequency of extreme high-flow events to increase, leading to increased sedimentation, decreased water quality, and scour (USFWS 2022, p. D-6). The population is expected to decline as a result.

The population in the Pedernales River is very small and isolated. The Pedernales River is a flashy system, which experiences extreme high-flow events, especially in the lower reaches

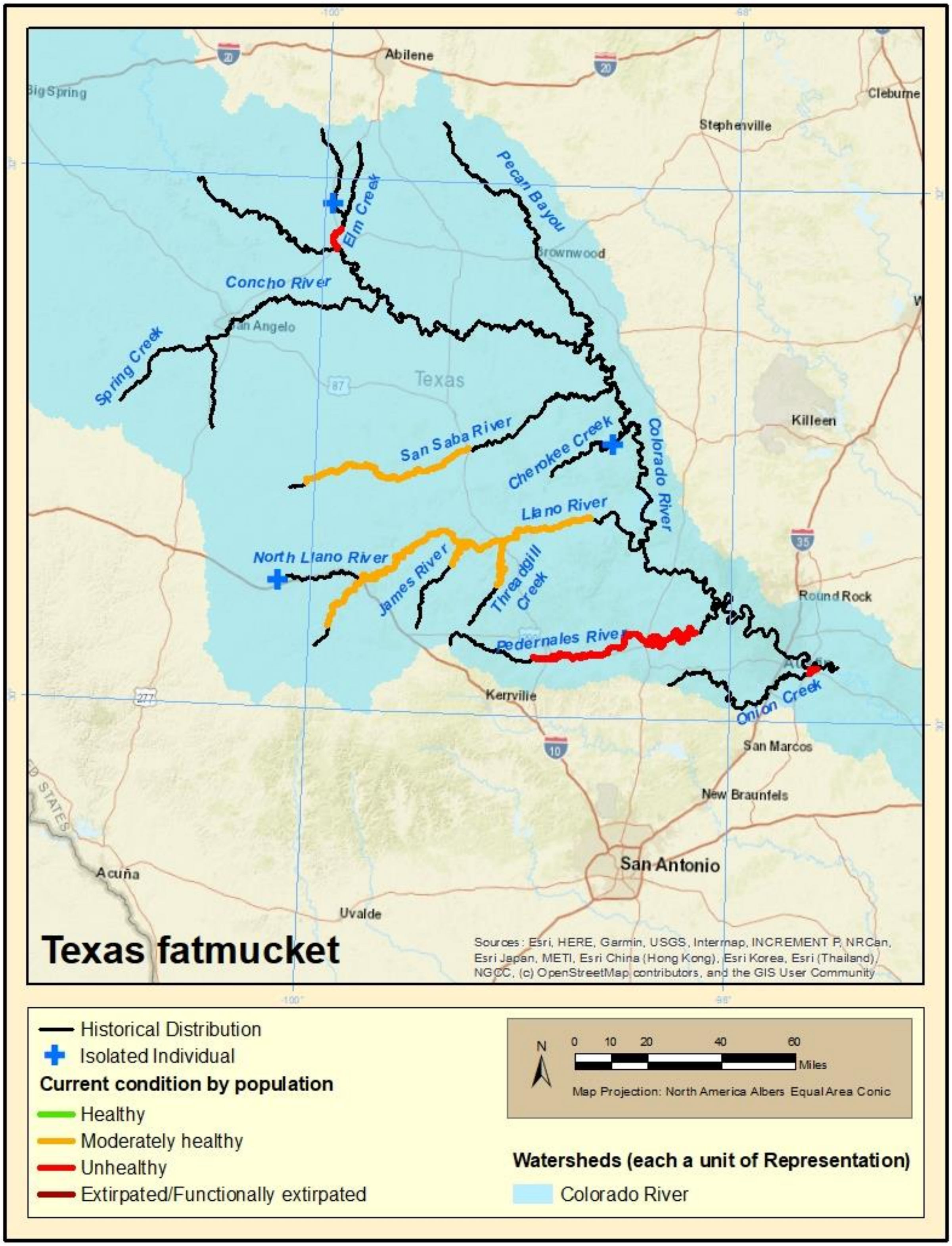

Figure 2. Location and current condition for the five current populations of Texas Fatmucket in the Colorado River basin.

in the vicinity of Pedernales Falls State Park and below (USFWS 2022, p. D-6). Occasional, intense thunderstorms can dramatically increase streamflow and mobilize large amounts of silt and organic debris (Lower Colorado River Authority 2017, p. 82). The increasing frequency of high-flow events, combined with the very low abundance, result in a population that is likely to be extirpated and currently considered unhealthy (USFWS 2022, pp. 98-100, D-6).

The population in Onion Creek is also very small and isolated. Few live individuals of Texas Fatmucket have been found in Onion Creek since 2010, and we consider this population functionally extirpated (USFWS 2022, p. D-7). The upper reaches of Onion Creek frequently go dry (Basin and Bay Expert Science Team 2011, pp. 2-117), and several privately owned, low-head, in-channel dams exist along the upper and lower Onion Creek (City of Austin 2018, p. 4), which are barriers to fish passage and mussel dispersal, preventing recolonization after low-water events. Onion Creek is close to the City of Austin, and continued development in the watershed is expected to continue to degrade habitat conditions.

The Texas Fatmucket has some redundancy given the existing five populations, though only two of those populations are of at least moderate health. The species also has some adaptive capacity or representation in the form of genetic diversity and mantle lure variation (i.e., mantle lures of differing color and shape) that support reproduction (Hannes 2017, pp. 8-18; Howells et al. 2011, entire; USFWS 2022, p. 18).

Guadalupe Orb

Guadalupe Orb historically occurred throughout the length of the Guadalupe and Blanco Rivers within the Guadalupe River basin (Horne and McIntosh 1979, p. 122; Howells 2010, p. 26; Randklev et al. 2017, pp. 109-110; Figure 3). In the Guadalupe River, the species ranged from Comal, Guadalupe, Kendall, Kerr, and Victoria Counties (Randklev et al. 2017, pp. 109-110).

There are two remaining populations of the Guadalupe Orb, one in the upper Guadalupe River and one in the San Marcos and lower Guadalupe River (Figure 3). Historically, populations throughout the basin were likely connected by fish migration, but due to impoundments and low water conditions, the two remaining populations are isolated from one another, and repopulation of extirpated locations is unlikely to occur without human assistance. The upper Guadalupe River population is in unhealthy condition (USFWS 2022, pp. 124-131). The Lower Guadalupe River population, which also extends into the San Marcos River, is in moderate condition (USFWS 2022, pp. 124-131).

The population in the upper Guadalupe River occurs over approximately 95 rmi or 153 rkm, and water quantity and quality are in moderate condition (USFWS 2022, p. 129). The population occurs in low numbers, and with little to no reproduction. This population is considered unhealthy and is expected to become functionally extirpated soon (USFWS 2022, pp. D-17-D-18). This stream reach is sensitive to potential changes in groundwater inputs to stream flow and is vulnerable to ongoing and future hydrological alterations that reduce flows during critical conditions and degrade substrate quality and water quality.

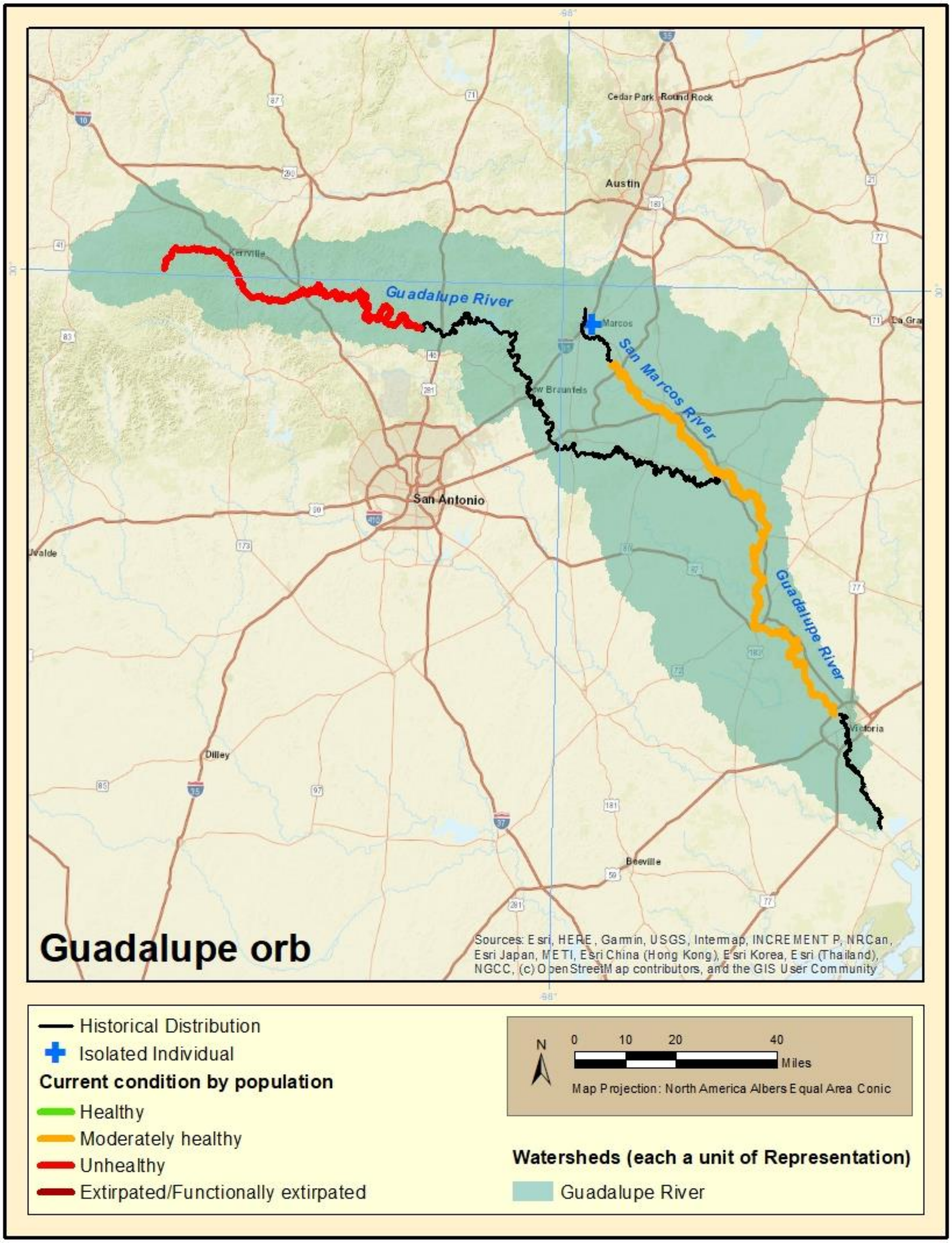

Figure 3. Location and current population conditions of Guadalupe Orb in the Guadalupe River basin.

The population in the San Marcos and lower Guadalupe River currently occupies a relatively long stream length, is observed in relatively high abundances, and exhibits evidence of reproduction. Significant spring complexes contribute substantially to base flow during dry periods in this system and are expected to continue to contribute to baseflows for the next 50 years due to conservation measures implemented by the Edwards Aquifer Habitat Conservation Plan partners (USFWS 2022, p. D-17). However, this population is subject to extreme high-flow events that scour and mobilize the substrate. Water quality degradation and sedimentation are threats.

The Guadalupe Orb exhibits some redundancy in the form of two populations, but only one population is in moderate health. Both populations exist in the Guadalupe River basin, so the species' representation is limited.

Texas Pimpleback

Texas Pimpleback historically occurred through almost the entire mainstem Colorado River, as well as numerous tributaries, including the Concho, North and South Concho, San Saba, Llano, and Pedernales Rivers, and Elm and Onion Creeks (Howells 2010, pp. 110-113; Randklev et al. 2017, p. 109; Figure 4). Now, there are five remaining populations of Texas Pimpleback, and the species currently occupies 325 rmi or 523 rkm (USFWS 2022, pp. 109-117; Figure 4). Three of the remaining Texas Pimpleback populations are unhealthy and are not reproducing. Two of the remaining populations are moderately healthy (USFWS 2022, pp. 109-117). Historically, populations of Texas Pimpleback were likely connected by fish migration, but due to impoundments and low water conditions, the remaining populations are fragmented and isolated from one another, and repopulation of extirpated locations is unlikely to occur without human assistance.

The population in the Concho River is limited by very low levels of flowing water (including periods of almost complete dewatering), poor water quality, and poor substrate quality associated with excessive sedimentation. The drought of 2011– 2013 resulted in extremely low flows in this river (USGS 2013, pp. 13, 18), and only one live adult has been found since that time. This population may be functionally extirpated (USFWS 2022, p. 111).

The population in the Middle Colorado and Lower San Saba Rivers is the largest known population. This population has relatively high abundance but has little evidence of reproduction (USFWS 2022, p. D-13). We expect this population to decline as old individuals die and few young individuals are recruited into the reproducing population. The combination of reduced flows, degraded water quality, and substrate degradation will reduce the resiliency of this population and may cause it to become extirpated (USFWS 2022, p. D-13).

The population in the Upper San Saba River is currently unhealthy and does not appear to be reproducing (USFWS 2022, pp. 109-117). In addition to the high risk of low water levels, the very small population size and lack of reproduction will likely result in the extirpation of this population (USFWS 2022, p. D-14). The losing reach near Hext, Texas, separates the upper and lower San Saba River populations (USFWS 2022, p. D-14). Thus, this population is isolated and no longer connected to the lower San Saba River population.

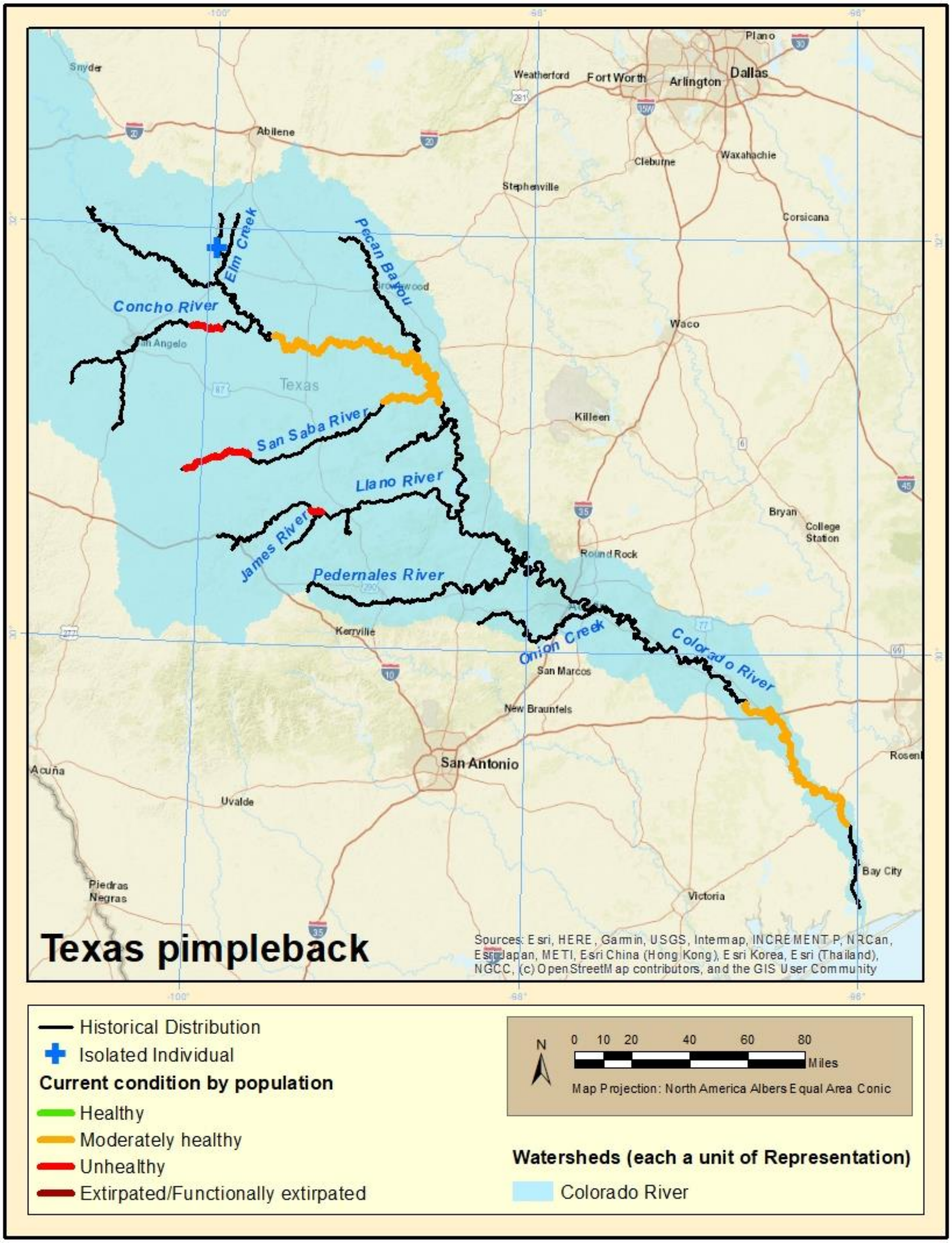

Figure 4. Location and current population condition for the five populations of Texas Pimpleback in the Colorado River basin.

The Texas Pimpleback population in the Llano River occupies a very short stream length, which is negatively affected by substrate degradation during periods of low flows (USFWS 2022, p. D-14). This population, due to accessibility of the location, is especially vulnerable to collection and vandalism. The small population size, the frequency of low water levels, and flooding with scour, cause this population to be considered unhealthy (USFWS 2022, pp. D-14-D-15).

The population in the Lower Colorado River is relatively abundant over a long stream length. However, because the species is a riffle specialist (Bonner et al. 2018, p. 244), Texas Pimpleback are especially sensitive to hydrological alterations (i.e., drying during extreme low-flow and flooding during high-flow events) which cause dewatering or scouring and movement of mature individuals to sites that may or may not be appropriate (as evidenced by the August 2017 scouring flood that degraded the quality of the Altair Riffle in the lower Colorado River, a formerly robust mussel bed; Bonner et al. 2018, pp. 240, 243, 266, and 273). We expect this population to be at risk of extirpation due to these extreme flow events (USFWS 2022, p. D-15).

The Lower San Saba and middle Colorado population is the most robust and would be most resilient against stochastic events, such as floods. In terms of redundancy, the Texas Pimpleback has five remaining populations, though only two of those populations are at least moderately healthy (i.e., resilient). All populations of Texas pimpleback exist in the Colorado River basin, so the species' representation is limited. Texas Pimpleback exhibits some behavioral response to dewatering (Bonner et al. 2018, pp. 196-197), which could provide the species some additional adaptive capacity.

False Spike

Historically, False Spike occurred throughout the Guadalupe River basin (Figure 5), and populations were likely connected by fish migration. However, only one documented population of False Spike currently exists in the lower Guadalupe River (Figure 5). Due to impoundments, repopulation of extirpated locations is unlikely to occur without human assistance.

The lower Guadalupe River population of False Spike has fairly high abundance over a long reach, and flow protections afforded by the Edwards Aquifer Habitat Conservation Plan have contributed substantially to the resiliency of this population by sustaining base flows above critical levels (USFWS 2022, pp. D-1-D-2). However, despite these base flow protections, this population remains vulnerable to changes in water quality, sedimentation, and extreme high flow events, such as from hurricanes or other strong storms, which scour and deplete mussel beds (Strayer 1999, p. 468-469). Overall, this population is moderately healthy (USFWS 2022, pp. 75-82); however, because the species only exists in the form of a single population in one river basin, the species overall has limited redundancy and representation.

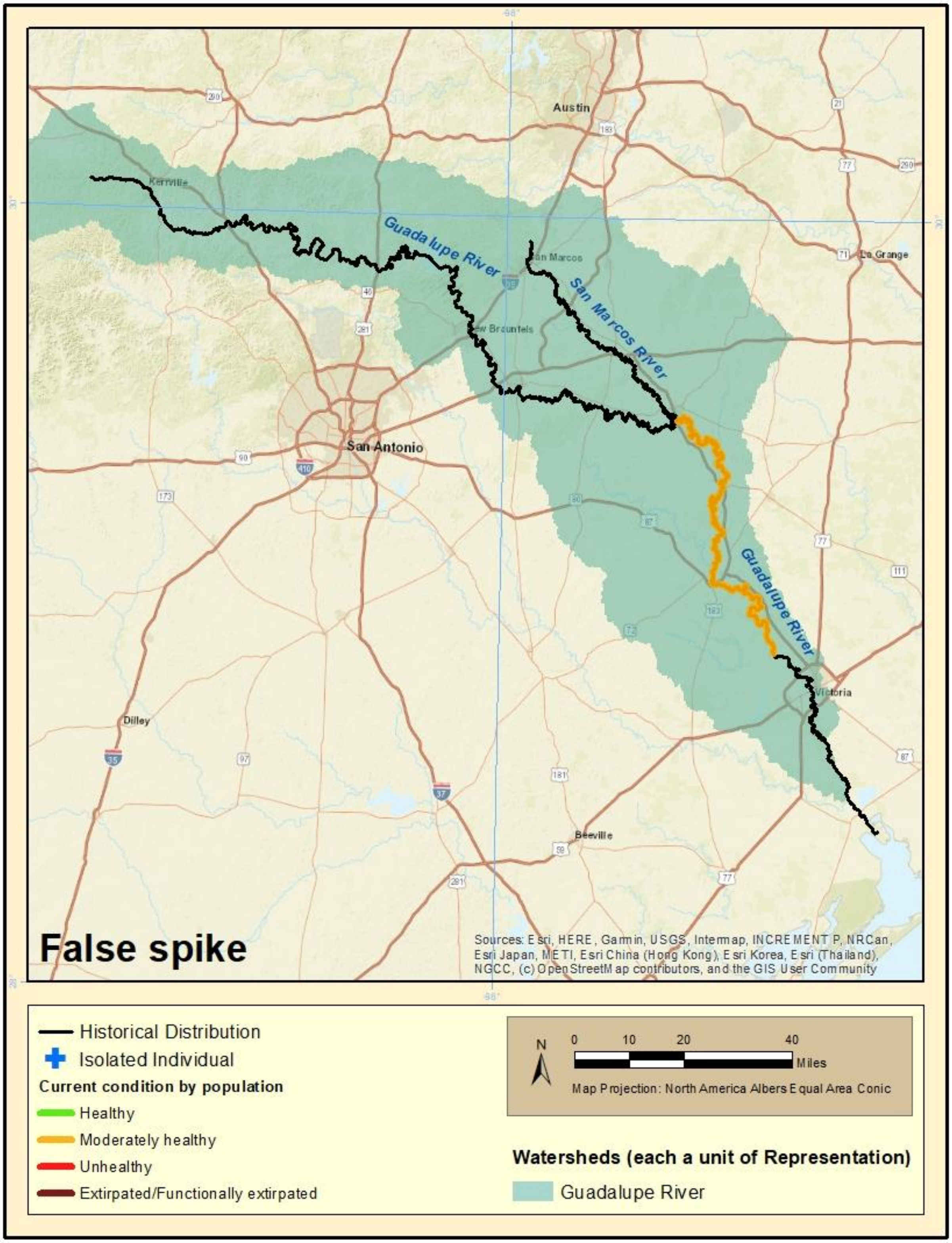

Figure 5. Location and current condition for the population of False Spike in the Guadalupe River basin.

Balcones Spike

Balcones Spike historically occurred throughout the Brazos and Colorado River basins (Figure 6). In the Brazos River basin, historical records document the occurrence of Balcones Spike in the Little River system and the Brazos River. The species has also been historically collected from the Leon River, a tributary of the Little River, in Bell and Coryell Counties (Strecker 1931 pp. 18-19; Randklev et al. 2017, p. 12) and from the Lampasas River, another tributary of the Little River (Randklev et al. 2017, p. 12).

There are three remaining populations of Balcones Spike—one in the Little River and some of its tributaries, one in the lower San Saba River, and one in the Llano River (Figure 6). The currently occupied stream length of the Balcones Spike population is 83 rmi or 134 rkm. Historically, most Balcones Spike populations were likely connected by fish migration, but due to impoundments, the populations are now isolated, and repopulation of extirpated locations is unlikely to occur without human assistance. All three populations of Balcones Spike are in low condition (USFWS 2022, pp. 82-90).

Brazos River Basin

The population in the Little River and its tributaries occurs over approximately 41 rmi or 66 rkm. Development in the watershed has reduced water quality and substrate conditions. Habitat condition is expected to decline further because of alterations to flows and water quality associated primarily with additional development in the Austin-Round Rock metropolitan area. Low water levels also remain a concern for the species (USFWS 2022, p. D-4).

Colorado River Basin

The current population of Balcones Spike in the lower San Saba River is known to occur from the CR 340 bridge-crossing downstream to the confluence of the San Saba River with the Colorado River. This population occupies approximately 42 rmi or 68 rkm of the San Saba River in San Saba County, Texas.

The Llano River population of Balcones Spike is by far the smallest population and is known to persist only in the immediate vicinity of the FM 1871 bridge-crossing in Mason County, Texas. This population is less than one rmi in length and is made of only a few small mussel beds.

Degradation of habitat for both Colorado River populations is expected to continue as flows continue to decline due to altered precipitation patterns (dewatering droughts and scouring floods) combined with enhanced evaporative demands and anthropogenic withdrawals to support existing and future demands for municipal and agricultural water (USFWS 2022, pp. D-3-D-4). Additionally, because of easy highway access and proximity to major cities, the Llano River population is frequently sampled by mussel collectors and researchers (USFWS 2022, p. 83).

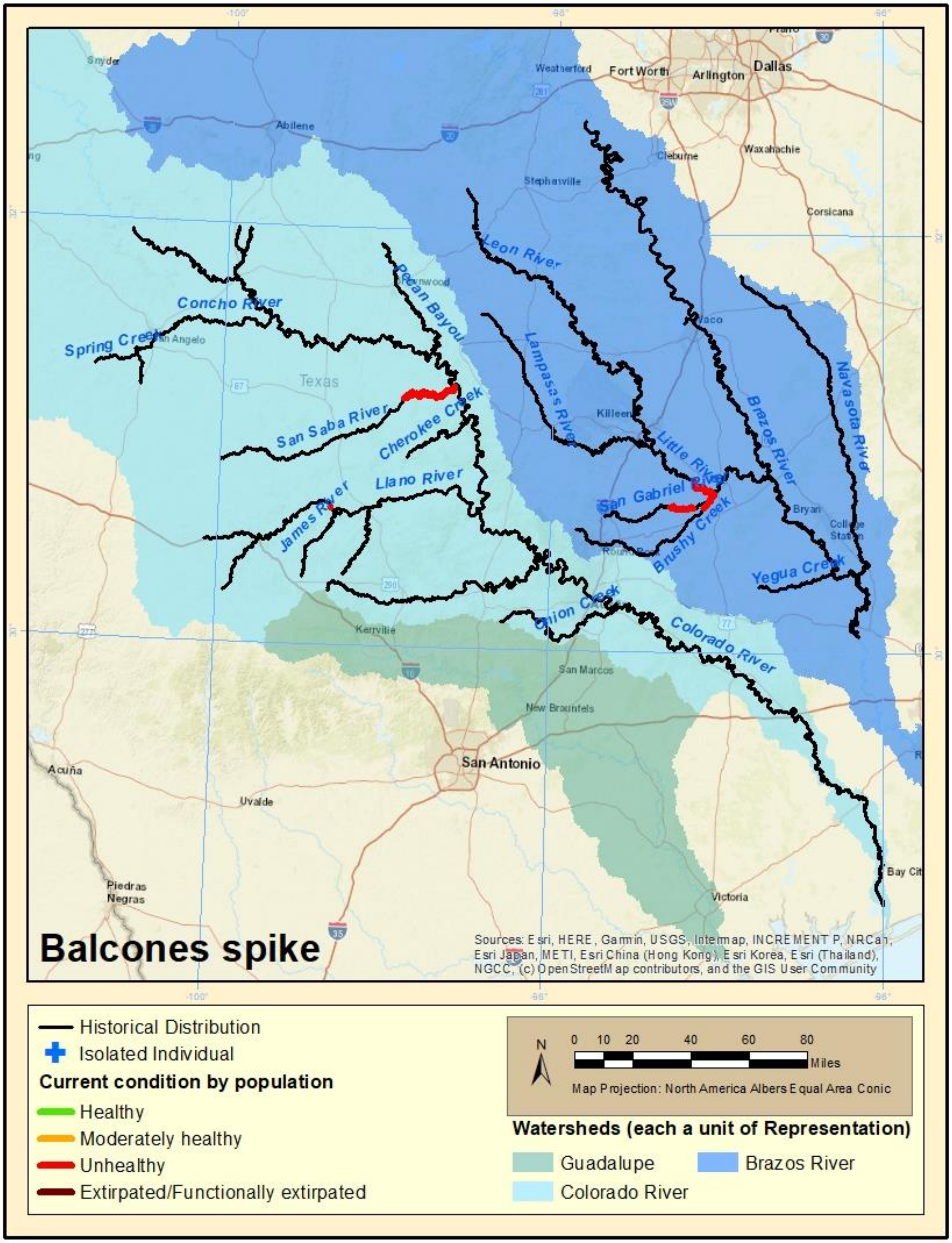

Figure 6. Location and current condition of the three populations of the Balcones Spike in the Brazos and Colorado River basins.

The Balcones Spike exhibits some redundancy with three populations; however, all current populations of the species are in unhealthy condition (i.e., they have low resiliency), which limits the species' redundancy. The species occurs in two river basins—the Colorado and Brazos River basins—which provides some adaptive capacity (i.e., representation).

Texas Fawnsfoot

Historical records suggest Texas Fawnsfoot inhabited much of the Colorado River basin, from the mainstem Colorado River in Wharton County upstream to the North Fork of the Concho River in Sterling County, and throughout the Concho, San Saba, and Llano Rivers and Onion Creek (Howells 2010, pp. 89-91; Figure 7). In the Brazos River, the species occurred from Fort Bend County to the lower reaches of the Clear Fork of the Brazos River in Shackelford County, as well as in the Leon, Little, Navasota, and San Gabriel Rivers, and Deer and Yegua Creeks (Howells 2010, pp. 89-91; **Error! Reference source not found.**).

Currently, there are seven remaining populations of Texas Fawnsfoot in the Trinity, Brazos, and Colorado River basins (Figure 7). Among these three basins, Texas Fawnsfoot currently inhabits about 660 rmi or 1062 rkm. Historically, Texas Fawnsfoot populations were connected by fish migration within each basin, but due to impoundments and low water conditions, the remaining populations are isolated from one another, and repopulation of extirpated locations is unlikely to occur without human assistance.

Four Texas Fawnsfoot populations are moderately healthy, and three are unhealthy (USFWS 2022, pp. 100-109).

Trinity River Basin

The population in the East Fork Trinity River occurs over a small stream reach (about 12 rmi or 19 rkm), which makes it especially vulnerable to a stochastic event, such as a spill or flood, and to changes in water quality (USFWS 2022, pp. 102, D-11). We have no evidence of reproduction, and we expect this population to decline as old individuals die and few young individuals are recruited into the reproducing population (USFWS 2022, p. D-11). This population is small and isolated from the middle and lower Trinity River population by unsuitable habitat affected primarily by altered hydrology from the Dallas-Fort Worth metro area. This population is considered unhealthy (USFWS 2022, pp. 100-109).

The population in the Middle Trinity River has experienced improved water quality over the past 30 years due to advancements in wastewater treatment technology and subsidized stream flows. However, water quality degradation and sedimentation are still of concern (USFWS 2022, p. D-12). Additionally, the middle Trinity River is a relatively long and unobstructed reach. We expect the population to persist in the middle Trinity River, as we expect that flows will remain within a normal range of variation (USFWS 2022, p. D-12).

Brazos River Basin

The population in the Clear Fork Brazos River is very small and isolated. This population likely experienced extensive mortality due to prolonged dewatering during the 2011– 2013 drought and due to the degradation of water quality associated with naturally occurring elevated salinity levels from the upper reaches of the river.

This population is likely functionally extirpated, although more survey effort is needed (USFWS 2022, p. D-8).

The population in the Upper Brazos River is characterized by low abundances, little to no reproduction, and reduced flows associated with continued drought and upstream dam operations (USFWS 2022, pp. D-8-D-9). Water quality degradation associated with naturally occurring salinity is expected to continue. This population is at risk of extirpation due to its small population size and continued poor habitat conditions (USFWS 2022, pp. D-8-D-9).

The population in the Middle/Lower Brazos River occupies a fairly long reach of river (346 rmi or 557 rkm) and exhibits evidence of reproduction. The lack of major impoundments and diversions in the Brazos River below Waco, Texas, benefits this population through maintenance of a natural hydrological regime (USFWS 2022, p. D-9). However, Texas Fawnsfoot surveys have yet to yield the species in numbers that would indicate a healthy population, and future habitat degradation from reduced flows, increased temperatures, and decreased water quality will likely reduce the resiliency of this population (USFWS 2022, p. D-9).

Colorado River Basin

The population in the Lower San Saba River has low abundance with little evidence of reproductive success. Habitat has experienced degraded substrate conditions caused by reductions in flow from water withdrawal and drought (USFWS 2022, pp. 100-109). We expect this population to become functionally extirpated due to lack of water and degradation of substrate (USFWS 2022, pp. D-9-D-10).

The population in the Lower Colorado River is expected to remain extant under current conditions, as this reach is expected to remain wetted but flowing at reduced amounts that reduce available habitat (USFWS 2022, pp. 100-109). Despite increasing demands for municipal water, we expect that the lower Colorado River will continue to have water associated with priority downstream agricultural and industrial water rights (USFWS 2022, pp. D-10-D-11). Similar to the lower Brazos River population, the Lower Colorado River is vulnerable to reduced flows and associated habitat degradation. Texas Fawnsfoot occurs in bank habitats that are likely to become exposed as river elevations drop, meaning the habitats can experience lower water levels or drying even while the river flows in the main channel. These low water levels can lead to desiccation, depredation, and increased water temperatures. Over time, we expect flows in the lower Colorado River to be reduced, negatively affecting substrate quality and water quality (through increased sediment load and water temperature) such that reproduction and abundance are negatively affected, resulting in overall unhealthy population conditions (USFWS 2022, pp. D-10-D-11).

Texas Fawnsfoot exhibits some redundancy with seven remaining populations, four of which are of at least moderate health. Texas Fawnsfoot also exists in several river basins—the Trinity, Colorado, and Brazos River basins—giving the species some adaptive capacity (i.e., representation). No gene flow currently exists between populations of different river basins (Inoue et al. 2018, p. 4).

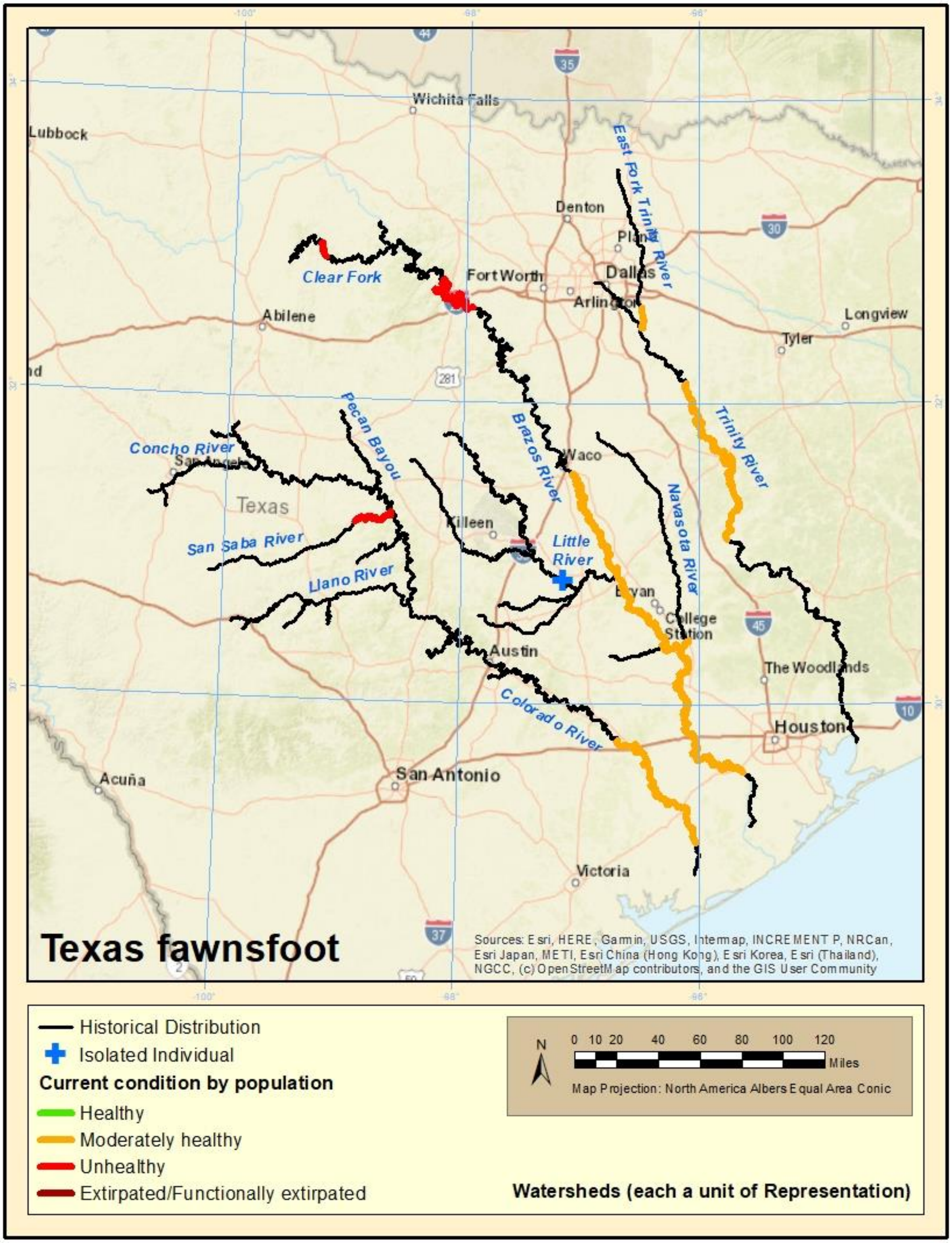

Figure 7. Location and current condition of the seven populations of Texas Fawnsfoot in the Trinity, Brazos, and Colorado River basins.

Summary

All seven species of Central Texas mussels exhibit various levels of resiliency, redundancy, and representation across the major river basins in which they occur. While some populations of some species have habitat or demographic factors that are healthy (such as stream length or abundance, no population exhibits all of the factors that would define a strong, healthy mussel population. Given our analysis of current condition, none of the species are in healthy condition overall.

Conservation Actions to Date

Since the 12-month finding on three of the Central Texas Mussels (USFWS 2011, entire), many agencies, non-governmental organizations, and other interested parties have been working to develop voluntary agreements to restore or enhance habitats for fish and wildlife in the region, including the Central Texas mussels. These agreements provide voluntary conservation including habitat enhancements that will, if executed properly, reduce threats to the species while improving in-stream physical habitat and water quality, as well as improving adjacent riparian and upland habitats. Examples of voluntary conservation agreements currently implemented include:

- Brazos River Authority (BRA) Candidate Conservation Agreement with Assurances (CCAA),
- Lower Colorado River Authority (LCRA) CCAA,
- Trinity River Authority (TRA) CCAA,
- USFWS Partners for Fish and Wildlife Program Private Lands Agreements and sub-recipient Cooperative Agreements,
- Texas Parks and Wildlife Department Landowner Incentive Program Agreements,
- U.S. Department of Agriculture–Natural Resources Conservation Service (USDA-NRCS) conservation plans, including the proposed Working Lands for Wildlife Project (NRCS 2019a, entire) and Conservation Technical Assistance (NRCS 2019b, entire).

The conservation benefits of these agreements and plans cannot be fully evaluated at the time of this recovery outline. For example, the BRA, LCRA, and TRA CCAAs have only recently been implemented, although the USFWS expects that many benefits to the Central Texas mussels will be realized over the term of these agreements. The USFWS also acknowledges additional conservation plans under development that should benefit the Central Texas mussels, including a Habitat Conservation Plan under development by the Guadalupe-Blanco River Authority.

Additionally, the Texas Parks and Wildlife Department (TPWD) has a review process for Aquatic Resource Relocation Permits which includes projects requiring the relocation of freshwater mussels within the state. Through this process, TPWD provides survey protocols (developed jointly with the USFWS; USFWS and TPWD 2023, entire), reviews projects for their impacts to mussels, and aids in the protection and conservation of mussels during in-stream activities. The TPWD along with other academic institutions, such as Texas A&M University and Texas State University, are conducting multiple ongoing scientific studies investigating species' needs and distributions.

Furthermore, some publicly and privately owned lands in the watersheds occupied by Central Texas mussels are also protected with conservation easements or are otherwise managed to support populations of native fish, wildlife, and plant populations (USFWS 2022, p. 140).

Lastly, work is underway to evaluate methods of captive propagation for the Central Texas mussels at USFWS hatcheries and research facilities, including the San Marcos Aquatic Research Center, Inks Dam National Fish Hatchery, and Uvalde National Fish Hatchery. This work also includes efforts to collect gravid females from the wild to infest host fish (Bonner et al. 2018, pp. 8, 9, and 11).

RECOVERY PLANNING

Recovery Priority Number

Recovery Priority Number: 5
The Guadalupe Fatmucket, Guadalupe Orb, Texas Pimpleback, False Spike, and Balcones Spike are assigned a recovery priority of 5, indicating that the species face a high degree of threat and have low recovery potential. The threats to the species are high due to ongoing sources of habitat loss, degradation, and modification, including impoundments, water use and management, ongoing drought conditions, water quality degradation, and sedimentation. The recovery potential of these mussels is low because recovery will require intensive management with uncertain probability of success. Recovery will require a large water management effort by many water users. The myriad of threats coupled with the large-scale effort required for recovery, as well as climate projections for continued drought and extreme precipitation events, make the potential for recovery of these four Central Texas mussels low.

Recovery Priority Number: 8
The Texas Fatmucket and Texas Fawnsfoot are assigned a recovery priority of 8, indicating that the species face a moderate degree of threat and have high recovery potential. The threats to the species are moderate because each species has four or more populations over which to spread the risk from ongoing threats, such as habitat loss, degradation, and modification, including impoundments, water use and management, ongoing drought conditions, water quality degradation, and sedimentation. The recovery potential of these mussels is relatively high compared to the other Central Texas mussels. Though intensive management may be needed to recover these species, recovery may not require the creation of additional populations if existing populations can be made more resilient.

Recovery Vision

In terms of the 3Rs, the long-term viability of the Central Texas mussels is dependent upon the maintenance and restoration of multiple (redundant), healthy (resilient) populations distributed throughout each species' historical range with appropriate population structure and genetic diversity (representation). Species' populations must be in sufficient number and distribution across the historical range to shield the species from losses in adaptive capacity from catastrophic events (e.g., droughts, floods, spills, etc.).

The overall recovery strategy for the Central Texas mussels will involve stemming any further reductions in range and abundance, restoring and managing watersheds and stream habitat to support additional resilient populations, and increasing redundancy and representation via those populations. Competing interests for limited water supplies from industry, agriculture, oil and gas exploration, and growing human populations will likely continue to affect instream habitats from a water quality and quantity perspective, further complicating recovery.

The Central Texas mussels face many threats (see **Primary Threats**), and the most significant impact of those threats is reduced access to high quality, flowing water. To increase the 3Rs and each species' viability, recovery will have to address issues of water quality and quantity. Actions to address water quality and quantity might include captive propagation and reintroduction to support populations through harsh conditions, protection of water quality in sensitive areas, restoration of natural hydrology where possible, and restoration and maintenance of riparian and in-stream habitat, among others.

Recovery of the Central Texas mussels will require flexible conservation and management to use the most up-to-date information as it becomes available and will involve cooperation among Federal, State, and local agencies, private landowners, academia, and other stakeholders.

Interim Recovery Program

Interim Recovery Strategy

The resiliency, redundancy, and representation of the species must be increased to ensure the long-term viability of the Central Texas mussels. To achieve this, each species needs multiple, resilient populations within the species' historical range that represent the species' breadth of genetic and ecological diversity (representation). The number of populations (redundancy) needed will depend on the health (resiliency) of each population, as well as the extent of genetic and/or ecological diversity within the historical range determined to be representative of the species. Here we present an interim recovery strategy with four collaborative components for recovering the Central Texas mussels.

Recovery of the Central Texas mussels will require maintaining and developing watershed and basin-wide partnerships among Federal, State, Tribal, and local agencies as well as private landowners and the public. Therefore, the recovery of Central Texas mussels will rely on the implementation of certain recovery actions accomplished in coordination with and through our partners.

Action Plan

The USFWS has identified preliminary recovery actions necessary to implement each of the components of the following interim recovery strategy.

1) Protect existing populations of Central Texas mussels by minimizing adverse effects to habitat and populations.

   a) Work with partners to remove or restructure existing impediments to streamflow and fish passage. Where possible, identify and curtail future potential impediments to

streamflow and fish passage. Implement efforts to avoid or minimize alterations to natural flow regimes by preventing stream channel fragmentation.

b) Work with partners to adapt flow releases from reservoirs, such as those operated by the Lower Colorado and Brazos River Authorities, so that flowing water is available to the Central Texas mussels and suitable habitat conditions are maintained.

c) Work with partners to avoid and minimize actions that contribute to the degradation of water quality, including threats to water quality from existing point and non-point sources, and proposed new sources of environmental pollutants. Develop plans to maintain and support healthy watersheds and river basins occupied by the species.

d) Develop a landscape approach with partners to increase instream flows and water quality throughout the species' habitats.

2) Continue and support surveying and monitoring efforts for the Central Texas mussels.

a) Support ongoing projects by TPWD, Texas State University, Texas A&M University, University of Texas – Austin, the River Authorities, and other surveying and monitoring efforts.

b) Support a reliable and authoritative database on survey, occurrence, and presence/absence data (i.e., Mussels of Texas database). Work with partners to ensure that survey and monitoring data are recorded in a consistent way to be entered into the database. Secure funding to maintain the database.

c) Evaluate currently and formerly occupied watersheds across the historical range to identify and prioritize areas for restoration and potential species reintroduction.

3) Conduct research to inform knowledge gaps and future conservation of the species.

a) Improve understanding of species' habitat needs, such as water temperature tolerances and water quality tolerances (e.g., dissolved oxygen, pH, salinity). Caged studies that expose juvenile mussels in-situ to stream conditions in containers known as silos are particularly useful in examining habitat quality (i.e., determining whether water quality or water quantity is limiting growth and survival).

b) Where needed, determine species' tolerances to chemical pollutants (e.g., ammonia, copper, heavy metals, pesticides).

c) Investigate stream flow requirements necessary to support and maintain mussel populations.

d) Investigate the suitability and feasibility for cryopreservation of the species' genetic and biological material.

e) Investigate species life history characteristics (e.g., laboratory and ecological fish hosts, fecundity, lifespan, and growth rates in response to abiotic factors).

4) Increase public knowledge, education, and support for the Central Texas mussels.

a) Develop programs and materials to inform the public of the need for and benefits of restoring and protecting native freshwater mussel populations. Coordinate with partners to host workshops and outreach events and produce social media outreach content.

b) Work with interested private landowners and others to ensure landscape Best Management Practices are used to avoid or minimize harmful effects to the species' populations or habitats.
c) Work with conservation partners to promote species conservation and public education regarding the Central Texas mussels.

Preliminary Steps for Recovery Planning

We will prepare a recovery plan pursuant to section 4(f) of the ESA. The recovery plan will include objective, measurable criteria which, when met, may result in a determination that the species be removed from the Federal list of Endangered and Threatened Wildlife. Recovery criteria will address threats meaningfully impacting the species. The recovery plan will include site-specific management actions as may be necessary for the conservation and survival of the species. Finally, the recovery plan will estimate the time and cost required to carry out those measures needed to achieve the goal of recovery and delisting for the Central Texas mussels.

Recovery plan preparation will be carried out by the USFWS Austin and Texas Coastal and Central Plains Ecological Services Field Offices and Southwest Regional Office and partners. During the recovery planning process, input, comments, and review will be sought from multiple stakeholders across the current and historical species' range. These will include Federal and State agencies, Tribes, and academic and private entities. Primary authorship of the Recovery plan will be the responsibility of USFWS staff, though our partners will be involved and engaged in all phases of the planning and implementation process. In fact, recovery will only be possible with direct involvement and support of our conservation partners.

Jonna Polk Digitally signed by Jonna Polk Date: 2024.06.12 12:25:33 -05'00'

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