Species Status Assessment Report for two Rio Grande Mussels: Salina Mucket (*Potamilus metnecktayi*) Mexican Fawnsfoot (*Truncilla cognata*)

Adult Salina Mucket (left photo; male top, female bottom) and Mexican Fawnsfoot (right photo) from the Rio Grande, Texas. Photo by Clint Robertson, Texas Parks and Wildlife Department.

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Species Status Assessment Report For Two Rio Grande Mussels: Salina Mucket (*Potamilus metnecktayi*) and Mexican Fawnsfoot (*Truncilla cognata*)

Prepared by the
U.S. Fish and Wildlife Service

EXECUTIVE SUMMARY

This species status assessment reports the results of the comprehensive status reviews for the Salina Mucket (*Potamilus metnecktayi* Johnson 1998) and Mexican Fawnsfoot (*Truncilla cognata* Lea 1860) (Rio Grande mussels) and provides a thorough account of the species' overall viabilities and extinction risks. The Salina Mucket and Mexican Fawnsfoot are freshwater mussels native to the Rio Grande drainage in Texas and Mexico. Salina Mucket occur in medium to large rivers, generally in nearshore habitats and crevices, undercut riverbanks, travertine shelves, and under large boulders adjacent to runs. Mexican Fawnsfoot occur in medium to large rivers, in or adjacent to riffle and run habitats as well as in stream bank habitats.

To evaluate the biological status of the Rio Grande mussels, both currently and into the future, we assessed a range of conditions to allow us to consider the species' resiliency, redundancy, and representation (together, the 3Rs). The Rio Grande mussels need multiple resilient populations distributed widely across their ranges to persist into the future and avoid extinction. Several factors influence whether the Rio Grande mussels' populations will grow to maximize habitat occupancy, which increases the resiliency of a population to stochastic events. These factors are the amount of fine sediments accumulated in the substrate, flowing water, and water quality. See Appendix B (Cause and Effects Tables) for a more detailed description of the factors and their effects on the species. As we consider the future viability of the species, more populations with high resiliency distributed across the known range of the species are associated with higher overall species viability.

The Rio Grande mussels are believed to be extirpated from the majority of their historical distribution in the United States (U.S.) and entirely from Mexico. Both species currently occur in single populations distributed in remote areas of the Rio Grande basin in Texas. We have assessed each species resiliency, redundancy, and representation currently and into the future by ranking the condition of each population. Rankings are a qualitative assessment of the relative condition of occupied streams based on the knowledge and expertise of Service staff, as well as published reports.

Our analysis of the past, current, and future conditions that the Rio Grande mussels need for long-term viability revealed there are three influences that pose the largest risk to future viability of each species. These risks are primarily related to habitat changes: the accretion of fine sediments, the loss of flowing water through either dewatering or inundation by impoundments, and impairment of water quality; all of which are anticipated to be exacerbated by climate change. Groundwater extraction and drought are expected to result in impaired water quality and reduced water levels, which reduce habitat availability and increase fine sediment accumulation in habitats

occupied by both species. In addition to landscape-scale threats, a low-water weir has been proposed for construction near Laredo, Texas, which would eliminate a substantial portion of remaining habitat for the Mexican Fawnsfoot. Additionally, the low-water weir would likely restrict fish host passage between the populations on the up and downstream sides of the structure resulting in genetic isolation.

Both Rio Grande mussels face a variety of risks, including loss of stream flow, contamination and impaired water quality, and inundation of existing habitats by impoundments. These risks play a crucial role in the future viability of each species. If populations lose resiliency, they are more vulnerable to extirpation, with resulting losses in representation and redundancy. Given our uncertainty regarding future water quality, flowing water availability, and substrate suitability within the populations, we have forecasted resiliency, redundancy, and representation the Rio Grande mussels may have under three future plausible scenarios, in which we made the following assumptions about stressors to the populations:

Scenario 1: Continuation/Moderate Effects
Rio Grande – Lower Canyons – There is a small to moderate water flow reduction due to drought, groundwater extraction, climate change, and management of the Rio Conchos. Stressors continue at a similar rate to the past decade, which result in further population decline. Older Salina Mucket individuals begin to die out of the population with limited levels of recruitment replacing them.

Rio Grande – Laredo – The low-water weir is not constructed, water quality declines, and there is a small water flow decline. Human population growth continues and additional water intake and treatment facilities are constructed. Stressors continue at a similar rate as the past decade, which result in further population declines. Older Mexican Fawnsfoot individuals begin to die out of the population with limited recruitment of juveniles.

Scenario 2A: Severe Effects, no weir construction
Rio Grande – Lower Canyons – There is a severe water flow reduction due to drought, climate change, groundwater extraction, and management of the Rio Conchos, as well as declines in spring flows from the Edwards-Trinity Aquifer. In combination, these declines in flow lead to degraded water quality in the stream reach. Older Salina Mucket individuals begin to die out of the population with limited levels of recruitment replacing them.

Rio Grande – Laredo – The low-water weir is not constructed, water quality and quantity decline. Habitat degradation occurs due to increased sedimentation, desiccation during drought, and exceedance of thermal and chemical tolerances. Older Mexican Fawnsfoot individuals begin to die out of the population with limited recruitment of juveniles.

Scenario 2B: Severe Effects, weir is constructed 25 years in the future
Rio Grande – Lower Canyons – There is a severe water flow reduction due to drought, climate change, groundwater extraction, and management of the Rio Conchos, as well as declines in spring flows from the Edwards-Trinity Aquifer. In combination, these declines in flow lead to a degraded water quality in the stream reach. Older Salina Mucket individuals begin to die out of the population with limited levels of recruitment replacing them.

Rio Grande – Laredo – The low-water weir is constructed, which results in inundation of approximately 14 river miles of habitat. There is a severe water flow reduction due to climate change, groundwater extraction, and management of upstream releases from Lake Amistad. Water quality degrades as the flow rate declines and discharges from municipal and industrial operations increase due to human population expansion. Older Mexican Fawnsfoot individuals begin to die out of the population with limited recruitment of juveniles.

We examined resiliency, representation, and redundancy for each of the Rio Grande mussels under each of these plausible scenarios (Tables ES-1 and ES-2). Resiliency of Rio Grande mussel populations depends on future water quality, availability of flowing water, and substrate suitability. We expect the two extant Rio Grande mussel populations to experience changes to these aspects of their habitat in different ways under the different scenarios. We projected the Rio Grande mussels expected future resiliency, representation, and redundancy based on the events that would occur under each scenario (Tables ES-3 and ES-4).

Under Scenario 1 (Continuation/Moderate Effects) – We expect the Salina Mucket population condition overall to decline from 'Low' currently to 'Very low', which puts the species at a high risk of extinction 50 years into the future. The species is also predicted to be extirpated from 83% of its currently occupied range at the 50-year time-step. The currently extirpated Salina Mucket populations (i.e. Rio Grande near Laredo and Rio Salado, Mexico) remain extirpated as repopulation of these areas is not naturally possible.

Mexican Fawnsfoot declines from a 'Low' current condition to 'Very Low' over the next 25 years; however, we project the species will be extinct 50 years into the future. Like Salina Mucket, the species is unable to repopulate currently extirpated populations in the Rio Grande upstream of Lake Amistad or the Rio Salado in Mexico.

Under Scenario 2A (Severe Effects, no weir) – We expect the Salina Mucket population to decline from a current overall 'Low' to 'Very low' condition over the next 50 years. This puts the species at a very high risk of extinction. The species is also predicted to undergo an 83% reduction in range over the next 50 years compared to currently occupied areas.

Based on our risk assessment for the Mexican Fawnsfoot, we predict the species will be extinct 50 years into the future despite the weir upstream of Laredo not being constructed. This extinction is attributable to degraded habitat and water quality coupled with die-off of adult individuals with little to no recruitment of juveniles.

Under Scenario 2B (Severe Effects, weir constructed 25 years into the future) – We expect the Salina Mucket population to decline from a current overall condition of 'Low' to 'Very low' over the next 50 years. This puts the species at a very high risk of extinction. The species is also predicted to undergo an 83% reduction in range over the next 50 years compared to currently occupied areas. The weir has no effect on this species as it does not occur in the proposed project area.

Based on our risk assessment for the Mexican Fawnsfoot, we predict the species will be extinct 50 years into the future assuming the weir is constructed at the 25-year time step. The low water weir significantly impacts instream habitats, leading to the extirpation of the largest and most dense beds of Mexican Fawnsfoot known to exist. The hydrological alterations caused by the weir, degraded habitat, decreases in flowing water and water quality, coupled with die-off of adult individuals with little to no recruitment of juveniles results in the extinction of the Mexican Fawnsfoot.

Table ES-1. Salina Mucket population conditions in 50 years under each scenario.

Salina Mucket – Overall Population Condition in 50 years			
Population	Scenario 1	Scenario 2	Notes
Rio Grande – Lower Canyons	Very Low	Very Low	83% loss of currently occupied range
Rio Grande – Laredo	Extirpated	Extirpated	None
Rio Salado (Mexico)	Extirpated	Extirpated	None

Table ES-2. Mexican Fawnsfoot population conditions in 50 years under each scenario.

Mexican Fawnsfoot – Overall Population Condition in 50 years				
Population	Scenario 1	Scenario 2A	Scenario 2B	Notes
Rio Grande – Laredo	Extirpated	Extirpated	Extirpated	The species becomes **extinct** within the next 50 years
Rio Grande – above Amistad	Extirpated	Extirpated	Extirpated	None
Rio Salado (Mexico)	Extirpated	Extirpated	Extirpated	None

Table ES-3. Species Status Assessment summary for the Salina Mucket currently and 50 years into the future.

Salina Mucket - Species Status Assessment Summary			
3Rs	**Needs**	**Current Condition**	**Future Condition (Viability)**
Resiliency: Population (Large populations able to withstand stochastic events)	• Suitable substrate: nearshore habitats, crevices, undercut banks, bedrock shelves, and seams of fine sediment • Sufficient water quality • Flowing river ecosystems • Sufficient occupied stream length	• 1 extant population, approximately 133 river miles • Extirpated from about 600 river miles • Population status: ○ 1 in low condition	Projections based on future scenarios in 50 years: • **Continuation/Moderate Effects –** the species loses 83% of its currently occupied range and declines to 'Very Low' condition. Habitat conditions decline marginally. • **Severe Effects -** the species loses 83% of its currently occupied range and declines to 'Very Low' condition. Habitat degrades rapidly as flowing water and water quality decline.
Representation (genetic and ecological diversity to maintain adaptive potential)	• Distinct variation in allele frequencies exists between multiple, genetically isolated populations across the species range	• Minimal genetic variation expected across the extant population. • Limited number of individuals all live in similar habitat so likely no unique adaptations exist	Projections based on future scenarios in 50 years: • **Continuation/Moderate Effects –** representation declines as the species undergoes range reductions. • **Severe Effects -** representation declines as the species undergoes range reductions.
Redundancy (Number and distribution of populations to withstand catastrophic events)	• Multiple populations in each area of genetic representation	• Only one extant population is known to exist	Projections based on future scenarios in 50 years: • **Continuation/Moderate Effects –** the species has no redundant populations now or into the future

Table ES-4. Species Status Assessment summary for the Mexican Fawnsfoot currently and 50 years in the future.

Mexican Fawnsfoot – Species Status Assessment Summary			
3Rs	**Needs**	**Current Condition**	**Future Condition (Viability)**
Resiliency: Population (Large populations able to withstand stochastic events)	• Suitable substrate: riffle and run habitats, nearshore bank habitats • Sufficient water quality and quantity • Flowing river ecosystems • Sufficient occupied stream length	• 1 extant population, approximately 184 river miles • Extirpated from about 205 river miles in U.S and Mexico. • Population status: ○ 1 low resiliency	Projections based on future scenarios in 50 years: • **Continuation/Moderate Effects –** species is extirpated from its currently known range. The species is extinct 50 years in the future. • **Severe Effects -** species is extirpated from its currently known range. The species is extinct 50 years in the future.
Representation (genetic and ecological diversity to maintain adaptive potential)	• Distinct variation in allele frequencies exists between multiple, genetically isolated populations across the species range	• Minimal genetic variation expected across the extant population. • Limited number of individuals live in similar habitat, so likely no unique adaptations exist	Projections based on future scenarios in 50 years: • **Continuation/Moderate Effects –** species is extinct 50 years in the future. Therefore, it has no representation. • **Severe Effects –** species is extinct 50 years in the future. Therefore, it has no representation.
Redundancy (Number and distribution of populations to withstand catastrophic events)	• Multiple populations in each area of genetic representation	• No redundancy, only one currently known population	Projections based on future scenarios in 50 years: • **Continuation/Moderate Effects –** species is extinct 50 years in the future. No redundancy exists. • **Severe Effects –** species is extinct 50 years in the future. No redundancy exists.

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CHAPTER 1. INTRODUCTION

This Species Status Assessment (SSA) report (SSA Report, Version 1.1, October 2021) provides a review of the ecological needs and current condition of two species of freshwater mussels (Family Unionidae) endemic to the Texas portion of the Rio Grande basin. This SSA report will refer to the species collectively as "Rio Grande mussels" and individually by common name and by scientific name (i.e. genus and specific epithet) where appropriate. The U.S. Fish and Wildlife Service (Service) will be making a determination on whether these two species of freshwater mussels warrant protections under the Endangered Species Act of 1973, as amended (Act).

The SSA framework (USFWS 2016, entire) is intended to support an in-depth review of the species' biology and threats, an evaluation of its biological status, and an assessment of the resources and conditions needed to maintain long-term viability. The intent is for the SSA report to be easily updated as new information becomes available and to support all functions of the Endangered Species Program from Candidate Assessment to Listing to Consultations to Recovery. As such, the SSA report will be a living document upon which other documents, such as listing rules, recovery plans, and 5-year reviews, would be based if the species warrants listing under the Act.

The SSA report for the Rio Grande mussels is intended to provide the biological support for the decision on whether or not to propose to list the species as threatened or endangered and, if so, where to propose designating critical habitat. Importantly, the SSA report does not result in a decision by the Service on whether this species should be proposed for listing as a threatened or endangered species under the Act. Instead, this SSA report provides a review of the available information strictly related to the biological status of the Salina Mucket (*Potamilus metnecktayi*) and Mexican Fawnsfoot (*Truncilla cognata*). The listing decision will be made by the Service, after reviewing this document and all relevant laws, regulations, and policies, and the results of a proposed decision will be announced in the Federal Register, with appropriate opportunities for public input.

The Salina Mucket (*Potamilus metnecktayi* Johnson 1998) and Mexican Fawnsfoot (*Truncilla cognata* Lea 1860) are both freshwater mussels native to the Rio Grande in Texas, and historically Mexico. The Rio Grande mussels have been petitioned species for listing under the Act, since 2009 (USFWS 2009, entire).

For the purpose of this assessment, we generally define viability as the ability of the Rio Grande mussels to sustain populations in natural river systems over time. Using the SSA framework (Figure 1.1), we consider conditions the species needs to maintain viability by characterizing the species status in terms of resiliency, redundancy, and representation (Wolf et al. 2015, entire).

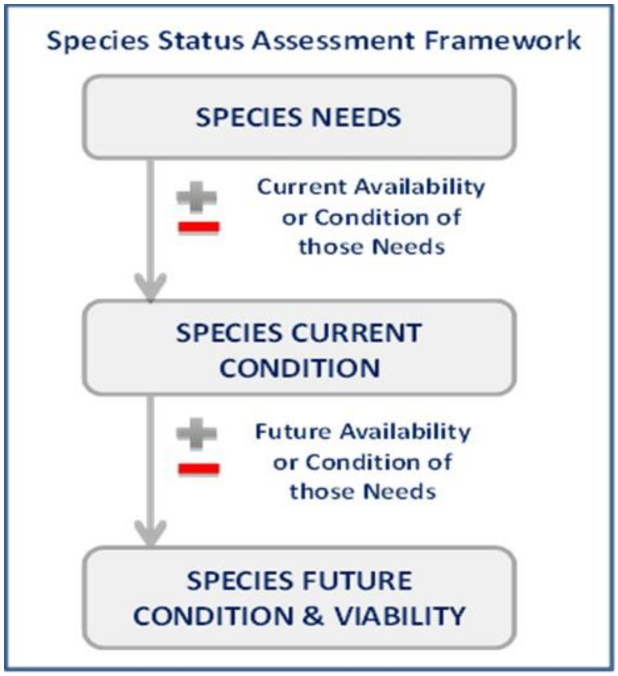

Figure 1.1 Species Status Assessment framework

Viability is the ability of a species to maintain populations in the wild over time. We use the conservation biology principles of resiliency, redundancy, and representation to assess viability (Shaffer and Stein 2000, pp. 308-311). To sustain populations over time, a species must have capacity to withstand:

(1) environmental and demographic stochasticity and disturbances (Resiliency),
(2) catastrophes (Redundancy), and
(3) novel changes in its biological and physical environment (Representation).

A species with a high degree of resiliency, representation, and redundancy (the 3Rs) is better able to adapt to novel changes and to tolerate environmental stochasticity and catastrophes. In general, species viability will increase with increases in resiliency, redundancy, and representation (Smith et al. 2018, p. 306).

- **Resiliency** is the ability of a species to withstand environmental stochasticity (normal, year-to-year variations in environmental conditions such as temperature, rainfall), periodic disturbances within the normal range of variation (fire, floods, storms), and demographic stochasticity (normal variation in demographic rates such as mortality and fecundity) (Redford et al. 2011, p. 40). Simply stated, resiliency is the ability to sustain populations through the natural range of favorable and unfavorable conditions.

  We can best gauge resiliency by evaluating population level characteristics such as: demography (abundance and the components of population growth rate – survival, reproduction, and migration), genetic health (effective population size and heterozygosity), connectivity (gene flow and population rescue), and habitat quantity, quality, configuration, and heterogeneity. Also, for species prone to spatial synchrony (regionally correlated fluctuations among populations), distance between populations and degree of spatial heterogeneity (diversity of habitat types or microclimates) are also important considerations.

- **Redundancy** is the ability of a species to withstand catastrophes. Catastrophes are stochastic events that are expected to lead to population collapse regardless of population health and for which adaption is unlikely (Mangel and Tier 1993, p. 1083).

  We can best gauge redundancy by analyzing the number and distribution of populations relative to the scale of anticipated species-relevant catastrophic events. The analysis entails assessing the cumulative risk of catastrophes occurring over time. Redundancy can be analyzed at a population or regional scale, or for narrow-ranged species, at the species level.

- **Representation** is the ability of a species to adapt to both near-term and long-term changes in its physical (climate conditions, habitat conditions, habitat structure, etc.) and biological (pathogens, competitors, predators, etc.) environments. This ability to adapt to new environments – referred to as adaptive capacity – is essential for viability, as species need to continually adapt to their continuously changing environments (Nicotra et al. 2015, p. 1269). Species adapt to novel changes in their environment by either [1] moving to a new, suitable environments or [2] by altering their physical or behavioral traits (phenotypes) to match the new environmental conditions through either plasticity or genetic change (Beever at al. 2016, p. 132; Nicotra et al. 2015, p. 1270). The latter (evolution) occurs via the evolutionary processes of natural selection, gene flow, mutations, and genetic drift (Crandall et al. 2000, p. 290-291; Sgro et al. 2011, p. 327; Zackay 2007, p. 1).

  We can best gauge representation by examining the breadth of genetic, phenotypic, and ecological diversity found within a species and its ability to disperse and colonize new areas. In assessing the breadth of variation, it is important to consider both larger-scale variation (such as morphological, behavioral, or life history differences which might exist across the range and environmental or ecological variation across the range), and smaller-scale variation (which might include measures of interpopulation genetic diversity). In assessing the dispersal ability, it is important to evaluate the ability and likelihood of the species to track suitable habitat and climate over time. Lastly, to evaluate the evolutionary processes that contribute to and maintain adaptive capacity, it is important to assess [1] natural levels and patterns of gene flow, [2] degree of ecological diversity occupied, and [3] effective population size. In our species status assessments, we assess all three facets to the best of our ability based on available data.

The format for this SSA report includes: (1) the resource needs of individuals and populations (Chapter 2); (2) the Salina Mucket and Mexican Fawnsfoot historical and current distributions (Chapter 3); (3) a framework for determining the distributions of resilient populations across the range for species viability (Chapter 4); (4) reviewing the likely causes of the current and future status of the species and determining which of these risk factors affect the species' viability and to what degree (Chapter 5); and (5) concluding with a description of the future species viability in terms of resiliency, redundancy, and representation (Chapter 6). This document is a compilation of the best available scientific and commercial information and a description of past, present, and likely future risk factors to the Rio Grande mussels.

CHAPTER 2. INDIVIDUAL NEEDS LIFE HISTORY AND BIOLOGY

In this chapter, we provide basic biological information about the Salina Mucket and Mexican Fawnsfoot, including their taxonomic histories, genetics, morphological descriptions, and known life history traits. We then outline the resource needs of individuals and populations of both species. Here we report those aspects of the life history of the species that are important to our analysis.

The Rio Grande mussels belong to the Family Unionidae, also known as the naiads or pearly mussels, a group of bivalve mollusks known to have been in existence for over 400 million years (Howells et al. 1996, p. 1). Unionidae now represents over 600 species worldwide and nearly 300 species in North America (Strayer et al. 2004, p. 429; Lopes-Lima et al. 2018, entire). This report follows the most recently published and accepted taxonomic treatment of North American freshwater mussels as provided by Williams et al. (2017, entire).

Freshwater mussels, including the Rio Grande mussels, have complex life histories (Smith 1985, p. 105) involving an obligate parasitic larval life stage, called glochidia, which are entirely dependent on a host fish for survival (Figure 2.1). Males release sperm into the water column, which is acquired by the female via the incurrent siphon (the tubular structure used to draw water into the body of the mussel). The sperm fertilizes the eggs, which are held during maturation in an area of the gills called the marsupial chamber. The developing larvae remain in the gill chamber until they mature and are ready for release. These mature larvae, called glochidia, are obligate parasites (cannot live independently of their hosts) on the gills, head, or fins of fishes (Vaughn and Taylor 1999, p. 913). Glochidia die if they fail to find a host fish, attach to a fish that has developed immunity from prior infestations, or attach to the wrong location on a host fish (Neves 1991, p. 254; Bogan 1993, p. 599). Glochidia encyst (enclose in a cyst-like structure) on the host's tissue, draw nutrients from the fish, and develop into juveniles after weeks or months of attachment (Arey 1932, pp. 214–215).

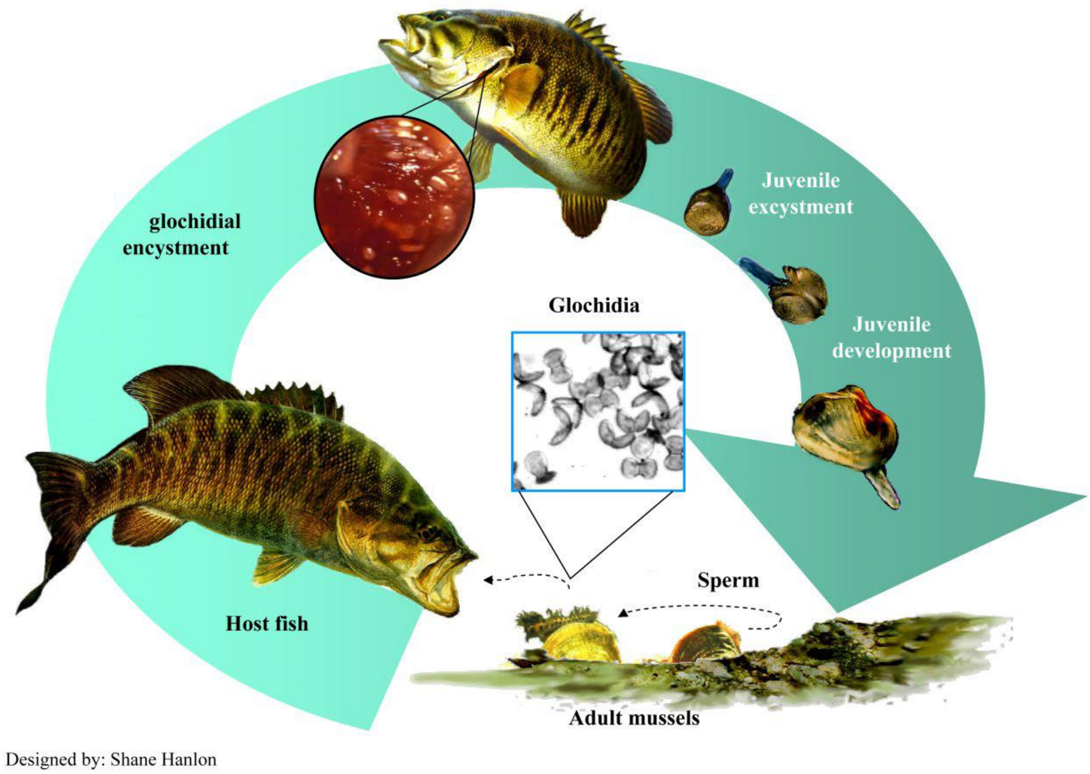

Figure 2.1. Generalized mussel life cycle diagram.

Many species of mussels are slow-growing but long-lived (Haag and Rypel 2010, p. 2) and some individuals have been estimated to be between decades and centuries old (Strayer et al. 2004, p. 433). The Rio Grande mussels are not adapted to lentic environments (e.g. lakes, ponds, and reservoirs) and do not survive or persist in such conditions (Randklev et al. 2020a and 2020b, entire). Both species are primarily sedentary with limited dispersal during the adult life stage, with nearly all dispersal occurring during the larval fish-host phase (Smith 1985, p. 105).

Mussels are generally immobile but experience their primary opportunity for dispersal and movement within the stream as glochidia attached to a mobile host fish (Smith 1985, p. 105). Upon release from the host, newly transformed juveniles drop to the substrate in the streambed (Figure 2.1). Juveniles that drop into unsuitable substrates typically die because their immobility prevents them from relocating to more favorable habitat. Juvenile freshwater mussels that drop into suitable habitats burrow into interstitial substrates and grow to a larger size that is less susceptible to predation and displacement from high flow events (Yeager et al. 1994, p. 220). Throughout the rest of their life cycle, mussels generally remain within the same small area where they excysted from the host fish, unless they were moved by high flow events.

All freshwater mussels require sufficiently high water quality to survive and reproduce, and many forms of pollutants (e.g. ammonia, heavy metals, salinity) are very toxic to individuals (Cope et al. 2008, p. 452). Relatively little is known about the specific feeding requirements of the Rio Grande mussels; however, like other mussels they are filter-feeders likely deriving nutrients from organic matter (e.g. algae, diatoms, bacteria, and fine organic particular matter). Lastly, species in the Unionidae often have specific stream habitat requirements (e.g. riffle, runs, pools, banks, crevices, etc.). In this chapter, we will further discuss the best available scientific information for each of the Rio Grande mussels.

2.1 Salina Mucket

2.1.1 Taxonomy

Salina Mucket (*Potamilus metnecktayi*) was described by Richard I. Johnson (1998, entire) with the holotype collected from the Rio Salado near Nuevo Laredo, Tamaulipas, Mexico. Johnson (1998) considered *P. metnecktayi* distribution as “Endemic to the lower Rio Grande System, Mexico and Texas”. Previously, Dall 1908 (p. 181) described *Lampsilis salinasensis* from the “Salinas River”, Coahuila, Mexico, which Johnson (1998) referred to as a “non-existent type locality”. Taylor (1966, p. 165) corrected the locality to “Rio Sabinas, at Sabinas, Coahuila” (Johnson 1998, entire). *Lampsilis salinasensis* is a junior synonym of *Disconaias fimbriata* (Frierson 1907, p. 86-89; Graf and Cummings 2021, entire). Metcalf (1982, pp. 48-49) identified fossil material from the Pecos River drainage as *L. salinasensis*, and Neck and Metcalf (1988, p. 265) referred to weathered dead shells from the lower Rio Grande downstream of Falcon Dam as *Potamilus salinasensis*. Both of these records likely represent *P. metnecktayi* specimens (Johnson 1998, pp. 428, 433). Turgeon et al. (1998, p. 32) recognized six species of *Potamilus* but did not include *P. metnecktayi*. Williams et al. (2017, p. 35) classified Salina Mucket as a member of the unionid subfamily Ambleminae (Williams et al. 2017, p. 35) and recognized *P. metnecktayi* as a valid taxon (Williams et al. 2017, p. 51). More recently, the taxonomic validity of the Salina Mucket was verified by Smith et al. (2020a, entire).

The recognized scientific name for Salina Mucket is *Potamilus metnecktayi*, and this report refers to it as such. The following taxonomic treatment follows Williams et al. (2017, p. 51).

Phylum: Mollusca
Class: Bivalvia
Order: Unionoida
Family: Unionidae
Subfamily: Ambleminae
Species: Potamilus metnecktayi

The Salina Mucket historically occurred in the Texas portion of the Rio Grande drainage in the United States and Mexico. The species was described from the Rio Salado south of Nuevo Laredo in the State of Tamaulipas, Mexico a tributary to the Rio Grande (Randklev et al. 2017, p. 157 and Johnson, 1998, entire). However, the current status of the species at its type locality in Mexico is unknown and presumed extirpated. Currently, the species is known to occur in a single population upstream of Lake Amistad in the main stem Rio Grande (Howells et al. 1996, p. 103; Burlakova et al. 2019, p. 346; Randklev et al. 2017, pp. 157, 258).

2.1.2 Genetic Diversity

Several genetic studies have included Salina Mucket. Most notably, Smith et al. (2019, p. 7) analyzed species boundaries within *Potamilus* and determined that the Salina Mucket is genetically distinct from other *Potamilus spp*. Smith et al. 2019a analyzed three specimens of Salina Mucket collected from the Rio Grande about 30 miles upstream of Langtry, Texas (Smith et al. 2019b, p. 4). Morphologically, the species resembles Bleufer (*Potamilus purpuratus)*, but it is genetically distinct (Johnson 1998, p. 432 and Smith et al. 2019a, p. 7). No known genetic samples have been collected or analyzed for historical portions of the species range, including its type locality in Mexico or the Lower Rio Grande in Texas downstream of Lake Amistad.

2.1.3 Morphological Description

The Salina Mucket is a medium-sized freshwater mussel with a brown, tan, or black periostricum (outermost shell surface), an ovate outline, and has a somewhat inflated shell (Figure 2.2) (Howells et al. 1996, p. 93; Johnson 1998, p. 430; Randklev et al. 2020a, entire). The species is sexually dimorphic with male shells more pointed along the posterior end and females more broadly rounded and truncate (Figure 2.2). Younger individuals occasionally have faint green rays (lines of color) on the periostracum (Johnson 1998, p. 430 and Randklev et al. 2020a, entire). Mature adults can reach lengths of over 120 mm (Johnson 1998, p. 4301). For a more detailed description of the morphological characteristics of Salina Mucket, see Howells et al. 1996 (pp. 103-104) and Randklev et al. 2020a (entire).

Figure 2.2. Adult Salina Mucket shells from the Lower Canyons of the Rio Grande, Texas. Photo credit: Randklev et al. 2020a, entire. Female (top) 67 mm and Male (bottom) 115 mm.

2.1.4 Life History

Freshwater mussel species vary in both onset and duration of spawning, how long developing larvae remain on the host fish, and which fish species serve as hosts. Little reproductive information is available for the Salina Mucket. Based on a closely related congener species (Bleufer, *P. purpuratus*), spawning is believed to occur in the fall, brooding occurs over winter, and release of glochidia occurs the following spring (Williams et al. 2008, p. 606 and Haag 2012, p. 177). Therefore, the species is considered a long-term brooder (bradytictic). Host fish inoculation strategies are largely unknown for the species, but the Salina Mucket most likely uses conglutinates (packages of glochidia shaped as food items) to infest fish hosts. See Figure 2.1 of a generalized freshwater mussel lifecycle.

For Salina Mucket, Freshwater Drum (*Aplodinotus grunniens*) have been identified as suitable host fish. However, this is the only fish species tested in laboratory experiments and other species could serve as ecological hosts in the wild. The glochidia remained encysted for 13 to 28 days during transformation to the juvenile stage (Bosman et al. 2015, entire). Once transformed, the juveniles will excyst from the fish and drop to the substrate. All *Potamilus spp.* have unique axe-head shaped glochidia which, unlike many other mussel species, grow in size while encysted on host fishes (Smith et al. 2020a, p. 2, 6, 10).

Longevity is not known for the Salina Mucket. However, Haag 2012 (pp. 196, 208) reported Bleufer (*P. purpuratus*) have a maximum lifespan of 10 years and age at maturity of 0-2 years, with a mean fecundity of 417,407 (Haag 2013, p. 750).

2.1.5 Resource Needs (Habitat) of Individuals

Adult Salina Mucket occur in medium to large rivers, generally in nearshore habitats and crevices, undercut riverbanks, travertine shelves, and under large boulders adjacent to runs (Table 2.1) (Howells et al. 1996, pp. 130-104; Karatayev et al. 2012, p. 210; Randklev et al. 2017, pp. 157, 159; Randklev et al. 2020a, entire). Small-grained material, such as clay, silt, or sand, gathers in these crevices and provides suitable anchoring substrate. These areas are considered flow refugia from the large flood events that occur regularly in the river this species occupies. Salina Mucket use flow refugia to avoid being swept away as large volumes of water move through the system, as there is relatively little particle movement in flow refugia, even during flooding (Strayer 1999, p. 472 and Christian et al. 2020, p. 17). Salina Mucket are not known to inhabit lakes, ponds, or reservoirs. The absence of the species from lentic habitats suggests its inability to cope with impoundments and reservoirs (Randklev et al. 2020a, entire).

Little is known about the specific feeding habits of the Salina Mucket. Like all adult freshwater mussels, the Salina Mucket is a filter feeder, siphoning suspended phytoplankton and detritus from the water column (Yeager et al. 1994, p. 221; Carman 2007, p. 8). Juvenile mussels live in the sediment and most likely feed interstitially rather than from the water column, using the relatively large muscular foot to sweep organic and inorganic particles found among the substrate into the shell opening (Yeager et al. 1994, pp. 220, 221).

Table 2.1. Life history and resource needs of the Salina Mucket

Life Stage	Resource Needs (Habitat)	References
Glochidia – Host Fish Attachment - **Fall (spawning) through the following spring (host infestation)**	• Presence of host fish (Freshwater Drum)	Haag 2012, pp. 148, 178 Bosman et al. 2015, entire Smith et al. 2020, pp. 6, 10
Juveniles - **Excystment from host fish ~40mm shell length**	• Flow refugia such as nearshore habitats, crevices, undercut riverbanks, travertine shelves, and large boulders. Likely similar habitat to adults • Low salinity (~1.0 ppt) • Low ammonia (~0.7 mg/L) • Low levels of copper and other contaminants • Dissolved oxygen levels within substrate >1.3mg/L • Flowing water	Yeager et al. 1994, pp. 220-221 Augspurger et al. 2003, p. 2569 Haag 2012, pp. 97, 101, 376-377 Randklev et al. 2017, p. 157 Randklev et al. 2020a, entire

Adults **- >40mm shell length**	• Flow refugia such as nearshore habitats, crevices, undercut riverbanks, travertine shelves, and large boulders • Stable areas of small-grained sediment, such as clay, silt, or sand, which provides suitable substrate for anchoring. • Dissolved oxygen levels in water column above 3 mg/L • Phytoplankton and detritus for food • Water temperature <30º Celsius (86º Fahrenheit) [based on other Texas mussel species] • Flowing water	Nichols and Garling 2000, p. 881 Chen et al. 2001, p. 214 Spooner and Vaughn 2008, pp. 308, 315 Haag 2012, pp. 26-30 Khan et al. 2019, entire Randklev et al. 2020a, entire

2.2 Mexican Fawnsfoot

2.2.1 Taxonomy

The Mexican Fawnsfoot was described as *Unio cognatus* by Lea (1860, p. 306), from the Rio Salado, in Mexico. The species was moved to the subgenus *Amygdalonaias* by Simpson (1900, p. 604) and then placed in the genus *Truncilla* by Frierson (1927, p. 89). Johnson (1999, pp. 39-40) synonymized *Truncilla cognata* as *Truncilla donaciformis* due to morphological similarities, and the holotype was a heavily weathered single valve. However, Mexican Fawnsfoot is currently classified in the unionid subfamily Ambleminae (Williams et al. 2017, p. 35) and is considered a valid taxon (Turgeon et al. 1998, p. 33; Williams et al. 2017, p. 44; Burlakova et al. 2019, entire; Smith et al. 2019a, p. 7).

The recognized scientific name for Mexican Fawnsfoot is *Truncilla cognata*, and this report refers to it as such. The following taxonomic treatment follows Williams et al. (2017, p. 44).

Phylum: Mollusca
Class: Bivalvia
Order: Unionoida
Family: Unionidae
Subfamily: Ambleminae
Species: *Truncilla cognata*

The Mexican Fawnsfoot historically occurred in the lower Rio Grande drainage in Texas and Mexico. The holotype was described from the Rio Salado, Mexico (State of Nuevo León); however, the species current status in the Rio Salado is unknown and presumed extirpated (Burlakova et al. 2019, p. 346; Randklev et al. 2020b, entire) (Figure 2.3).

2.2.2 Genetic Diversity

Genetic studies have been conducted for species within the genus *Truncilla.* Most notably, Smith et al. (2019a, p. 7) and Burlakova et al. (2019, entire) recognized the species as genetically distinct from other *Truncilla* species. However, the genetic diversity within the species is unknown, as only a limited number of individuals have been analyzed.

2.2.3 Morphological Description

The Mexican Fawnsfoot is a small-sized freshwater mussel with a yellow to green periostracum and faint chevron-like markings, an elongate outline, and laterally inflated shell (Figure 2.3) (Lea 1860, p. 368-369; Randklev et al. 2020b, entire). This species is not sexually dimorphic.

For a more detailed description of the morphological characteristics of Mexican Fawnsfoot, see Howells et al. (1996, p. 139-140).

Figure 2.3. Adult Mexican Fawnsfoot (44mm) from the Rio Grande near Laredo, Texas. Photo credit: Randklev et al. 2020b, entire.

2.2.4 Life History

Mussels in the genus *Truncilla* have miniaturized glochidia and use molluscivorous Freshwater Drum as hosts (Barnhart et al 2008, p. 373 and Smith et al. 2019a, p. 6). The primary host fishes for the Mexican Fawnsfoot are unknown; however, based on other *Truncilla spp.*, they are likely Freshwater Drum (*Aplodinotus grunniens)* specialists (Haag 2012, p. 178-179; Sietman et al. 2018, p. 1-2; Smith et al. 2019a, p. 6). To date, no empirical laboratory studies have tested host fishes for the Mexican Fawnsfoot. For the purpose of this report, we assume Freshwater Drum serve as a suitable host fish. The reproductive strategy (e.g. mantle lures or conglutinates) is also unknown for the Mexican Fawnsfoot. Some researchers have postulated that some female mussels of the genus *Truncilla* allow themselves to be preyed (female self-sacrifice) upon by Freshwater Drum to infest the host fish (Haag 2012, p. 178-179). However, this fails to explain the reproductive strategy of larger females that exceed the size range capable of being ingested by Freshwater Drum, or other potential host fish species (Sietman et al. 2018, p. 2). Therefore, it is possible that secondary reproductive strategies, such as broadcast of free glochidia or cryptic lures may be the primary method of glochidia dispersal (Haag 2012, p. 179).

Species in the genus *Truncilla* from the Southeastern United States have been reported to reach a maximum life span of 8-18 years (Haag and Rypel 2010, pp. 4-6; Sietman et al. 2018, p. 1). Longevity is unknown for the Mexican Fawnsfoot; however, for the purpose of this report we assume the species maximum life span is < 18 years.

2.2.5 Resource Needs (Habitat) of Individuals

Adult Mexican Fawnsfoot occur in medium to large rivers, in or adjacent to riffle and run habitats as well as in stream bank habitats (Table 2.2) (Karatayev et al. 2012, p. 211; Brewster 2015, p. 20-21; Randklev et al. 2017, pp. 221, 223, 234; Randklev et al. 2020b, entire). Small-grained material, such as clay, silt or sand, gathers in these crevices and provides suitable anchoring substrate. These areas are considered flow refuges from the large flood events that occur regularly in the river this species occupies. Mexican Fawnsfoot are able to use flow refuges to avoid being swept away as large volumes of water move through the system, as there is relatively little particle movement in the flow refuges, even during flooding (Strayer 1999, p. 472). However, these areas are topographic high points in a river system and are subject to exposure at reduced flow rates before the stream completely ceases to flow (Brewster 2015, p. 22). Mexican Fawnsfoot are not known to occur in lakes, ponds, or reservoirs (Randklev et al. 2020b, entire).

Little is known about the specific feeding habits of the Mexican Fawnsfoot, but like the Salina Mucket, it is a filter feeder, siphoning suspended phytoplankton and detritus from the water column (Yeager et al. 1994, p. 221; Carman 2007, p. 8).

Table 2.2. Life history and resource needs of the Mexican Fawnsfoot.

Life Stage	Resource Needs (Habitat)	References
Glochidia – Host Fish Attachment - **Fall (spawning) through the following spring (host infestation)**	• Presence of host fish (Freshwater Drum)	Haag 2012, pp. 178-179 Sietman et al. 2018, pp. 1-2
Juveniles - **Excystment from host fish through ~40mm shell length**	• Flow refugia such as depositional areas adjacent to pools, near point bars and banks. Likely similar habitat to adults • Low salinity (~1.0 ppt) • Low ammonia (~0.7 mg/L) • Low levels of copper and other contaminants • Dissolved oxygen levels within substrate >1.3mg/L • Flowing water	Yeager *et al.* 1994, pp. 220-221 Karatayev et al. 2012, p. 211 Augspurger et al. 2003, p. 2569 Haag 2012, pp. 101, 105, 376-377 Randklev et al. 2017, pp. 221, 223, 234 Randklev et al. 2020b, entire

Adults - **>30mm shell length**	• Flow refugia such as riffle and run habitats, adjacent depositional areas, and banks. Likely similar habitat to juveniles • Stable areas of small-grained sediment, such as clay, silt, or sand, which provide suitable substrate for anchoring. • Dissolved oxygen levels in water column above 3 mg/L • Phytoplankton and detritus for food • Water temperature <30º Celsius (86º Fahrenheit) • Flowing water	Nichols and Garling 2000, p. 881 Chen et al. 2001, p. 214 Spooner and Vaughn 2008, pp. 308, 315 Haag 2012, pp. 26-30 Khan et al. 2019, entire Randklev et al. 2020b, entire

CHAPTER 3. HISTORIC AND CURRENT POPULATIONS AND SPECIES NEEDS

In this chapter, we consider the Rio Grande mussel's historical distributions, current distributions, and what each species needs for viability. We first review the historical information on the range and distribution of each species, followed by a review of the current range. We then review the conceptual needs of each species, including population resiliency, redundancy, and representation to support viability and reduce the likelihood of extinction.

3.1 Salina Mucket

3.1.1 Historical Range and Distribution

The Salina Mucket is native to the Rio Grande (known in Mexico as the Rio Bravo) drainage in Texas and northern Mexico (Figure 3.1). In the Rio Grande system, Salina Mucket historically occurred from the confluence of the Rio Conchos with the Rio Grande (Presidio County, Texas) downstream to just below the current location of Falcon Dam (Starr County, Texas). This stretch of occupied stream accounted for approximately 686 total river miles (rmi) (1,104 river kilometers (rkm)) in the mainstem Rio Grande (Howells et al. 1996, pp. 103-104; Johnson 1998, p. 433; Karatayev et al. 2012, pp. 210-211; Randklev et al. 2017, p. 157; Randklev et al. 2018, p. 135; Randklev et al. 2020a, entire). Additionally, the species historically occurred in the lower Pecos River to approximately 1.0 rmi upstream of the river's confluence with the Rio Grande. However, the Pecos River population is now considered extirpated, as the last live individual was encountered in the 1960's and the lower portion of the Pecos River is now inundated by Lake Amistad (Figure 3.1). Other possible reports of the species from the Pecos and Devils Rivers remain unconfirmed and are likely misidentified Bleufer (*P. purpuratus)* or Tampico Pearlymussel (*Cyrtonaias tampicoensis).*

With no live collections from the Rio Grande having occurred since the early 1970's (Howells 2002, p. ii and Miller 2020, entire), Salina Mucket were believed extirpated entirely from Texas until 2003 when the species was rediscovered upstream of Lake Amistad (Howells 2003, p. ii; Randklev et al. 2017, p. 157). Long dead, sub-fossil shells, have been encountered downstream of Lake Amistad in the lower Rio Grande; however, no live individuals have ever been reported downstream of Lake Amistad (Karatayev et al. 2012, p. 211; Randklev et al. 2017, p. 157; Miller 2020, entire).

Based on the species description (Johnson 1998, p. 429), we assume the lower Rio Salado, a Rio Grande tributary partially located in the Mexican State of Tamaulipas, was historically occupied by Salina Mucket in approximately the lower 48 rmi (77.2 rkm) before the river's confluence with the Rio Grande. The Don Martin dam project on the Rio Salado started in 1927 and was completed sometime in the early 1930s (Garza 2016, entire). This impoundment in the Mexican State of Coahuila, would have likely extirpated, or fragmented, any historical populations further upstream in the Rio Salado basin. Surveys of the upper Rio Salado and its tributaries in north-central Coahuila completed in 2001, 2002, and 2017 did not result in the collection of any live Salina Mucket (see Areas Presumed Extirpated, Chapter 3.1.3). No known records exist for Salina Mucket from other tributaries to the Rio Grande on the Texas or Mexico side of the border. As such, we believe the historical range as described above, is accurate.

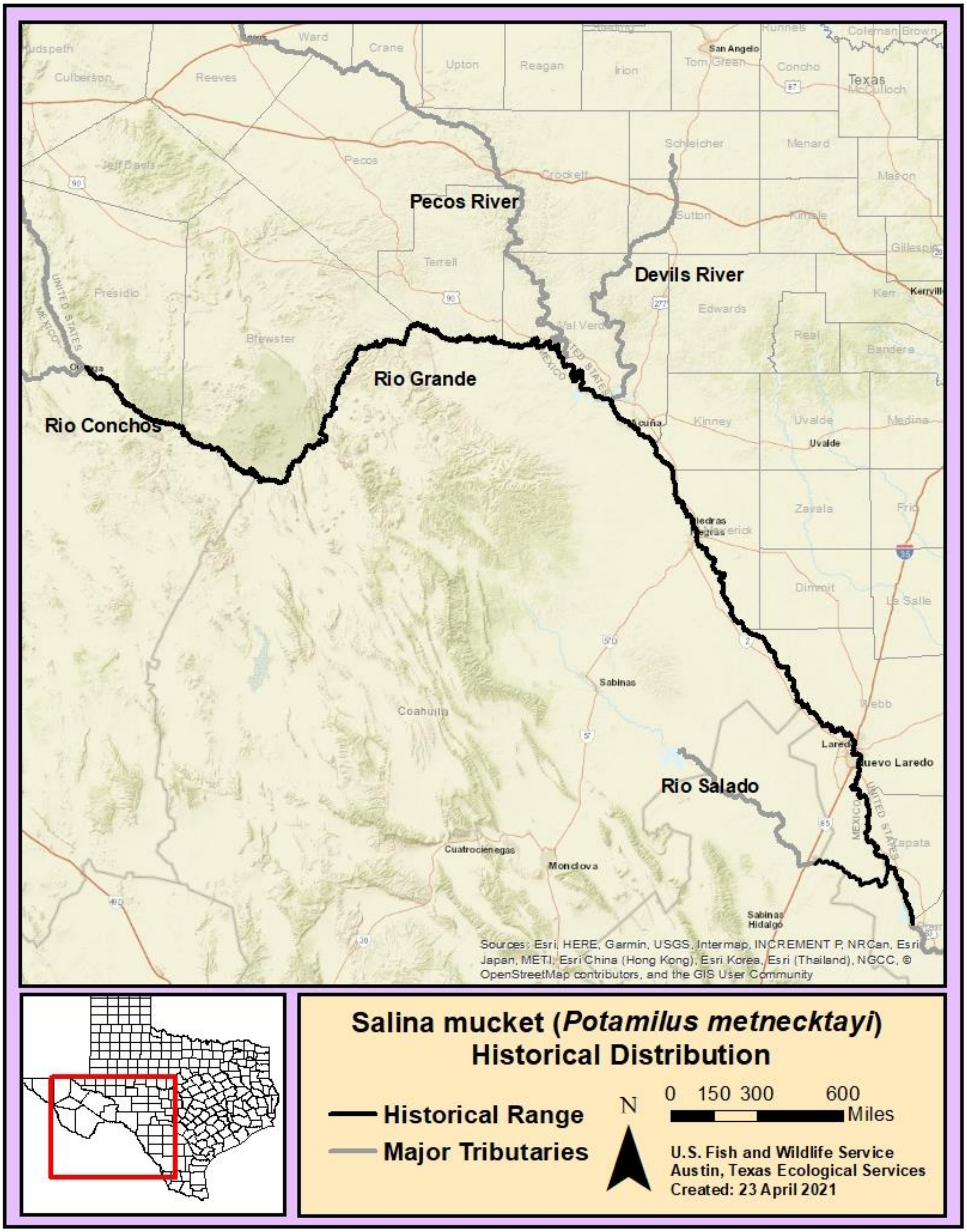

Figure 3.1. Historical distribution (black) of Salina Mucket in the Rio Grande basin (Texas and

Mexico) and major tributaries (grey). Data compiled from the Mussel of Texas Database (Randklev et al. 2020c, entire), publications, museum records, and historical reports.

3.1.2 Current Range and Distribution

In this assessment, we define a population of Salina Mucket at a spatial scale larger than that of an individual mussel bed. This assessment defines a population as the collection of mussel beds within a hydrologically connected stream reach through which infested host fish may travel. This connection allows for ebbs and flows in mussel bed occupancy, distribution, and abundance throughout the stream reach. Currently, one known population of Salina Mucket remains in the Lower Canyons of the Rio Grande (Figure 3.2). This population is discussed below:

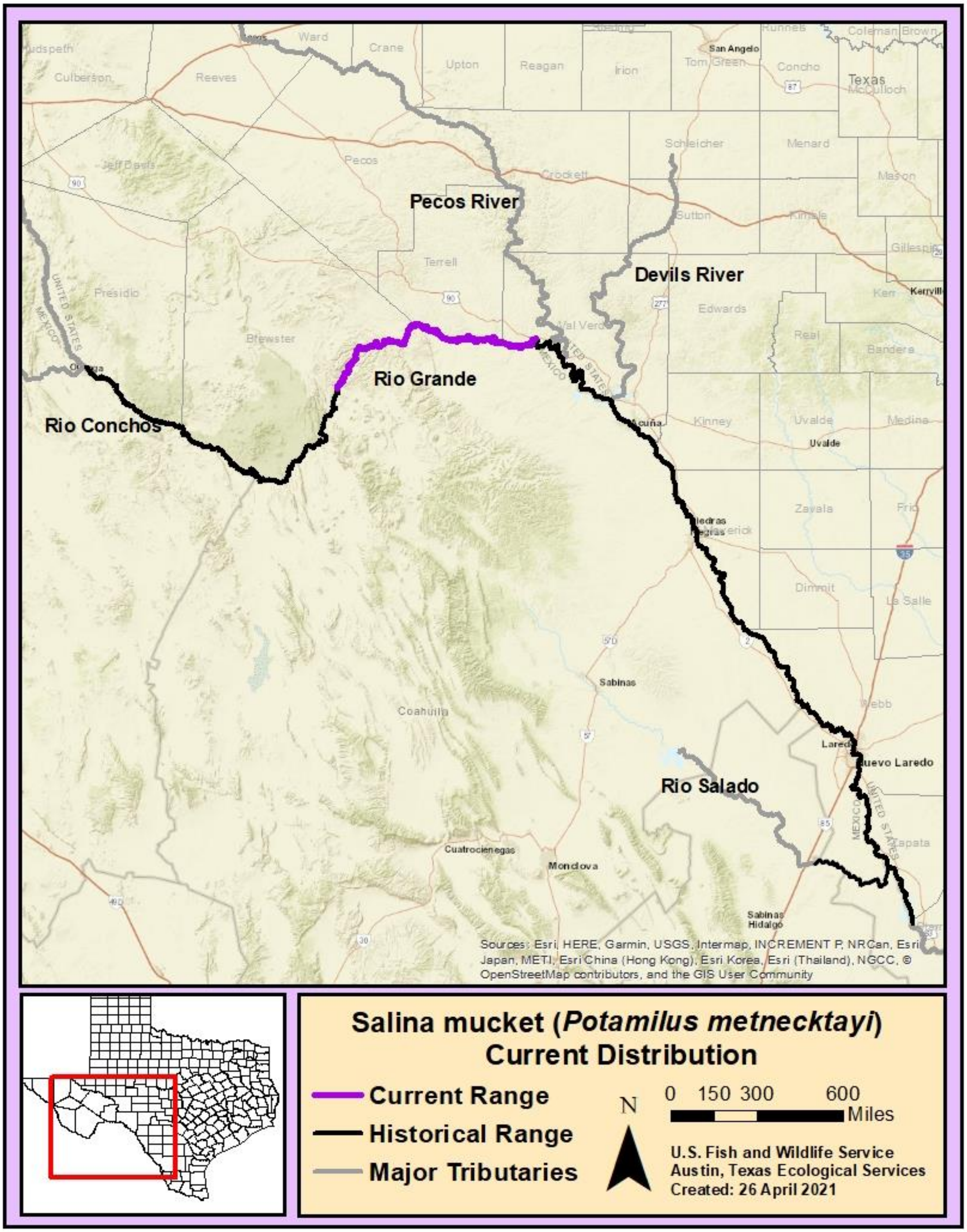

Figure 3.2. Presumed current range of Salina Mucket (purple), historical range (black) and major tributaries (grey) in the Rio Grande basin, Texas and Mexico. Data compiled from the Mussels of Texas Database (Randklev et al. 2020c, entire), publications, museum records, and historical

reports.

3.1.2.1 Rio Grande – Lower Canyons

The only known remaining population of Salina Mucket is located in the Lower Canyons of the Rio Grande just downstream of Big Bend National Park, in Brewster, Terrell, and Val Verde counties, Texas. Burlakova et al. (2010, p. 161) recommended Salina Mucket and several other Texas endemic mussels be classified as "critically endangered" and noted the mean relative density (mussels per search hour) of Salina Mucket at 0.029 (p. 158). Between 2003 and 2008, Karatayev et al. (2012, p. 210) found 19 live Salina Mucket at one site near Dryden, Texas while conducting basin-wide surveys. They also reported the observation of shell material at an additional seven sites (n=159 shells). Salina Mucket was the rarest species encountered during their surveys in the Rio Grande (Karatayev et al. 2012, p. 210). Subsequent surveys by Randklev et al. (2017, pp. 154-174) conducted in 2014 and 2015 confirmed the presence of Salina Mucket in the same general reach of the Lower Canyons (n=22 sites) with 92 live individuals found at 22 of 114 sites. This study also confirmed the first live report of a Salina Mucket in Brewster County, Texas, the farthest observed upstream locality for the species. Measured shell lengths of observed live Salina Muckets indicated the presence of mostly older individual. The presence of smaller individuals indicates recent recruitment (Randklev et al. 2017, p. 159). However, visual and tactile searches, which are common and widely used sampling methodologies, are biased toward finding larger sized individuals (Strayer and Smith 2003, pp. 47-48).

For purposes of this analysis, we presume the entire stream reach between La Linda, Texas and Langtry, Texas – approximately 133 river miles (214 rkm), is currently occupied by Salina Mucket. Individual mussel beds in the Rio Grande – Lower Canyons vary in density, with the densest sites near San Francisco Creek and Johns Marina, Terrell County, Texas and sites with lower densities located upstream of the San Francisco Creek confluence and downstream of Johns Marina (Randklev et al. 2017, p. 168).

The Rio Grande – Lower Canyons reach extends for approximately 127 rmi (204 rkm) below Big Bend National Park through private lands along the U.S.-Mexico border. This reach of the Rio Grande is largely spring-fed with significant spring-flow inputs occurring upstream of the confluence of San Francisco Creek (Donnelly 2007, p. 3; Bennett et al. 2009, p. 1). The area was designated a National Wild and Scenic River in 1978 (Garrett and Edwards 2014, p. 396), which affords some protection from Federal development projects, but does not limit state, local, or private development (National Wild and Scenic Rivers System 2021, p. 1). The Lower Canyons reach is characterized by swift rapids interspersed by pools, often bounded by high canyon walls (Garrett and Edwards 2014, p. 396), and transitions into slow-moving, impounded waters at the inflow areas to Amistad Reservoir, which was constructed in 1969.

3.1.3 Areas Presumed Extirpated

The Salina Mucket historically occupied approximately 734 rmi (1,181 rkm) in the U.S. and Mexico and is presumed extirpated from approximately 82% of its historical range (Karatayev et al. 2015, p. 7). Areas from which we presume Salina Mucket has been extirpated include the Pecos River (Texas), the Rio Grande downstream of Lake Amistad (Texas), and the Rio Salado (Mexico). The areas of presumed extirpation are discussed below:

3.1.3.1 Rio Grande – Downstream of Lake Amistad

The Salina Mucket is known in the Rio Grande downstream of Lake Amistad (Howells et al. 1996, pp. 103-104; Karatayev et al. 2012, pp. 210-211; Randklev et al. 2017, p. 157) only from sub-fossil shell material, and no live individuals have been recorded from this portion of the basin. However, shell evidence suggests at one time, a large, wide-spread population of Salina Mucket likely occurred there.

The Rio Grande in the Laredo area is heavily influenced by development along the Texas – Mexico border. Rapid human population growth, as well as industrialization on the Mexican side of the river, has stressed the existing wastewater treatment facilities, resulting in a high sedimentation load (Texas Clean Rivers Program 2013, p. 9) and impaired water quality in the Rio Grande (Texas Clean Rivers Program 2013, p. 7). Flows are regulated by releases from Amistad Reservoir based on hydropower generation and water deliveries for downstream irrigation needs (Texas Water Development Board 2021d, p. 1) and water management in the Rio Grande is governed by treaty (USIBWC 2021, entire). These water diversion and delivery projects have resulted in substantial daily variation in stream discharge and depth (Randklev et al. 2018, p. 734).

3.1.3.2 Rio Salado Basin

The Salina Mucket historically occurred in the Rio Salado basin in Mexico. Rio Salado and several of its tributaries were surveyed in the early 2000s, resulting in several recently dead shells collected in 2001 and 2002 in the Rio Sabinas (Strenth et al. 2004, p. 225). The surveyed portions of riverbed were reported to be dry with no evidence of recent water flow or live Salina Mucket.

In the mainstem Rio Salado, several old shells and one recently dead shell were collected at two sites in 2002 (Strenth et al. 2004, p. 227). As with the Rio Sabinas, the river exhibited no flow and at one site, household waste was reported. No living mussels or shells encountered by Strenth et al. (2004, entire) during this survey were identified as Salina Mucket. These rivers, and many others in this region of Mexico, have been noted as losing flow and becoming dry or intermittent since the mid-1990s (Contreras-B. and Lozano-V. 1994, p. 381).

In 2017, four sites in the Rio Salado system were visited including the Rio Salado, Rio San Rodrigo, and Rio Nadadores (Hein et al. 2017, entire). While these surveys focused on locating Texas Hornshell (*Popenaias popeii*), the areas surveyed were within presumed historical Salina Mucket habitat. Several of the locations in the Rio Sabinas contained suitable habitat for the Salina Mucket; however, these surveys provided no evidence of Salina Mucket. Therefore, for the purposes of our analysis, we presume Salina Mucket is extirpated from the Rio Salado and its tributaries.

3.2 Mexican Fawnsfoot

3.2.1 Historical Range and Distribution

The Mexican Fawnsfoot is native to the Rio Grande drainage in Texas and northern Mexico (Figure 3.3). Mexican Fawnsfoot occurred historically in the Rio Grande from approximately the confluence of the Pecos River with the Rio Grande (Val Verde County, Texas) to just downstream of Falcon Dam (Starr County, Texas). This represents approximately 340 rmi (541 rkm) of historically occupied river. Presumably, the Mexican Fawnsfoot may have occupied the lower section (approximately one mile) of the Pecos River (Metcalf 1982, p. 52); however, inundation by Lake Amistad in the late 1960s likely extirpated that population.

Based on species descriptions (Lea 1860; Johnson 1999, pp. 38-40, 64), we assume the lower Rio Salado was historically occupied by the Mexican Fawnsfoot in the Mexican State of Nuevo León in the lower 48 rmi (77 rkm) before its confluence with the Rio Grande. However, the exact collection location of the holotype is unknown. The Don Martin dam project in Coahuila would have likely extirpated or fragmented any historical populations further upstream in the Rio Salado basin. No other known records exist for Mexican Fawnsfoot from other tributaries to the Rio Grande on the Texas or Mexico sides. As such, we believe the historical range, as described above, is accurate.

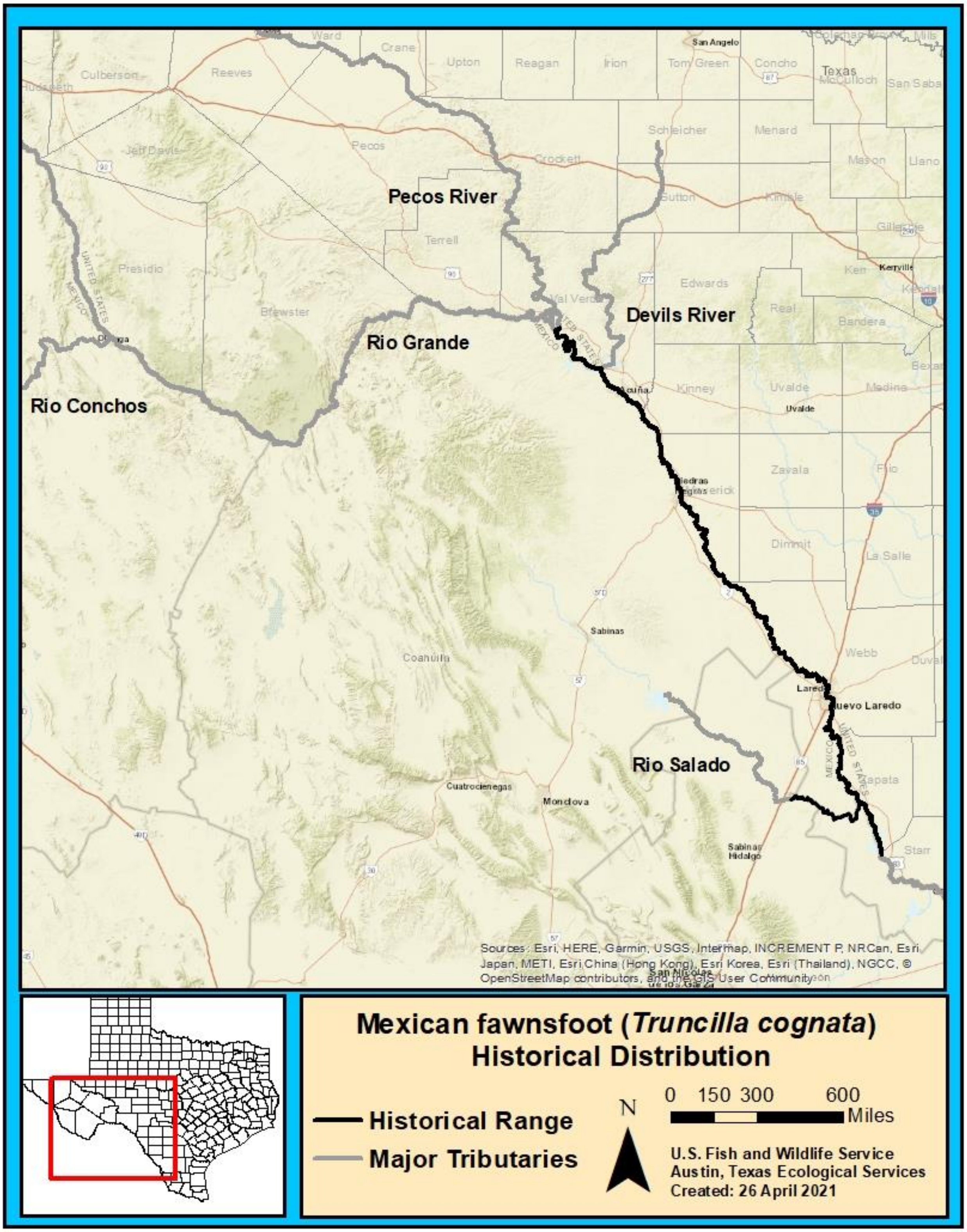

Figure 3.3. Historical distribution (black) of Mexican Fawnsfoot in the Rio Grande basin (Texas and Mexico) and major tributaries (grey). Data compiled from the Mussel of Texas Database (Randklev et al. 2020c, entire), publications, museum records, and historical reports.

3.2.2 Current Range and Distribution

In this assessment, we define a population of Mexican Fawnsfoot at a larger scale than the mussel bed; it is the collection of mussel beds within a stream reach between which infested host fish may travel, allowing for ebbs and flows in mussel bed abundance throughout the population's occupied reach. Currently, only a single remaining population of Mexican Fawnsfoot is known between the vicinities of Eagle Pass and Laredo, Texas (Figure 3.4). This population is discussed below:

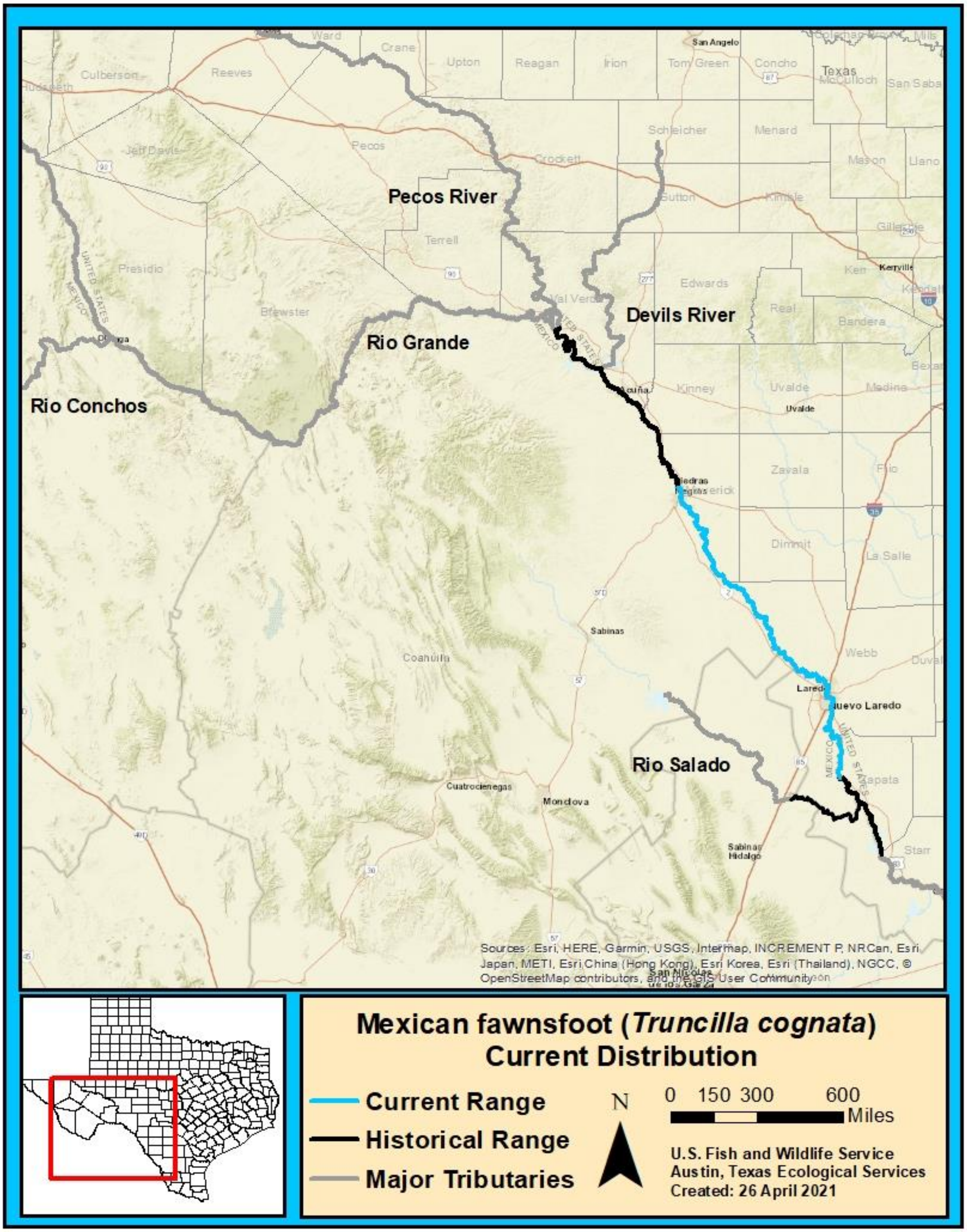

Figure 3.4. Presumed current range of Mexican Fawnsfoot (blue), historical range (black), and majority tributaries (grey) in the Rio Grande basin, Texas (USA) and northern Mexico. Data compiled from the Mussel of Texas Database (Randklev et al. 2020c, entire), publications,

museum records, and historical reports.

3.2.2.1 Rio Grande – Downstream of Lake Amistad

The only remaining Mexican Fawnsfoot population occurs from approximately Eagle Pass, Texas downstream to San Ygnacio, Starr County, Texas, a total of approximately 184 rmi (90 rkm) (Randklev et al. 2017, p. 221). Falcon Dam, completed in 1954, presumably caused the extirpation of Mexican Fawnsfoot in the 40-mile length of river inundated by the impoundment (Randklev et al. 2017, p. 176). Mexican Fawnsfoot were believed extirpated from Texas as no live or dead individuals were found from 1972 to 2003, until a single live individual was located in Webb County, Texas in 2003 (Howells 2001, entire; Howells 2004, p. 35; Randklev et al. 2020b, entire). During extensive surveys between 2001 and 2011 throughout the Rio Grande drainage, only 19 live Mexican Fawnsfoot were located from Laredo and Webb counties, Texas. No live individuals were found downstream of the Laredo (Texas) and Nuevo Laredo (Mexico) wastewater treatment plants (Karatayev et al. 2015, p. 14); however, fresh dead (still containing soft tissue) Mexican Fawnsfoot were located in Zapata County, Texas. Of the live individuals encountered, shell size ranged from 20.5 to 33 mm (Karatayev et al. 2012, p. 211). Brewster 2015 (p. 30) noted that at a single site (in the upstream vicinity of Laredo, Texas) extremely low flows due to a major drought in July 2013 likely resulted in the elimination of the largest known Mexican Fawnsfoot population where 35 live and 206 very recently dead individuals were discovered. Randklev et al. (2017, pp. 223, 224) reported a total of 213 live Mexican Fawnsfoot from 30 of 114 sites surveyed in the Rio Grande basin with live individuals found primarily in Webb and Zapata counties and upstream of Falcon Lake.

The Rio Grande in the Laredo area is heavily influenced by development along the Texas – Mexico border. Rapid human population growth as well as industrialization on the Mexican side has stressed the existing wastewater treatment facilities, and Rio Grande water quality is quite impaired as a result (Texas Clean Rivers Program 2013, p. 7). The river also has a high sedimentation load in this reach (Texas Clean Rivers Program 2013, p. 9). Flows are regulated by releases from Amistad Reservoir based on hydropower generation and water deliveries for downstream irrigation needs (Texas Water Development Board 2021, p. 1). Water management in the Rio Grande is governed by treaty (USIBWC 2021, entire).

3.2.3 Areas Presumed Extirpated

The Mexican Fawnsfoot historically occupied approximately 389 rmi (626 rkm) in Texas and Mexico, and it is presumed to be extirpated from approximately 52% of this range (Karatayev et al. 2015, p. 7). Areas from which we presume Mexican Fawnsfoot has been extirpated include the Pecos River (Texas), Rio Salado (Mexico), the Rio Grande upstream of Amistad Dam (Texas), and the Rio Grande downstream of Falcon Lake (Texas). The areas of presumed extirpation are discussed briefly below.

3.2.3.1 Rio Salado Basin

The Mexican Fawnsfoot historically occurred in the Rio Salado basin; however, the current status of the population remains unknown and is likely extirpated (Burlakova et al. 2019, p. 346). The Rio Salado, Rio Sabinas, and several other tributaries were surveyed in the early 2000s. The surveyed portions of river were reported dry with no indicators of recent stream flow. No evidence of Mexican Fawnsfoot, either through the observation of live individuals or collection of shell material, was reported.

In 2017, four sites in the Rio Salado system were visited, including the Rio Salado, Rio Sabinas, Rio San Rodrigo, and Rio Nadadores (Hein et al. 2017, entire). While several of the locations contained apparently suitable habitat, no live Mexican Fawnsfoot or shell material were found during these surveys. Therefore, for the purposes of our analysis, we presume Mexican Fawnsfoot has been extirpated from the Rio Salado and its tributaries.

3.2.3.2 Lake Amistad

There are very few reports of Mexican Fawnsfoot for the Rio Grande reach near Del Rio, Texas (around the current location of Amistad Reservoir), likely due to upstream and downstream effects of Amistad Dam. Howells et al. (1997, p. 123) report Mexican Fawnsfoot collection by Metcalf from the Rio Grande near Del Rio, Texas in 1972. However, subsequent surveys of that stream reach have yielded no Mexican Fawnsfoot, live or dead, in either the upstream or downstream vicinity of Lake Amistad (Randklev et al. 2017, p. 221). Consequently, it is unlikely that this reach is inhabited by a significant population of Mexican Fawnsfoot, and any historical population that inhabited this reach was likely extirpated by the construction and filling of Lake Amistad in the late 1960s.

3.3 Needs of Rio Grande Mussels

As discussed in Chapter 1, for the purpose of this assessment, we define viability as the ability of the species to sustain populations in the wild over time (in this case, 50 years). Using the SSA framework, we describe the species' viability by characterizing the status of the species in terms of its resiliency, redundancy, and representation (the 3Rs). Using various time frames and the current and projected levels of the 3Rs, we thereby describe the species' level of viability over time.

3.3.1 Population Resiliency

For the Rio Grande mussels to maintain viability, their populations or some portion thereof must be resilient. Stochastic events that have the potential to affect their populations include high flow events, drought, pollutant discharge, and accumulation of fine sediment. Multiple factors influence the resiliency of populations, including occupied stream length, abundance, and recruitment. Influencing those factors are habitat elements that determine whether Salina Mucket and/or Mexican Fawnsfoot populations can grow to maximize habitat occupancy, thereby increasing the resiliency of populations. These factors and habitat elements are discussed below and shown in Tables 3.1 through 3.6.

3.3.1.1 Population Factors

Occupied Stream Length – Most freshwater mussels are found in aggregations, called mussel beds, that can vary in size from less than 50 to greater than 5,000 square meters (m^2), and are separated by stream reaches in which mussels are absent or rare (Vaughn 2012, p. 983). As discussed above, we define a population of the Rio Grande mussels at a spatial scale larger than an individual mussel bed. This assessment defines a population as the collection of mussel beds within a hydrologically connected stream reach through which infested host fish may travel. This connection allowing for ebbs and flows in mussel bed occupancy, distribution, and abundance throughout the stream reach. Therefore, resilient populations must occupy stream reaches long enough such that stochastic events that affect individual mussel beds do not eliminate the entire population (Table 3.1). Repopulation by infested fish from other source mussel beds within the reach can allow the population to recover from these events. However, given mussel survey sites are often located at points of easy access (e.g. bridge crossings, boat ramps, fishing access) and may go years or decades between sampling visits, it can be difficult to interpret the exact length of occupied stream habitat. Therefore, we may utilize the 'very low' condition category in cases where we suspect the stream length has reduced over time (e.g. extirpation of beds, or older individuals dying out) but recent survey data is lacking.

Species	**Occupied Stream Length**				
	High	**Moderate**	**Low**	**Very Low**	**Extirpated**
Both Rio Grande Mussels	≥ 50 continuous river miles	50 < continuous river miles ≥ 20	< 20 continuous river miles	< 20 continuous river miles	None

Table 3.1. Occupied stream length (as continuous river miles) of high, moderate, low, and very low resiliency Rio Grande mussel populations.

Abundance – Mussel abundance in a stream reach is a product of the number of mussel beds times the density of mussels within those beds. For populations to be resilient, there must be many mussel beds of sufficient density such that local stochastic events do not eliminate all individuals from the bed(s), allowing the mussel bed(s) and the overall population in the stream reach to recover from any one event. We measure abundance by the number of beds within the population, and the estimated density of mussels within each. We consider mean density of ≥ 4 mussels catch per unit effort (CPUE, mussels per search hour) to be high and assume that would be sufficient to support resilient populations (Table 3.2).

Species	**Abundance (CPUE)**				
	High	**Moderate**	**Low**	**Very Low**	**Extirpated**
Both Rio Grande Mussels	≥ 4.0	< 4.0 and ≥ 2.0	< 2.0 and ≥ 0.5	< 0.5	None

Table 3.2. Abundance of mussels, described as catch-per-unit-effort, for high, moderate, low, and very low resiliency Rio Grande mussel populations.

Reproduction – Resilient mussel populations must reproduce and recruit young individuals into the reproducing population. Population size and abundance reflects previous influences on the population and habitat and provide a current "snap-shot" of the population, while reproduction and recruitment reflect stable, increasing or decreasing population trends that reflect the future viability of the population. For example, a large, dense population of freshwater mussels that contains mostly older individuals and lacks younger individuals is not likely to remain large and dense into the future, as there are few young individuals to sustain the population over time. Conversely, a population that is less dense but has many young and/or gravid (i.e. pregnant) individuals may be likely to increase in density in the future as younger individuals mature and boost the reproductive capacity of the population. Detection of very young juvenile mussels during routine abundance and distribution surveys can be inefficient due to sampling bias towards larger individuals. Sampling for freshwater mussel frequently involves tactile searches and mussels below about 35 millimeters (mm) can frequently escape detection. Therefore, the assessment verifies reproduction for the Rio Grande mussels by the frequent capturing of small-sized individuals near the low end of the detectable range size (~35 mm) over time and by capturing gravid females during the reproductively active time of year. Given age-at-maturity is largely unknown for the Rio Grande mussels and the small adult size of Mexican Fawnsfoot (Randklev et al. 2020a and 2020b, entire), for the purpose of this assessment, we consider populations with three or more distinct age classes highly resilient. Age classes are defined as multiple individuals within a similar shell size length, which indicates that multiple individuals are part of the same cohort or reproductive event.

Species	Reproduction				
	High	Moderate	Low	Very Low	Extirpated
Both Rio Grande Mussels	3 or more distinct age classes represented by multiple individuals. Evidence indicates multiple successful recruitment events in previous years.	2 distinct age classes represented by multiple individuals. Evidence indicates sporadic or limited successful recruitment events.	1 age class present. Recruitment events are not regular enough to indicate recurring reproduction.	No definable age structure as not enough live individuals were encountered.	None

Table 3.3. Reproduction of mussels, described as number of age classes, for high, moderate, low and very low resiliency Rio Grande mussel populations.

3.3.1.2 Habitat Elements that Influence Resiliency

Substrate – Salina Mucket occur in flow refuges such as crevices, undercut riverbanks, travertine shelves, large boulders, and near shore deposition areas such as banks, point bars, and backwater pools. These refuges must have seams of clay or other fine sediments within which the mussels may anchor, but not so much excess sediment that the mussels are smothered.

Mexican Fawnsfoot occur primarily in riffles as well as near-shore depositional habitats. Habitats with clean-swept substrate with seams of fine sediments are considered to have suitable substrate, and those with copious fine sediment both in crevices and on the stream bottom are considered less suitable (Table 3.4).

Species	Substrate				
	High	**Moderate**	**Low**	**Very Low**	**Extirpated**
Salina Mucket	Stable, scour-free habitats consisting of heterogeneous mixtures of mud, sand, and gravel present. Banks stable and not eroding. AND/OR Bedrock fissures and crevices present. Substrate sufficient to provide lodging within crevices but not to fill completely.	Moderately stable habitat consisting of heterogeneous mixtures of mud, sand, and gravel present, but some areas of scour or depositional sedimentation present. Banks largely stable but isolated collapse is present. AND/OR Bedrock fissures and crevices present. Substrate sufficient to provide lodging while other areas scoured or too heavily filled.	Lacking stable habitats consisting of heterogeneous mixtures of mud, sand, and gravel present, frequent areas of scour, excessive depositional sedimentation present, and unstable banks leading to frequent sloughing. AND/OR Crevices obstructed. Relatively high amount of sedimentation and filling of interstitial spaces.	Depositional areas and bank habitats severally degraded, almost non-existent. Crevices and bedrock shelves filled with sediment such that mussel occupation may be precluded.	None
Mexican Fawnsfoot	Riffle and run habitat present. Substrate sufficiently stable to prevent dislodging during high flow events.	Riffle and run habitat present. Substrate sufficiently stable to prevent dislodging during most but not all high flow events.	Riffle and run habitat eroding, unstable, or being buried by mobilized sediments from upstream.	Riffle and run habitats severally degraded, almost non-existent.	None

Table 3.4. Stream substrate conditions for high, moderate, low, and very low resiliency Rio Grande mussel populations. Note – substrate conditions vary between species.

Flowing Water – The Rio Grande mussels are not found in lakes or in pools without flow, or in areas that are regularly dewatered. Therefore, stream reaches with continuous flow are considered suitable habitat, while those with little or no flow either caused by dewatering or impoundment are considered not suitable (Table 3.5). Freshwater mussels are known to be sensitive to changes in flow rate; however, empirical studies of flow requirements for the Rio Grande mussels have not been conducted. As such, we use the 'very low' condition category in areas where we believe the stream flow rates are significantly degraded, but the species are not yet extirpated.

Species	**Flowing Water**				
	High	**Moderate**	**Low**	**Very Low**	**Extirpated**
Both Rio Grande Mussels	Flowing water present year-round. No recorded periods of zero flow days AND no inundation from reservoirs	Flowing water present almost year-round. Few instances of zero flow days.	Flowing water does not persist throughout the occupied stream reach.	Flowing water does not persist throughout the occupied stream reach.	Dry stream bed or zero flow days occur with sufficient frequency to preclude survival OR the stream is impounded by a reservoir.

Table 3.5. Flowing water conditions, for high, moderate, low, and very low resiliency Rio Grande mussel populations.

Water Quality – Freshwater mussels, as a group, are sensitive to changes in water quality parameters such as dissolved oxygen, salinity, ammonia, and pollutants (see Chapter 5 for more information). Habitats with appropriate levels of these parameters are considered suitable, while those habitats with levels outside of the appropriate ranges are considered less suitable (Table 3.6). Freshwater mussels are known to be sensitive to changes in various water quality parameters. However, no empirical studies of water quality tolerances for the Rio Grande mussels have been conducted. As such, we may use the 'very low' condition category in areas where we believe the water quality is likely degraded such that few individuals persist, and reproduction is likely limited (i.e. nearing extirpation) but data availability is limited.

Species	**Water Quality**				
	High	**Moderate**	**Low**	**Very Low**	**Extirpated**
Both Rio Grande Mussels	No known contaminant, dissolved oxygen, or temperature issues.	Contaminants known, low dissolved oxygen or high temperature documented but not at	Contaminants known, low dissolved oxygen or high temperature documented. Levels sufficiently	Contaminants known, low dissolved oxygen or high temperature documented. Levels	Water quality issues significant enough to preclude mussel habitation.

		levels that put population at risk of extirpation.	high to put population at risk of extirpation.	sufficiently high to put a population at risk of extirpation.	

Table 3.6. Water quality conditions for high, moderate, low, and very low resiliency Rio Grande mussel populations.

3.3.1.3 Species Representation

Maintaining representation in the form of genetic or ecological diversity is important to maintain the Rio Grande mussels' capacity to adapt to future environmental changes. Mussels need to maintain populations throughout their ranges to retain the genetic variability and life history attributes that can buffer the species' response to environmental changes over time (Jones et al. 2006, p. 531). The Rio Grande mussels have likely lost genetic diversity as populations have been extirpated throughout their ranges. As such, retaining the remaining representation in the form of genetic diversity is likely critical to the species' capacity to adapt to future environmental change.

3.3.1.4 Species Redundancy

The Rio Grande mussels need multiple, resilient populations distributed throughout their ranges to provide for redundancy. The more populations, and the wider the distribution of those populations, the more redundancy the species will exhibit. Redundancy reduces the risk that a large portion of the species' range will be negatively affected by a catastrophic natural or anthropogenic event at a given point in time. Species that are broadly distributed across their historical range are considered less susceptible to extinction and more viable than species confined to a small portion of their range (Carroll et al. 2010, entire; Redford et al. 2011, entire). Historically, most Rio Grande mussel populations were likely connected by fish migration throughout the Rio Grande, upstream through the Pecos River, and throughout tributaries in the United States and Mexico. However, due to impoundments and river reaches with unsuitable water quality (e.g. high salinity) they have become isolated from one another and repopulation of extirpated locations is unlikely to occur without human assistance.

CHAPTER 4. CURRENT CONDITION

In our assessment, we define a mussel population as a collection of hydrologically connected mussel beds throughout which host fishes infested with glochidia may travel. This allows for dispersal of juveniles among and within the mussel beds across the larger population, thereby contributing to maintenance of overall genetic variability. This chapter discusses the current condition of each species populations and assess their resiliency, redundancy, and representation.

4.1 Methodology

To summarize the overall current condition of the Rio Grande mussels, we developed and assigned condition categories for three population and three habitat factors (i.e. Habitat Quantity, Abundance, Reproduction, Substrate, Flowing Water, and Water Quality). See Chapter 3.3 for a detailed description of each factor by species. Habitat quantity was determined by summing the stream length of all hydrologically connected mussel sites (mussel beds) with live records since 2000 using ArcGIS (river miles and river kilometers). The remaining five factors were scored using a combination of best available scientific information and professional judgment of Service species expert biologists. For each species and population, the population and habitat factors were assigned one of four numerical scores based on condition: 4 for healthy, 3 for moderate, 2 for low, 1 for very low, and 0 for extirpated. For each population, the six factors were averaged to determine the overall condition.

In the event that the mean habitat factors score (i.e. Substrate, Flowing Water, and Water Quality) exceeded the mean population factors score (i.e. Habitat Quantity, Abundance, and Reproduction), the overall population condition score was capped at the mean population factors score. We did this to ensure that species responses to habitat conditions that may be occurring at scales finer than those used by the quantitative habitat condition model are captured by the model. Stated another way, mussels are likely responding to habitat variations that are undetected by typical habitat quantification metrics and available data, and we wanted to ensure that these responses are adequately reflected in our overall population condition scores.

Table 4.1 displays the presumed ranges of probabilities of persistence of a population with a given current condition category over the next 25 years. This accounts for approximately three generations of Salina Mucket and two generations of Mexican Fawnsfoot.

Likelihood of Persistence:	**High**	**Moderate**	**Low**	**Very Low**
Range of Presumed Probability of Persistence over ~25 years	**90 – 100%**	**60 – 90%**	**10 – 60%**	**<10%**
Range of Presumed Probability of Extirpation over ~25 years	**0 – 10%**	**10 – 40%**	**40 – 90%**	**>90%**

Table 4.1. Presumed probability of persistence of current condition categories for the Rio Grande mussels.

Given each Rio Grande mussel species has only one extant population, we opted to take a more in-depth approach at estimating their current condition. To do this, we subdivided each current population (see Chapter 3, Figures 3.2 and 3.4 for an overview of current populations) into three stream segments (i.e. upstream, middle, and downstream) to reflect varying habitat and species conditions within a population. These stream segments are defined by known changes in mussel habitat availability, water quality and quantity, and mussel abundance across the entire population. Each segment was scored individually for two of the population and three habitat factors, as described above. These segments were then used to produce current conditions at a fine scale for the entire population. Occupied stream length was not scored for the segments because we were artificially subdividing the occupied reach.

4.2 Salina Mucket

4.2.1 Current Population Resiliency

Table 4.2 provides detailed descriptions of the population and habitat factors used to create condition categories for each population as part of the assessment for the Salina Mucket. Table 4.3 displays the overall current condition of Salina Mucket populations according to the factors described in Table 4.2. When assessing the current condition of the species, we included populations known to be extirpated to assess current condition of the species in the context of the historical range of the species.

Salina Mucket – Population and Habitat Factors						
Current Condition	**POPULATION FACTORS**			**HABITAT FACTORS**		
	Habitat Quantity	**Abundance**	**Reproduction**	**Substrate**	**Flowing Water**	**Water Quality**
High	> 50 continuous river miles occupied	≥ 4.0 CPUE	3 or more distinct age classes represented by multiple individuals. Multiple successful recruitment events in previous years.	Stable, scour-free habitats consisting of heterogeneous mud, sand, and gravel mixtures. Banks stable and not eroding. AND / OR Bedrock fissures and crevices present, substrate provides lodging within crevices but does not fill completely.	Flowing water present year-round. No recorded periods of zero flow days AND no inundation from reservoirs.	No known contaminant, dissolved oxygen or temperature issues.
Moderate	20-50 continuous river miles occupied	4.0 > CPUE ≥ 2.0	2 distinct age classes represented by multiple individuals. Sporadic or limited successful recruitment events.	Moderately stable habitat consisting of heterogeneous mixtures of mud, sand, and gravel present, but some areas of scour or depositional sedimentation present. Banks largely stable but isolated collapse is present. AND/OR Bedrock fissures and crevices present. Substrate sufficient to provide lodging while other areas scoured or too heavily filled.	Flowing water present almost year-round. Few instances of zero flow days.	Contaminants known, low dissolved oxygen or high temperature documented but not at levels to put population at risk of extirpation.

Low	< 20 continuous river miles occupied	2.0 > CPUE ≥ 0.5	1 age class present. Recruitment events are not regular enough to indicate recurring reproduction.	Lacking stable habitats consisting of heterogeneous mud, sand, and gravel mixtures , frequent scour areas, excessive sediment deposition, and unstable banks leading to frequent sloughing. AND / OR crevices obstructed. Relatively high sedimentation and filling of interstitial spaces.	Flowing water does not persist throughout the occupied stream reach.	Contaminants known, low dissolved oxygen or high temperature documented. Levels sufficiently high to risk extirpation.
Very Low	< 20 continuous river miles occupied	< 0.5	No definable age structure as not enough live individuals were encountered.	Depositional areas and bank habitats severely degraded, almost non-existent. Crevices and bedrock shelves filled with sediment, mussel occupation may be precluded.	Flowing water does not persist throughout the occupied stream reach.	Contaminants known, low dissolved oxygen or high temperature documented. Levels sufficiently high to risk extirpation.
Extirpated	None	None	No individuals present.	No suitable habitat present.	Dry stream bed or zero flow days occur with sufficient frequency to preclude survival OR the stream is impounded by a reservoir.	Water quality issues significant, precludes mussel habitation.

Table 4.2 Salina Mucket population and habitat characteristics used to create condition categories in Table 4.3.

4.2.2 Salina Mucket - Population Segments

The Salina Mucket population, located upstream of Amistad Reservoir in the Rio Grande, was subdivided into three segments based on population density and habitat conditions. Population and habitat factors were then scored for each segment based on current information. These segments and scores are described below and reflected in Table 4.3.

4.2.2.5 Upstream Segment

This segment occurs in the upstream most portion of the current Salina Mucket range for approximately 61 rmi (98 rkm) in Brewster County, Texas (Figure 4.1). The segment begins just downstream of the La Linda Texas International Bridge and ends at the Brewster and Terrell county line. The topography of this segment is dominated by steep canyon walls, predominantly bedrock stream bed, and limited depositional areas. Riverine flow in this segment is heavily influenced by outflows from the Rio Conchos and spring discharges from the Edwards-Trinity Plateau Aquifer (Randklev et al. 2018, p. 734). Multiple springs throughout this segment contribute to base flow and incrementally increase water quality downstream (Bennett et al. 2009, entire; Urbanczyk and Bennett 2017, p. 9). Species occurrence data in this segment, compiled from multiple sources, indicate that Salina Mucket occur at a mean abundance of 0.6 mussels per search hour (catch-per-unit-effort, CPUE). That is, one live Salina Mucket is collected for roughly every two hours of search effort. Surveys during 2015, the most recent comprehensive survey of this segment, found 25 live Salina Mucket from 11 of 24 sites sampled (Randklev et al. 2017, p. 163).

4.2.2.6 Middle Segment

This segment represents the approximate middle of the currently known population of Salina Mucket. The segment begins at the Brewster and Terrell county line and continues downstream for 22 rmi (35 rkm) to near Dryden, Texas (locally referred to as Johns Marina, a popular boat ramp) (Figure 4.1). Riverine flows in this segment are typically higher velocity than upstream, and water quality appears to improve given the combined effects of spring inputs, Rio Conchos flows, and intermittent flows from San Francisco and Sanderson creeks. The river channel has greater access to the floodplain in this section, which increases habitat diversity, thus increasing habitat availability for Salina Mucket (Miller 2020, entire). Salina Mucket are more abundant, although still considered rare, in this segment. Randklev et al. (2017, p. 163) found 66 live Salina Mucket from 11 of 14 sites sampled during 2015. Between 2003 and 2008, Karatayev et al. (2012, p. 210) found 19 live Salina Mucket at one site near Dryden, Texas while conducting basin-wide surveys. They also reported the observation of shell material at an additional 7 sites (n=159 shells). Overall, within this segment, the Salina Mucket has an meean CPUE of 1.35 live mussels per hour.

4.2.2.7 Lower Segment

The lower segment begins at approximately Dryden, Texas and extends downstream for 50 rmi (80 rkm) to Langtry, Texas in Terrell and Val Verde counties Texas (Figure 4.1). Stream habitat, water quality, and flows are similar to those observed in the middle segment. However, the abundance of Salina Mucket appear lower in this segment with a mean CPUE of 0.6 live mussels per hour. Surveys conducted between 2013 and 2015 (Dascher et al. 2018, p. 318; Burlakova and

Karatayev, unpublished database; Randklev et al. 2017, pp. 163-165; and Randklev et al. 2020c, entire) collected 9 live Salina Mucket found from three sites in this segment. Presumably, this reduced occupancy is due to a combination of effects including inundation from Lake Amistad, irrigation, decreased flows due to a reduced number of spring inputs and effects of evapotranspiration. Additional studies in this population segment are needed to better elucidate the species occupancy (Karatayev et al. 2012, p. 214).

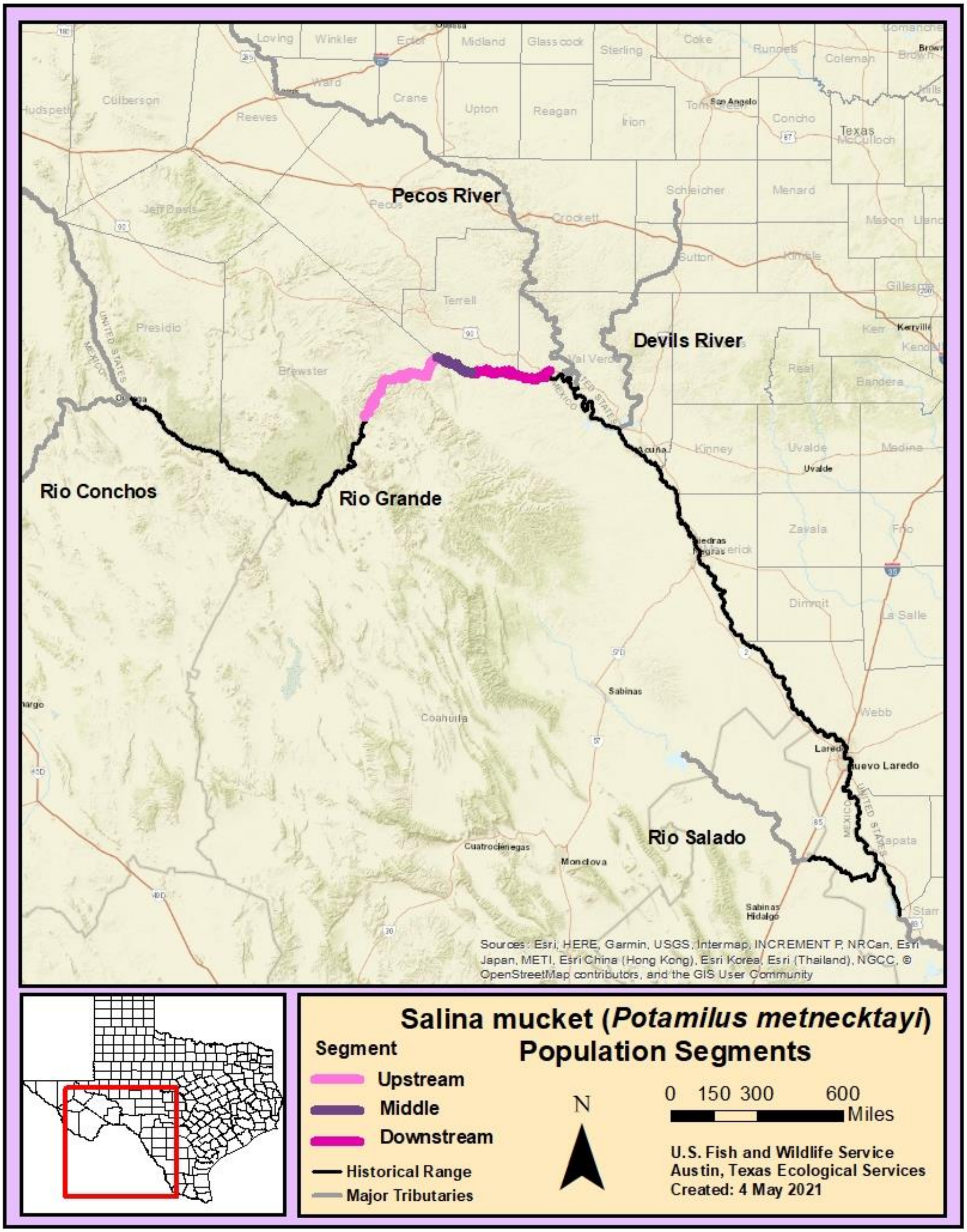

Figure 4.1. Individual population segments within the current range of Salina Mucket. These population segments are used to assign overall current population condition more precisely.

4.2.2.8 Overall Condition

Overall, the single extant population of Salina Mucket occurs in areas of relatively little development but of marginal habitat and water quality (Table 4.3). The available information indicates that the Salina Mucket is currently restricted to approximately 16% of its historic range in the U.S. and Mexico in the Lower Canyons of the Rio Grande, Texas. The species has been extirpated from a large portion of the Rio Grande, as well as the Pecos River (Texas) and the Rio Salado (Mexico) (see Chapter 3.1). As described previously, the species abundance varies throughout the population with the majority of live individuals located in the middle segment. This population segment shows evidence of recent recruitment in the form of multiple age classes of individuals. However, given the degraded habitat quality and low numbers, this may not be sustainable long-term. We consider this population to be in low condition overall due to low abundance, limited evidence of recruitment, and degraded habitat. See Figure 4.2 for a description of habitat and population condition metrics.

Salina Mucket – Current Population Conditions								
		Population Factors			Habitat Factors			
Population	**Stream Reach**	**Habitat Quantity**	**Abundance**	**Reproduction**	**Substrate**	**Flowing Water**	**Water Quality**	**Overall**
Rio Grande – Lower Canyons	**Overall**	High	Low	Low	Moderate	Moderate	Moderate	**Low**
	Upstream		Low	Low	Moderate	Moderate	Low	
	Middle		Low	Low	Moderate	Moderate	Moderate	
	Downstream		Low	Low	Moderate	Moderate	Moderate	
Rio Grande – Below Amistad	**Overall**	Extirpated	Extirpated	Extirpated	Moderate	Moderate	Moderate	**Extirpated**
Rio Salado, Mexico	**Overall**	Extirpated	Extirpated	Extirpated	Low	Low	Low	**Extirpated**

Table 4.3. Current resiliency of Salina Mucket populations. For extirpated streams, stream length estimates are for historical distributions. See Table 4.2 for detailed descriptions of condition categories.

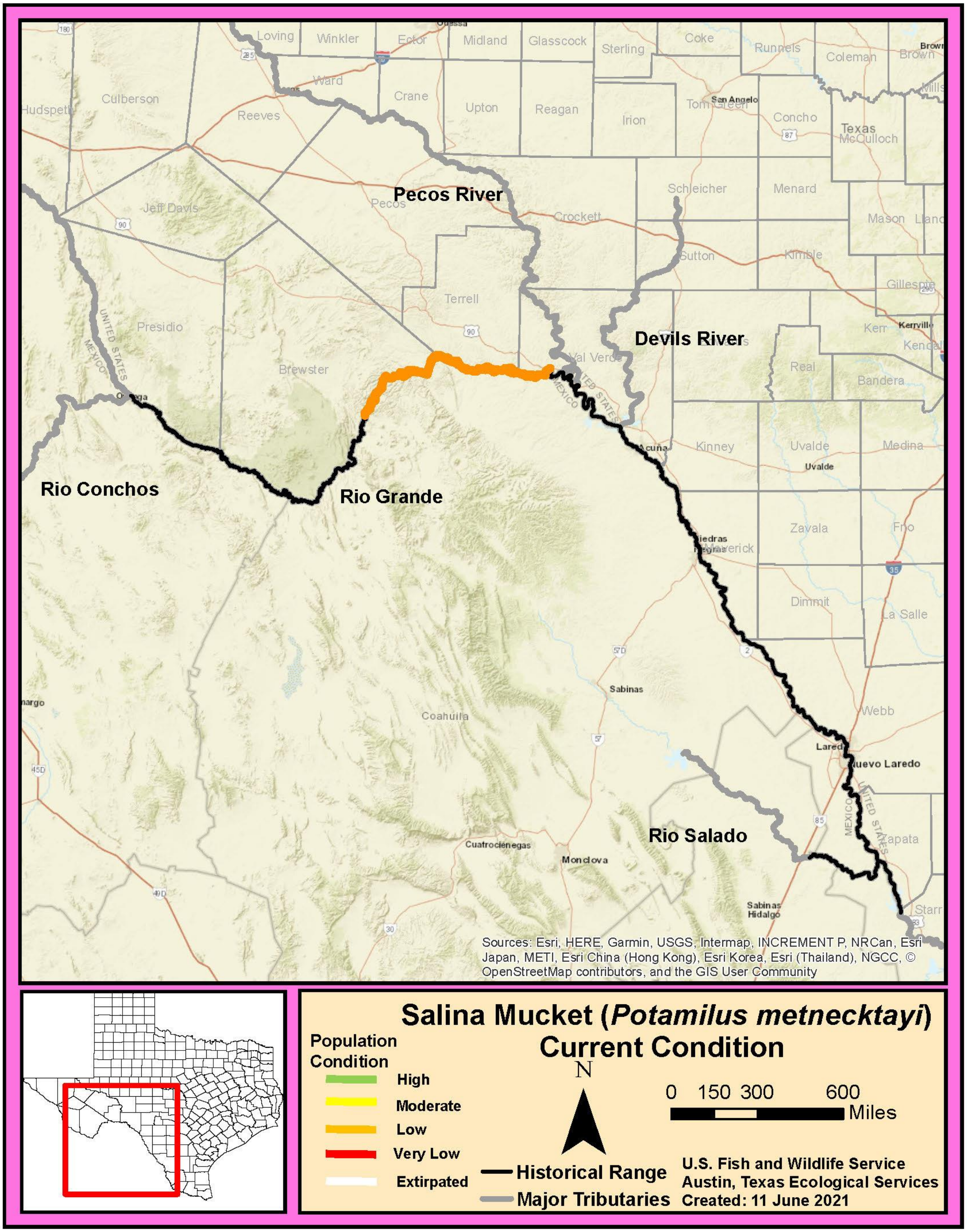

Figure 4.2. Location and overall current condition of Salina Mucket (orange, low condition) across the species historical range (black) in the Rio Grande basin.

4.2.3 Current Species Representation

There is only one known Salina Mucket population. We do not expect any significant differences in localized adaptations within this population as the entire population occurs in similar habitat and faces similar stressors. As such, we consider this species to have representation in a single population. Any representation that historically occurred throughout the Rio Grande or in Mexico has been lost.

4.2.4 Current Species Redundancy

Within the Rio Grande basin, the Salina Mucket has no redundant populations. Only one extant population is known to occur in the Lower Canyons area between Big Bend National Park and Lake Amistad. No other extant populations are known to exist.

4.3 Mexican Fawnsfoot

4.3.1 Current Population Resiliency

Table 4.4 provides detailed descriptions of the population and habitat factors used to create condition categories for each population as part of the assessment for the Mexican Fawnsfoot. Table 4.5 displays the overall current condition of Mexican Fawnsfoot populations according to the factors described in Table 4.4. When assessing the species current condition, we included extirpated populations to include the entire historically known distribution of the species.

Mexican Fawnsfoot – Population and Habitat Factors						
Current Condition	POPULATION FACTORS			HABITAT FACTORS		
	Habitat Quantity	**Abundance**	**Reproduction**	**Substrate**	**Flowing Water**	**Water Quality**
High	> 50 continuous river miles occupied	$\geq$ 4.0 CPUE	3 or more distinct age classes represented by multiple individuals, multiple successful recruitment events in previous years.	Riffle and run habitat present. Substrate sufficiently stable to prevent dislodging during high flow events.	Flowing water present year-round. No recorded periods of zero flow days AND no inundation from reservoirs.	No known contaminant, dissolved oxygen or temperature issues.
Moderate	20-50 continuous river miles occupied	4.0 > CPUE $\geq$ 2.0	2 distinct age classes present represented by multiple individuals. Evidence indicates sporadic or limited successful recruitment events.	Riffle and run habitat present. Substrate sufficiently stable to prevent dislodging during most but not all high flow events.	Flowing water present almost year-round. Few instances of zero flow days.	Contaminants known, low dissolved oxygen or high temperature documented but not at levels to put population at risk of extirpation.
Low	< 20 continuous river miles occupied	2.0 > CPUE $\geq$ 0.5	1 age class present. Recruitment events are not regular enough to indicate recurring reproduction.	Riffle and run habitat eroding, unstable, or being buried by mobilized sediments from upstream.	Flowing water does not persist throughout the occupied stream reach.	Contaminants known, low dissolved oxygen or high temperature documented. Levels sufficiently high enough to risk extirpation.

Very Low	< 20 continuous river miles occupied	< 0.5	No definable age structure as not enough live individuals were encountered.	Riffle and run habitats severally degraded, almost non-existent.	Flowing water does not persist throughout the occupied stream reach.	Contaminants known, low dissolved oxygen or high temperature documented. Levels sufficiently high enough to risk extirpation
Extirpated	None	None	No individuals present.	No suitable habitat present.	Dry stream bed or zero flow days occur with sufficient frequency to preclude survival OR the stream is impounded by a reservoir.	Water quality issues significant enough to preclude mussel habitation.

Table 4.4 Mexican Fawnsfoot population and habitat characteristics used to create condition categories in Table 4.5.

4.3.2 Mexican Fawnsfoot – Population Segments

The Mexican Fawnsfoot population, located between approximately Eagle Pass and San Ygnacio Texas, was subdivided into three segments based on population density and habitat conditions. Population and habitat factors were then scored for each segment based on the current information. These segments and scores are described below and reflected in Table 4.5.

4.3.2.1 Upstream Segment

This segment begins about 6 rmi (9.6 rkm) upstream of Eagle Pass, Texas and continues downstream for approximately 106 rmi (170 rkm) through Maverick and Webb counties, Texas to 3 rmi (4.8 rkm) upstream of the Laredo Columbia Solidarity International Bridge (Figure 4.3). The flows in this stretch of the Rio Grande are almost entirely composed of release from Lake Amistad (TWDB 2021, p.1). This segment has significant diversions including the Maverick Canals, multiple low water weirs, and pumping for irrigation purposes. The habitat within the segment is largely degraded with a very low abundance of Mexican Fawnsfoot. Randklev et al. (2017, p. 224) collected only 3 live Mexican Fawnsfoot from 2 of 20 sites in Maverick County during 2015. This represents the most recent live records of the species within that segment from the last 30 years. The mean CPUE for Mexican Fawnsfoot in this segment is 0.35 live mussels per hour, which is considered very low according to our defined categories. Based on these data, current population and habitat factor conditions have been assigned to this segment and can be found in Table 4.3.

4.3.2.2 Middle Segment

The middle segment begins about 3 rmi (4.8 rkm) upstream of the Laredo Colombia Solidarity International Bridge and continues downstream through Webb County, Texas for 33 rmi (53 rkm) to the Interstate-35 Juarez-Lincoln International Bridge in Laredo, Texas (Figure 4.3). Stream habitat improves marginally in this segment and is less influenced by flows from Lake Amistad. The mean CPUE of Mexican Fawnsfoot is highest in this segment at about 1.48 live mussels per hour. Several studies have documented the presence of Mexican Fawnsfoot in this segment. Randklev et al. 2017 (pp. 227-232) reported 160 live individuals from 13 sites during surveys in 2014 and 2015. Brewster (2015) collected a total of 69 live individuals and 241 recently dead specimens from seven sites during 2013 and 2014 (pp. 16-18). They also noted that at a single site (near Pico Road, approximately the center of this segment) extremely low flows due to a major drought in July 2013 likely resulted in the elimination of the largest known Mexican Fawnsfoot population where 35 live and 206 very recently dead individuals were discovered (Brewster 2015, p. 30). Additionally, 19 live individuals were collected from surveys conducted between 2001-2011 (Karatayev et al. 2012, p. 213). Further, anecdotal reports indicate that in the Lower Rio Grande near Laredo Texas, jet/air boat operations along shallow portions of river may be dislodging and degrading riffle and run habitat within locations where Mexican fawnsfoot are found (Miller 2021, entire). Based on these data, current population and habitat factor conditions have been assigned to this segment and can be found in Table 4.3.

4.3.2.3 Downstream Segment

The downstream-most segment begins just upstream of the Juarez-Lincoln International Bridge in Laredo, Texas and continues through Webb and Zapata counties, Texas for 45 rmi (72 rkm) downstream to San Ygnacio, Texas, where impoundment effects of Falcon Lake begin (Figure 4.3). Historically, this segment most likely extended downstream further into Zapata and possibly Starr counties; however, the completion and inundation of Lake Falcon (1954) presumably extirpated Mexican Fawnsfoot occupying habitats underneath the current reservoir. This segment is heavily influenced by effluents from four waste-water treatment plants on the U.S. side of the river and several on the Mexican side. Fecal coliform and bacteria concentrations in this segment of the Rio Grande have been documented as exceeding established limits for decades. Historical collection data indicates a spike in bacteria concentration just upstream of the Juarez-Lincoln International Bridge, at the beginning of this population segment (USIBWC 2012, pp. 6-7, 9-10). It is believed that degraded water quality from point and non-point sources coupled with hydrological alterations from urban runoff, diversions, and low-water weirs have contributed to the decline of Mexican Fawnsfoot in this segment. Currently, the mean catch per unit effort in this segment is categorized as very low at 0.37 live mussels per hour. Randklev et al. (2017, p. 229) reported finding 23 live Mexican Fawnsfoot from 10 sites within this segment during surveys in 2014 and 2015. Miller (2020, entire) noted that a very small population of Mexican Fawnsfoot occurs downstream of the confluence of Delores Creek near the Webb and Zapata county line. This population’s persistence is likely attributed to cleaner inflows from Delores Creek, which improve water quantity and quality for a short distance in the mainstem Rio Grande. Current population and habitat factor conditions assigned to this segment are in Table 4.3.

Figure 4.3. Individual population segments within the current range of Mexican Fawnsfoot. These population segments are used to assign overall current population condition more precisely.

4.3.2.4 Overall Condition

Overall, the single extant population occurs in areas of significant development and hydrological alteration with very limited abundance across the entire population and only limited evidence of recruitment. The available information indicates that the Mexican Fawnsfoot is currently restricted to approximately 48% of its known historic range in the U.S. and Mexico, which is comprised of only one extant population in the Lower Rio Grande near Laredo, Texas. The species has been extirpated from a large portion of the Rio Grande near Lake Amistad (Texas) and presumably the Rio Salado (Mexico) (see Chapter 3.1). As described above, the species abundance varies throughout the population with the majority of the remaining live individuals located in the small, middle segment. This population shows some evidence of recent recruitment by the presence of multiple age classes, but multiple age classes are only found in the middle segment. However, given predicted human growth in this portion of the basin, this population will likely see increased threats. The overall population is considered in low condition due to very low species abundance, limited evidence of recruitment, and degraded habitat (Figure 4.4).

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Mexican Fawnsfoot – Current Conditions								
		Population Factors			**Habitat Factors**			
Population	**Stream Reach**	**Habitat Quantity**	**Abundance**	**Reproduction**	**Substrate**	**Flowing Water**	**Water Quality**	**Overall**
Rio Grande – Laredo	**Overall**	High	Very Low	Low	Moderate	Moderate	Moderate	**Low**
	Upstream		Very Low	Low	Moderate	Moderate	Moderate	
	Middle		Low	Moderate	Moderate	Moderate	Moderate	
	Downstream		Very Low	Low	Moderate	Moderate	Moderate	
Rio Grande – above Amistad	**Overall**	Extirpated	Extirpated	Extirpated	Very Low	Very Low	Moderate	**Extirpated**
Rio Salado, Mexico	**Overall**	Extirpated	Extirpated	Extirpated	Low	Low	Low	**Extirpated**

Table 4.5. Current resiliency of Mexican Fawnsfoot populations. For extirpated streams, stream length estimates are historical distributions. See Table 4.4 for description of condition categories.

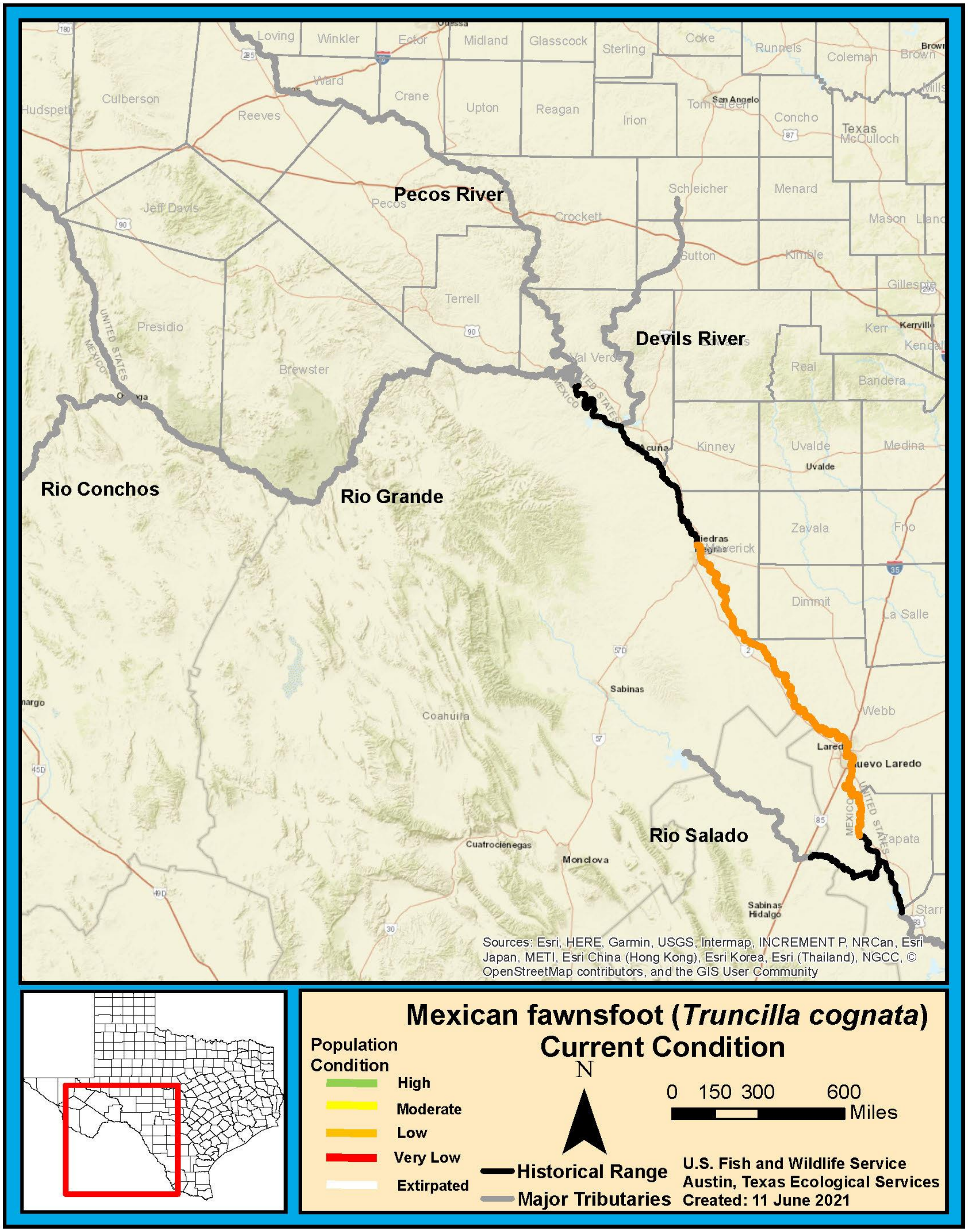

Figure 4.4. Current range and overall condition of Mexican Fawnsfoot (orange) across the species historical range (black) in the Rio Grande basin

4.3.3 *Current Species Representation*

The Mexican Fawnsfoot occupies one known population. We do not expect any significant differences in localized adaptations as the entire population occurs in similar habitat and faces similar stressors. As such, we consider this species to have representation in a single population. Any representation that historically occurred throughout the Rio Grande or in Mexico has been lost.

4.3.4 *Current Species Redundancy*

Within the Rio Grande basin, the Mexican Fawnsfoot has no redundant populations. Only one extant population is known to occur in the Rio Grande between Lake Amistad and Laredo, Texas. No other known extant populations exist.

CHAPTER 5. INFLUENCES ON VIABILITY

In this chapter, we evaluate the past, current, and future influences affecting the Rio Grande mussels needs for long term viability. We analyzed these factors in detail using the tables in Appendix B in terms of causes and effects to the species. These tables analyze the pathways by which each influencing factor affects the species and each of the causes are examined for its historical, current, and potential future effects on the species' status. Current and potential future effects, along with current expected distribution and abundance, determine present viability and, therefore, vulnerability to extinction. We organized these influences around the stressors (i.e., changes in the resources needed by the Rio Grande mussels) and discuss the sources of those stressors. For more information about each of these influences, see Appendix B. Risks not known to have effects on Rio Grande mussels, such as overutilization for commercial and scientific purposes and disease, are not discussed in this SSA report.

5.1 Increased Fine Sediment

Freshwater mussels require specific stream substrates (e.g. silt, sand, gravel, and larger cobbles) in order to anchor themselves into place in the streambed. Interstitial spaces (small openings between rocks and gravels) in the substrate provide essential habitat for juvenile mussels. Juvenile freshwater mussels burrow into interstitial substrates, making them particularly susceptible to degradation of this habitat feature. When clogged with sand or silt, interstitial flow rates and spaces may become reduced (Brim Box and Mossa 1999, p. 100), thus reducing juvenile habitat availability and survivorship. Excessive fine sediments can also embed larger crevices; potentially causing a change in overall substrate composition and even leading to smothering of adult or juvenile mussels that occupy those spaces.

Under natural conditions, fine sediments collect on the streambed and in crevices during low flow events. Much of the accumulated sediment is dislodged and washed downstream during high flow events (also known as cleansing flows). However, the increased frequency and duration of low flow events (from groundwater extraction, instream surface flow diversions, and drought) combined with a decrease in cleansing flows (from reservoir management and drought) has caused sediment to accumulate to some degree beyond historical quantities in stream reaches occupied by both populations of Rio Grande mussels. When water velocity decreases, which can occur from reduced streamflow or inundation, water loses its ability to mobilize sediment and carry it in suspension. This sediment can fall to the substrate and lead to the smothering of mussels that cannot adapt to softer or finer substrates (Watters 2000, p. 263). Sediment accumulation can be exacerbated when there is a simultaneous increase in the sources of fine sediments in a watershed. In the range of the Rio Grande mussels, these sources include streambank erosion from agricultural activities, livestock grazing, roads, border maintenance (e.g. boat ramp and road maintenance) among others (Figure 5.1).

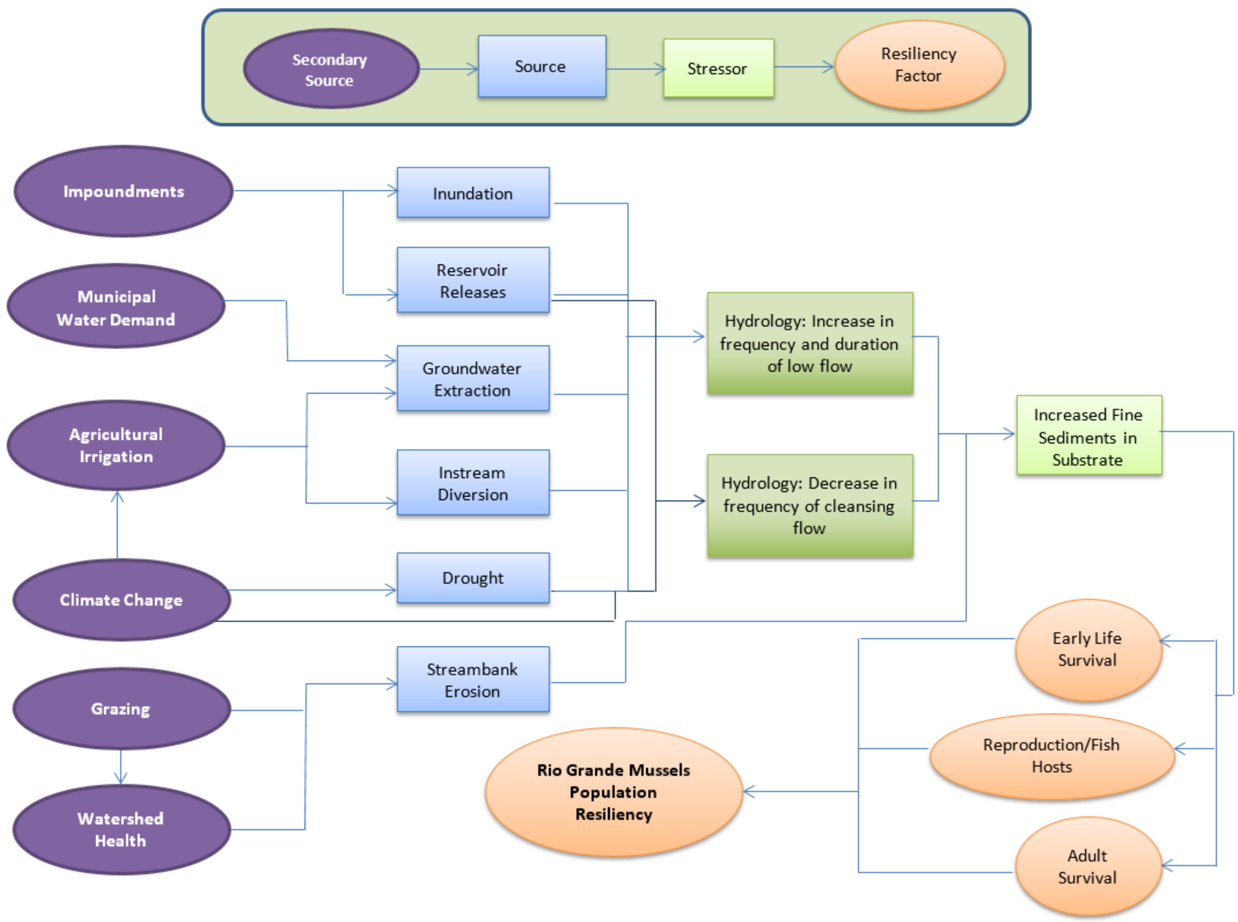

Figure 5.1. Sources of fine sediments within Salina Mucket and Mexican Fawnsfoot populations.

5.2 Water Quality Impairment

Water quality can be impaired through contamination or by alteration of naturally occurring water chemistry. Chemical contaminants are ubiquitous throughout the environment and are a major reason for the current declining status of freshwater mussel species nationwide (Augspurger et al. 2007, p. 2025). Chemicals enter the environment through both point and nonpoint discharges, including spills, industrial sources, municipal effluents, and agricultural runoff. These sources contribute organic compounds, heavy metals, pesticides, herbicides, and a wide variety of newly emerging contaminants to the aquatic environment. Ammonia is of particular concern downstream of agricultural areas and water treatment plant outfalls as freshwater mussels have been shown particularly sensitive to increased ammonia levels at multiple life stages (Augspurger et al. 2003, p. 2569). It is likely for this reason that Mexican Fawnsfoot are not found for many miles downstream of multiple wastewater treatment plants that discharge into the Rio Grande from both the U.S. and Mexico near Nuevo Laredo (Karatayev et al. 2015, p. 9).

Water quality impairment also occurs due to alteration of parameters such as dissolved oxygen, water temperature, or salinity. Dissolved oxygen may be reduced by increased nutrient inputs from surface runoff or wastewater effluent. Juvenile freshwater mussels have been demonstrated to be particularly sensitive to low dissolved oxygen (Sparks and Strayer 1998, pp. 132– 133). Increases in water temperature due to climate change and low flow conditions during drought can exacerbate the effects of low dissolved oxygen levels by reducing dissolved oxygen within the waterbody and increasing freshwater mussel oxygen consumption rates. Additionally, elevated water temperatures can have its own direct metabolic effects on both juvenile and adult mussels affecting their available energy for maintenance, growth, and reproduction (Ganser et al. 2013 p. 1169). In large reservoirs, deep water is very cold and often devoid of oxygen and necessary nutrients. Cold water (less than 11 °Celsius (C) (52 °Fahrenheit (F)) has been shown to stunt mussel growth and delay or hinder spawning. Because glochidia release may be temperature dependent, it is likely that relict individuals living in the constantly cold hypolimnion (deepest portion of the reservoir) in these reservoirs may never reproduce or will reproduce less frequently. Because inundation of occupied habitats is detrimental to the survival of both Rio Grande mussels from both a short-term survival perspective and a long-term reproductive potential perspective, neither species are considered tolerant of occupying reservoirs (Randklev et al. 2020a, 2020b, entire).

Finally, salinity appears to be particularly limiting to Salina Mucket. Inflows from the Rio Conchos, Mexico contribute significantly to base flow in the Rio Grande upstream of Lake Amistad. Ward (2017, pp. 5-6) reported the Rio Grande mean daily flow rate as 140 cubic feet per second (cfs) above the Rio Conchos confluence and 990 cfs downstream. Spring inputs also account for some increases in riverine base flow. Brauch (2012, p. 4) noted that U.S. International Boundary and Water Commission (USIBWC) gauge data shows overall riverine flow increases as much as 60% due to spring water inputs throughout the Lower Canyons stretch of the Rio Grande. However, the spring inputs are often saline and thermal (hot water) and contribute to elevated salinity in the Lower Canyons of the Rio Grande (Urbanczyk and Bennet 2017, entire). Persistent inflows from the Rio Conchos are likely critical to maintaining appropriate salinity levels for the Salina Mucket (Urbanczyk and Bennet 2017, p. 16). Additionally, aquifers have become increasingly saline due to salinized water recharge. Hoagstrom (2009, p. 27) provides an overview of causes and impacts of salinization in a Rio Grande tributary, the Pecos River. Irrigation return flows exacerbate increasing salinity levels as salts build up on irrigated land and then are washed into the Rio Grande and its tributaries.

A reduction in surface flow from drought, instream diversion, or groundwater extraction concentrates contaminant and salinity levels, increases water temperatures in streams and exacerbates detrimental effects to the Rio Grande mussels. See Figure 5.2 for a depiction of how water quality affects these species.

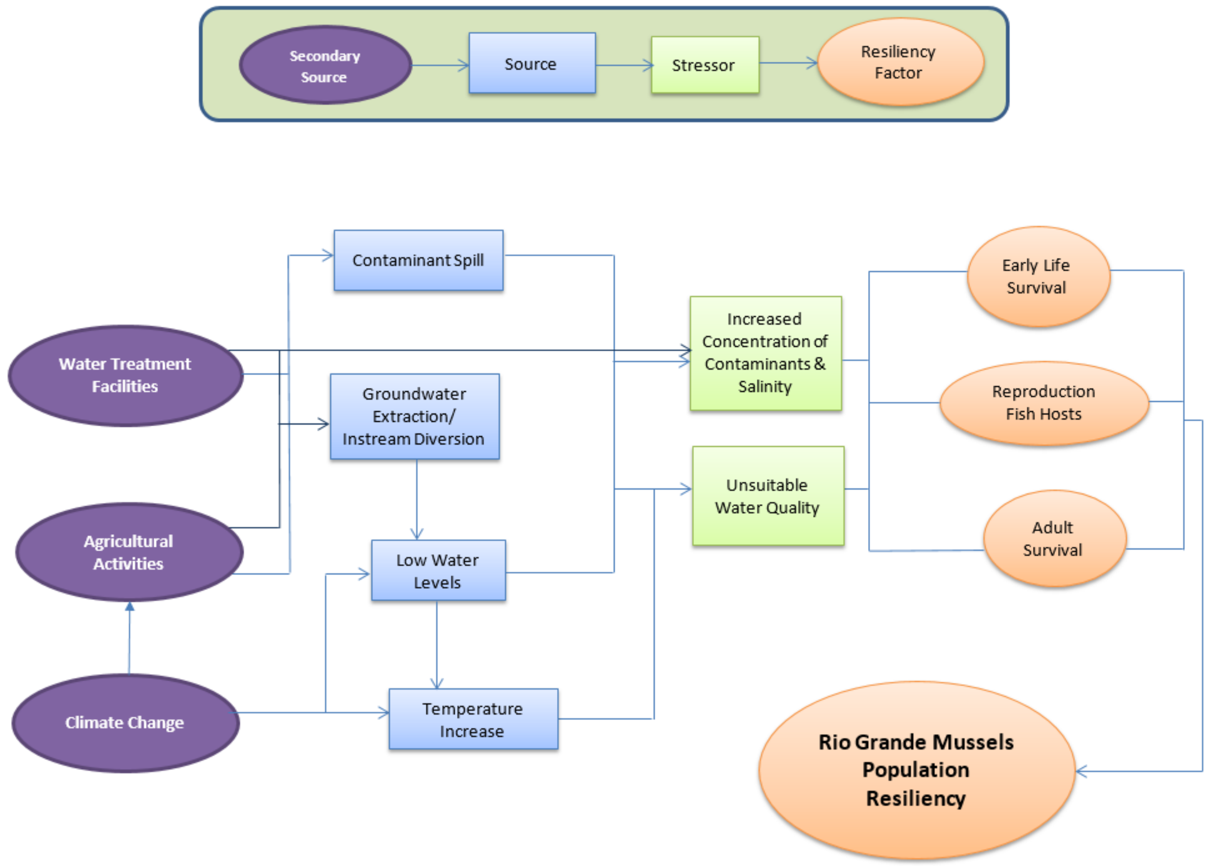

Figure 5.2. Sources of water quality impairment within Salina Mucket and Mexican Fawnsfoot populations.

5.3 Loss of Flowing Water

The Rio Grande mussels need flowing water to survive. Low flow events (including stream drying) severe flooding, and inundation are all forms of hydrologic alteration that can eliminate appropriate habitat conditions for both species, and while the species may survive these events if they last for a short time, populations that experience these conditions frequently or continuously will not persist (Figure 5.3).

Inundation has primarily occurred in the Rio Grande basin upstream of dams, both large (e.g. Amistad and Falcon) and small (e.g. water weirs, diversion dams, such as those in the Rio Grande below Amistad). Inundation causes an increase in sediment deposition, eliminating interstitial spaces both mussel species need to anchor themselves and for juvenile growth. Inundation may also alter water quality (see section 5.2, Water Quality Impairment).

Very low water levels are detrimental to the Rio Grande mussels, as well. Droughts that have occurred in the recent past have led to extremely low flows in rivers across the desert Southwest.

The areas inhabited by the Rio Grande mussels have some resiliency to drought because they are partially spring fed (e.g. Salina Mucket, Lower Canyons Rio Grande), or have managed flow from major reservoirs (e.g. Mexican Fawnsfoot, downstream of Amistad). However, drought in combination with increased groundwater pumping and regulated reservoir releases may lead to lower river flows of longer duration than have been recorded in the past. This hydrological alteration can be detrimental to mussel populations. Streamflow in the Rio Grande downstream of the confluence with the Rio Conchos (near the Rio Grande – Lower Canyons) has been declining since the 1980s (Miyazono et al. 2015, p. A-3). Overall river discharge for the Rio Grande is projected to continue to decline due to increased drought as a result of climate change (Nohara et al. 2006, p. 1087). The Rio Grande – Lower Canyons is very incised, and the Salina Mucket occurs in crevices along the steep banks. Reductions in discharge in this area may lead to a higher proportion of the population being exposed than similar decreases at other populations. Mexican Fawnsfoot utilizes riffle and near shore depositional areas as habitat, both areas are bathymetric high points in a river system. Therefore, decreased flows will likely lead to greater exposure of these habitats in both area and duration during drought and low flows.

As spring and riverine flows decline due to drought or declining water tables exacerbated by groundwater pumping, the habitat that can be occupied by the Rio Grande mussels could be further reduced and eventually cease to exist. While these species may survive short periods of low flow conditions, as low flows persist, mussels face increased risks due to oxygen deprivation, increased water temperature, and, ultimately, stranding, reducing survivorship, reproduction, and recruitment in the population.

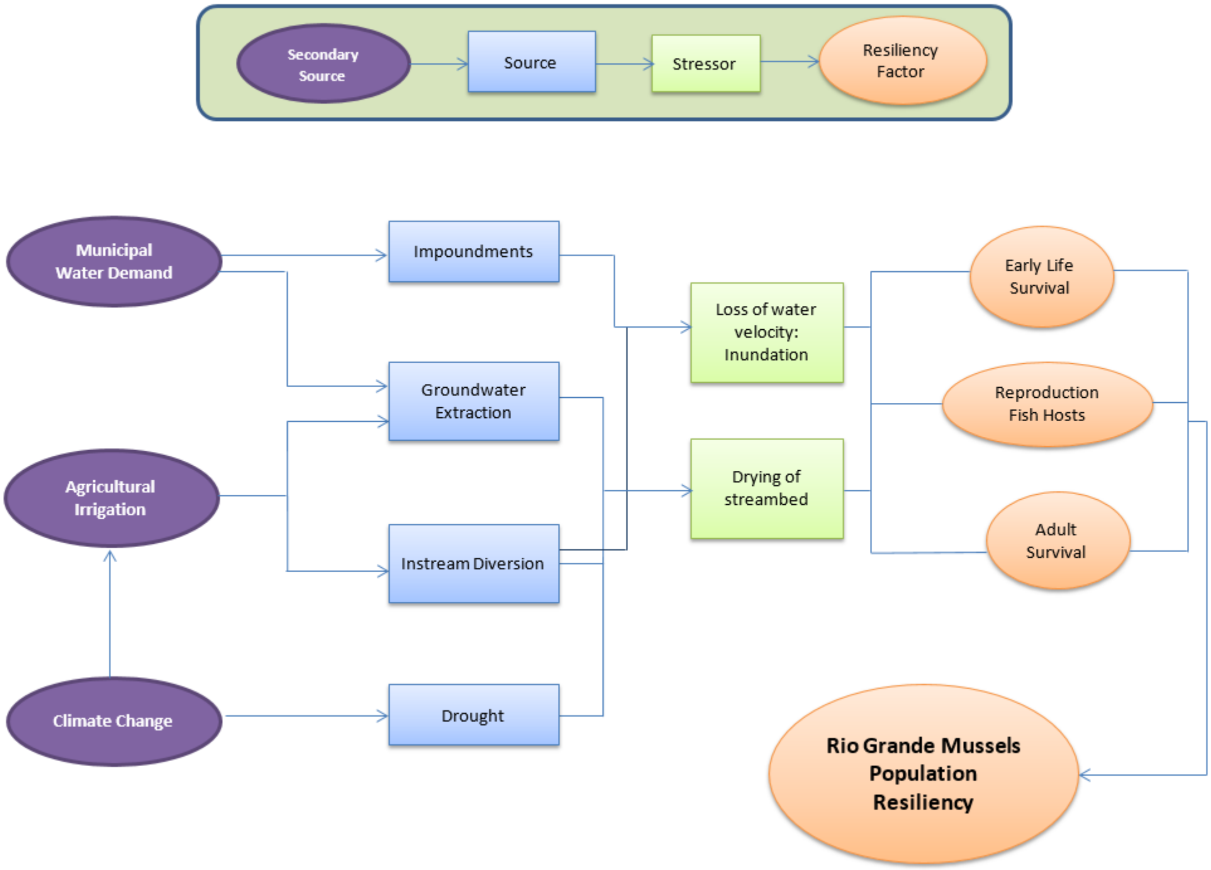

Figure 5.3. Sources of flow loss within Salina Mucket and Mexican Fawnsfoot populations.

5.4 Barriers to Fish Movement

The natural ranges of the Rio Grande mussels historically extended throughout the mainstem Rio Grande and select major tributaries in Texas (see Chapter 3 Populations and Species Needs, for a more in-depth description). The overall distribution of mussels is, in part, a function of the dispersal of their host fish. Mussels colonize new areas through movement of infested host fish, and newly metamorphosed juveniles excysting from host fish into suitable habitats in new locations.

Today, each species has only a single remaining population with an uneven distribution within the larger population. This range restriction has greatly reduced the species ability to recolonize new areas, expand its current range, or maintain more distant mussel beds through fish host movement. The construction and operation of large and small impoundments also limits potential for immigration and emigration among populations. At the species level, populations that are eliminated due to stochastic events cannot be recolonized naturally, leading to reduced overall redundancy and representation. The Rio Grande mussels have no redundant populations to serve as sources to restore populations eliminated due to stochastic events.

Over time, by preventing fish passage among stream reaches occupied by differing populations, impoundments can lead to genetic isolation between individual populations and others throughout the species range. Small or isolated populations are susceptible to genetic drift (random loss of genetic diversity) and inbreeding depression. At the population level, this can make some populations less adaptable and resilient to changing environmental conditions. The Rio Grande mussels have no redundant populations to serve as sources to restore genetic variability if the remaining population experiences genetic drift or inbreeding depression.

The Rio Grande mussels' primary host fish (Freshwater Drum, *Aplodinotus grunniens*) is known to be a common and widespread species. We do not expect the distribution or abundance of the host fish to be a limiting factor for Rio Grande mussels. There are no known fish host barriers within the range of the Salina Mucket; therefore, we will not be carrying this stressor forward for that species. However, there are multiple low water weirs and other potential fish host barriers within the range of the Mexican Fawnsfoot; therefore, we will carry this stressor forward for that species.

5.5 Increased Predation

Predation on freshwater mussels is a natural ecological interaction. Raccoons, snapping turtles, and fish are known to prey upon multiple mussel species including the Rio Grande mussels. Under natural conditions, the level of predation occurring is not likely to pose a significant risk to any given population. However, during periods of low flow, terrestrial predators have increased access to portions of the river that are otherwise too deep and inaccessible under normal flow conditions. As drought and low flow are projected to occur more often and for longer periods due to the anticipated effects of future climate change (Figure 5.4), we expect predation will become a more significant risk. Further, because each species only has one extant population, the otherwise natural levels of predation could be much more detrimental to the species. However, at this time, predation on the Salina Mucket has not been observed at levels that would indicate it will have a detrimental impact on the long-term viability of the species. Therefore, we are not carrying this stressor forward in the future analysis for Salina Mucket. Conversely, the Mexican Fawnsfoot occupies primarily riffle habitats, which are topographic high points in a stream system. These areas are relatively shallow even under normal flow conditions and are prone to partial dewatering or desiccation during drought events. Reductions in water levels would put the Mexican Fawnsfoot at an increased risked of predation from terrestrial predators. Therefore, we are carrying this stressor forward in future analysis for Mexican Fawnsfoot.

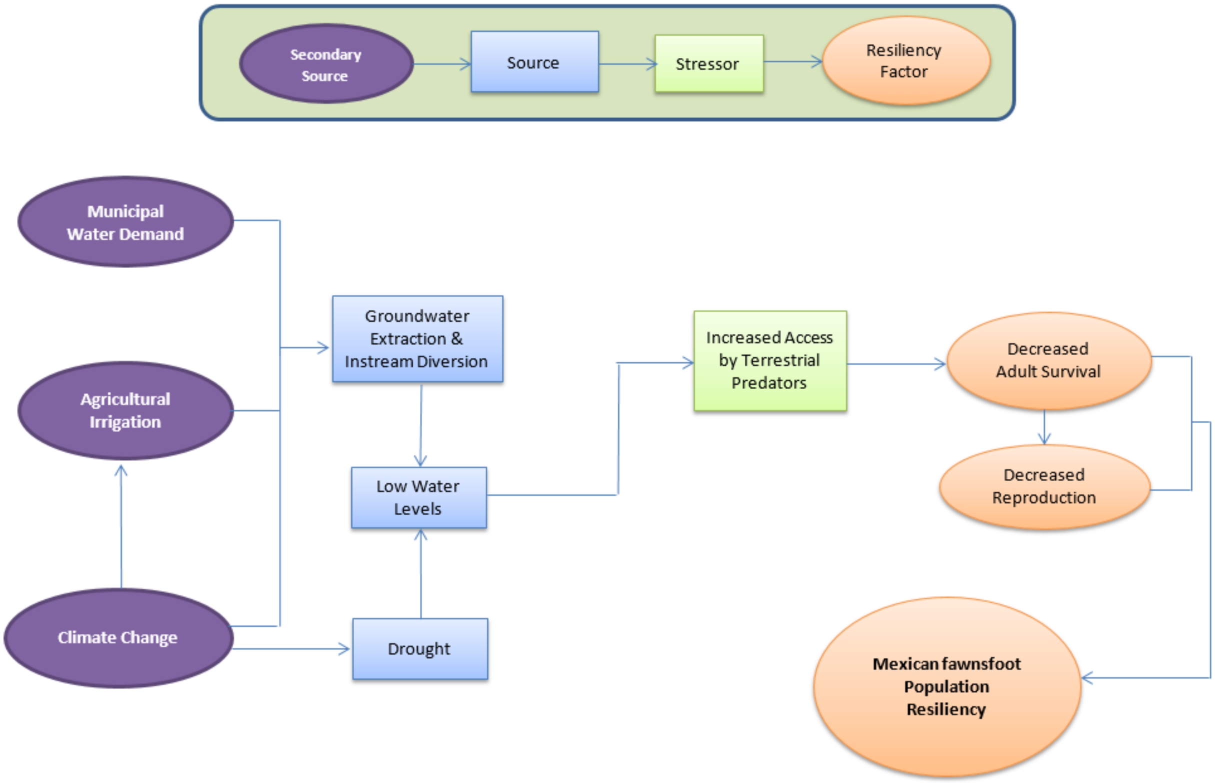

Figure 5.4. Sources of increased predation within Mexican Fawnsfoot populations.

5.6 Climate Change

Climate change has begun, and continued greenhouse gas emissions at or above current rates will cause further warming (Intergovernmental Panel on Climate Change (IPCC) 2013, pp. 11–12). Warming in the Southwest is expected to be greatest in the summer (IPCC 2013, pp. 11–12), and annual mean precipitation is very likely to decrease in the Southwest (IPCC 2013, pp. 11–12; Ray et al. 2008, p. 1). In Texas, the number of extreme hot days (high temperatures exceeding 95° Fahrenheit) are expected to double by around 2050 (Kinniburgh et al. 2015, p. 83). Texas is considered one of the "hotspots" of climate change in North America with West Texas highlighted as an area that is expected to show greater responsiveness to the effects of climate change (Diffenbaugh et al. 2008, p. 3). Even if precipitation and groundwater recharge remain at current levels, increased groundwater pumping and resultant aquifer shortages due to increased temperatures are nearly certain (Loaiciga et al. 2000, p. 193; Mace and Wade 2008, pp. 662, 664-665; Taylor et al. 2012, p. 3). Climate change effects, such as air temperature increases and an increase in drought frequency and intensity, have been occurring throughout the ranges of the Rio Grande mussels (Kinniburgh et al. 2015, p. 88). These effects are expected to exacerbate several of the stressors discussed above, such as water temperature and loss of flowing water (Wuebbles et al. 2013, p. 16). In our analysis of the future condition of the Rio Grande mussels, we considered climate change to be an exacerbating factor in the increase of fine sediments, changes in water quality, loss of flowing water, and predation.

5.7 Summary

Our analysis of past, current, and future influences on Rio Grande mussels requirements for long-term viability revealed there are three influences that pose the largest risks to future viability. These risks are primarily related to habitat changes: the accretion of fine sediments, the loss of flowing water, and impairment of water quality; all of which are anticipated to be exacerbated by climate change. We did not assess overutilization for scientific and commercial purposes or disease, because these risks do not appear to be occurring at a level that affect the Rio Grande mussels. The predation of freshwater mussels at their current conditions is not anticipated to influence the future viability of the Rio Grande mussels. Fish host availability and movement of glochidia are not anticipated to influence the future viability of Salina Mucket; however, fish host availability and movement may affect the future viability of Mexican Fawnsfoot and will be carried forward for this species. The accretion of fine sediments, the loss of flowing water, impairment of water quality, and their associated habitat impacts, as well as management efforts, are carried forward in our assessment of the future conditions of the Rio Grande mussels.

CHAPTER 6. VIABILITY

We have considered what the Rio Grande mussels need for viability and the current condition of those needs (Chapters 3 and 4), and we reviewed the risk factors that are driving the historical, current, and future conditions of the species (Chapter 5 and Appendix B). We now consider the range of plausible species' future conditions. We apply our forecasts to the concepts of resiliency, redundancy, and representation to describe the future viability of the Salina Mucket and Mexican Fawnsfoot.

6.1 Introduction

The Rio Grande mussels have declined significantly in overall distribution and abundance throughout their ranges. The Salina Mucket currently occupies approximately 16% of its historical range in the U.S. and Mexico, and the Mexican Fawnsfoot currently occupies approximately 48% of its historical range in the U.S. and Mexico. The historical range of Mexican Fawnsfoot appears to have always been more restricted than Salina Mucket. Both species currently occur in single extant populations that have undergone significant range reductions. The primary historical reasons for these range reductions are reservoir construction and unsuitable water quality. Large reservoirs have been constructed throughout the Rio Grande basin, and inundation coupled with reduced flows, drought, and withdrawals have significantly altered the hydrology of the Rio Grande in Texas (Randklev et al. 2018, p. 734).

The construction of large reservoirs across the basin exacerbates risks at the species level for both Rio Grande mussels by isolating individual populations and prohibiting natural recolonization from host fish carrying glochidia. In the past, this recolonization would have allowed for the species to ebb and flow from suitable areas over time. However, due to the presence of these large reservoirs, both species are confined to distinct reaches of the Rio Grande and are no longer able to expand and occupy additional upstream or downstream habitats. For example, the one remaining Salina Mucket population, occupying a greatly reduced reach in the Lower Canyons of the Rio Grande, could be eliminated entirely by a single stochastic event such as contaminant spill or drought. Because Amistad Reservoir has eliminated downstream habitat, the species could become extinct.

For the one remaining Mexican Fawnsfoot population, the effects of reservoirs extend beyond isolation and habitat fragmentation. The resultant reservoir releases rarely mimic natural flow regimes, and the change in timing and frequency of cleansing flows results in increases in fine sediments, predation, and decreased water quality. Once the additional exacerbating effects of climate change are considered – increased temperature and decreased stream flow – the Mexican Fawnsfoot population faces a high level of risk into the future.

Climate change has already begun to affect the Rio Grande basin of Texas and Mexico where theses mussels occur, resulting in higher air temperatures, increased evaporation, increased groundwater pumping, and changing precipitation patterns such that water levels have already reached historic lows range-wide (Dean and Schmidt 2011, p. 336). These increasingly common and extended low flow conditions put both species at elevated risk of habitat loss from increased fine sediments, poor water quality, and increased predation risk. Additionally, a low-water weir proposed for construction in the Lower Rio Grande in the upstream vicinity of Laredo, Texas would eliminate approximately 7% of currently occupied Mexican Fawnsfoot habitat, where the densest population segment is known to exist.

These risks, individual or compounded, could result in the significant reduction or extirpation of the existing Rio Grande mussel populations, further reducing the overall redundancy and representation of the species or driving them to extinction. Historically, both species, with a large range of interconnected populations, would have been resilient to stochastic events such as drought and sedimentation because lost populations could be recolonized over time by dispersal from nearby surviving populations. This connectivity made both Rio Grande mussels highly resilient overall. However, under current conditions, restoring that connectivity on a large scale is not feasible due to large reservoirs, unsuitably low flows, and lack of redundant populations.

Consequently, due to these current conditions, the viability of the Rio Grande mussels now solely depends on maintaining the remaining population of each species.

6.1.1 Scenarios

For the purposes of this assessment, we have prepared future scenarios to forecast viability of the Rio Grande mussels over the next 10, 25, and 50 years. We chose 10 years to evaluate what is likely to occur in the near term, and 25 and 50 years because they are within the range of the available hydrological and climate change model projections and provide us with a shorter- and longer-term analysis (Mace and Wade 2008, entire; Texas Water Development Board 2021a and 2021b, entire). The Continuation/Moderate Effects scenario (Scenario 1) models the future conditions for the Rio Grande mussels as continuing the current trajectory of the previous decade with marginal increases in specific stressors. The Severe Effects scenario (Scenario 2) assumes a more precipitous decline in habitat condition and significantly increased threats over time as compared to current day.

While this report was drafted, the 2014 IPCC Synthesis Report was the best available science and the 2022 Sixth Assessment report was not yet available. As such, this report is based off the future climate trajectories as outlined in the 2014 IPCC Synthesis Report. The 2014 Synthesis Report of the Intergovernmental Panel on Climate Change (IPCC 2014, pp. 9, 22, 57) included four pathways of varying future climate trajectories. For this SSA report, the future scenarios included the effects of future climate change through climate models of a RCP 4.5 (lower greenhouse gas emissions) and RCP 8.5 (higher greenhouse gas emissions). Scenario 1 (Continuation/Moderate Effects) utilizes the RCP 4.5 scenario, where CO_2 emissions continue to increase during the first half of the 21st century and then stabilize and decline from 2050 to 2100. Under RCP 4.5, current conditions, which include increased warming, frequency and severity of extreme weather events, such as flooding and droughts, are expected to continue. Global surface temperature is projected "*more likely than not*" to exceed 1.5^{o}C warmer by 2100 as relative to the last century (1850-1900) (IPCC 2014, p. 60). Scenario 2 (Severe Effects) utilizes the RCP 8.5 scenario, which predicts a more dramatic increasing trend with more significant increases in the frequency and severity of extreme weather events, such as drought and floods. Under RCP 8.5, global mean surface temperature is projected to "*likely*" exceed warming of 2.0ºC by 2100, and perhaps be as high as 4.8ºC relative to 1850-1900 (IPCC 2014, p. 60). Moreover, even minor shifts in global temperatures, including evapotranspiration, can have dramatic effects on species distribution and abundance as the two most powerful environmental forces that influence the presence of living organisms are temperature and water presence (USGCRP 2017, pp. 232-238).

Because we have uncertainty regarding the specific timing and amount of flow loss and/or water quality degradation, we have forecasted what the Salina Mucket may have in terms of resiliency, redundancy, and representation under two plausible future scenarios, Scenario 1 and Scenario 2. Additionally, for Salina Mucket the 10-year time-step represents one generation, 25-years represents between 2 and 3 generations, and the 50-year time-step represents between 4 and 5 generations.

For Mexican Fawnsfoot, we have forecasted the species future status under the same two scenarios with one addition. A low-water weir, proposed for construction on the Rio Grande in the upstream vicinity of Laredo, Texas would uniquely affect the extant Mexican Fawnsfoot population (Rio Grande Regional Water Planning Group 2010, pp. 4-74 and Rio Grande Regional Water Plan [Region M] 2021, p. 632). As such, we have separated Scenario 2 for this species into two parts, A and B. Mexican Fawnsfoot Scenario 2A does not forecast the weir construction occurring. Conversely, Scenario 2B assumes the weir is completed 25-years into the future. For Mexican Fawnsfoot, which has a longer lifespan, the 10-year time-step represents about one generation, the 25-year time-step represents between 1 and 2 generations, whereas the 50-year time-step represents approximately 3 to 4 generations.

For each scenario, we describe the stressors that would occur for each population. Because there is a great deal of uncertainty in how each of these stressors would affect the Rio Grande mussels in the future, we use what is known about existing and historical population trends to predict how stressors will affect the remaining populations of mussels for each scenario, and each time-step.

Continuation/Moderate Effects:

- **Rio Grande – Lower Canyons** – Low levels of climate change are occurring, leading to reduced streamflow at nearly all locations. In this scenario, we project the existing levels of degradation (e.g. water quality/quantity and stream habitat loss) continue with no conservation. The frequency of drought and floods continue at the same rate as the previous decade (2010-2020) and outflows from the Rio Conchos in Mexico continue at approximately current levels. Human population growth and associated infrastructure development (e.g. water intakes, wastewater treatment plants, dams, and diversions), as described in the 2021 Texas Water Development Board Regional Water plans occur as projected. The human population within the Salina Mucket extant range (i.e. Brewster, Terrell, and Val Verde counties) is projected to increase by approximately 26% (65,736 to 82,969) from 2020 to 2050. Water demand is projected to increase in the same counties by approximately 12% (23,170 acre-feet (Ac-ft) to 26,018 Ac-ft) from 2020-2050 (TXWDB 2021a and 2021b, entire). The IPCC emission scenario for an RCP of 4.5 translates to an approximate increase in air temperature of approximately 1.5ºC by the year 2100 (IPCC

2014, pp. 9, 22, 57).

- **Rio Grande – Laredo** – We project water quality declines marginally, and there is a small decline in streamflow due to a combination of anthropogenic uses, drought, and climate change. Projected human population growth in the region and increased water demands occur (TWDB 2010a, 2021b, 2021c, entire). Additional infrastructure associated with human population growth (e.g. water intakes and wastewater treatment plants) are completed and operating; however, the Laredo low-water weir is not constructed. The human population within the Mexican Fawnsfoot extant range (i.e. Maverick, Webb, and Zapata counties) is projected to increase by approximately 63% (397,954 to 646,999) from 2020 to 2050. Water demand is projected to increase in the same counties by approximately 12% (150,090 Ac-ft to 167,427 Ac-ft) from 2020-2050 (TXWDB 2021a and 2021b, entire). The IPCC emission scenario of RCP 4.5 translates to an approximate increase in air temperature of 1.5°C by the year 2100 (IPCC 2014, p. 60).

Severe Effects:

- **Rio Grande – Lower Canyons** – In this scenario, we project a severe reduction of streamflow due to drought, groundwater extraction, and management of the Rio Conchos and Edwards-Trinity aquifer springs. Drought and flood frequency and severity accelerate at a rate faster and more severe than the preceding decade (2010-2020). The 2020 drought in the Far West Texas Region (Region E) is determined to be worse than the most recent drought of record, which occurred during the 1950s. The human population within the Salina Mucket extant range (i.e. Brewster, Terrell, and Val Verde counties) is projected to increase by approximately 26% (65,736 to 82,969) from 2020 to 2050. Water demand is projected to increase in the same counties by approximately 12% (23,170 Ac-ft to 26,018 Ac-ft) from 2020-2050 (TXWDB 2021a and 2021b, entire). The IPCC emission scenario of RCP 8.5 translates to an approximate increase in air temperature of 2.0°C by 2100, and perhaps as high as +4.8°C as relative to 1850-1900.

- **Rio Grande – Laredo** – Projected human population growth in the region and water demands (as described by the Texas Water Development Board) occur. We project additional infrastructure associated with human population growth (e.g. water intakes and wastewater treatment plants) are completed and operating. The human population within the Mexican Fawnsfoot extant range (i.e. Maverick, Webb, and Zapata counties) is projected to increase by approximately 63%, from 397,954 to 646,999 from 2020 to 2050. Water demand is projected to increase in the same counties by approximately 12% from 150,090 Ac-ft to 167,427 Ac-ft from 2020-2050 (TXWDB 2021a and 2021b, entire). Water quality and streamflow decline in this portion of the basin. In Scenario 2A for the Mexican Fawnsfoot, the low-water weir is not constructed. In Scenario 2B for the Mexican Fawnsfoot, weir construction is completed 25 years in the future. The IPCC emission scenario of RCP 8.5 which translates to an approximate increase in air temperature of 2.0°C by 2100, and perhaps as high as +4.8°C, relative to 1850-1900.

Resiliency of the Rio Grande mussels depends on the combination of projected future conditions of the three population and three habitat factors (see Chapter 4, Table 4.2 and 4.4 for detailed category definitions). We expect the lone extant Salina Mucket and Mexican Fawnsfoot populations to experience changes to these aspects of their condition in different ways under the different scenarios. We project the expected future resiliency of each population based on the events that would occur under each scenario for each of the three population segments. We then used the population segment conditions to better analyze and determine an overall condition for each entire population. For these projections, populations in high condition are expected to have high resiliency at that time (i.e., they occupy habitat of sufficient size to allow for ebbs and flows of density of mussel beds within the population). Populations in high condition are expected to persist into the future (>90% chance of persistence beyond 25 years) and would withstand stochastic events that may occur. Populations in moderate condition have lower resiliency than those in high condition, but the majority (60–90%) are expected to persist beyond 25 years. Populations in moderate condition are smaller and less dense than those in high condition. Populations in low condition have low resiliency and may not be able to withstand stochastic events. As a result, they are less likely to persist beyond 25 years (10–60%). Finally, populations in very low condition are nearing extirpation with individuals so rare they may escape detection, have very low resiliency, and have less than a 10% probability of persistence beyond 25 years. Very low condition will be used for populations that lack recent enough survey data to be determined extirpated but may already be so. Stated another way, populations in very low condition are at the brink of extirpation and any remaining individuals are nearing the end of their lifespan.

6.2 Salina Mucket

For the Salina Mucket, we projected the species future condition under two scenarios, Continuation/Moderate Effects and Severe Effects (see section 6.1.1).

6.2.1 Scenario 1 – Continuation/Moderate Effects

6.2.1.1 Resiliency

Rio Grande – Lower Canyons – In Scenario 1 (Continuation/Moderate Effects), we project the population would experience a small to moderate reduction in flow due to groundwater extraction or drought as result of climate change, and management of the Rio Conchos would not provide a reliable source of surface water in the next 10 years. Water flow reductions would have large impacts to this population as the continued persistence of the species is driven largely by water availability. In the next decade, we expect streamflow declines in the upstream segment of this population as the inflows from the Rio Conchos and associated Edwards-Trinity aquifer springs decline or become less reliable. The population factors for the Salina Mucket would remain largely unchanged in the first decade, and the species would remain in 'Low' condition overall for the 10-year time-step under Scenario 1. However, at the 25-year time-step, we anticipate the effects of low water quality and quantity to begin further reducing the resiliency of this population where the species is less dense, primarily the upstream and downstream segments. Additionally, water quantity and water quality are likely to continue to degrade across the entire population as flows decline and sedimentation becomes more prevalent. Given the Salina Mucket has an average lifespan of approximately 9 years, we project the population abundance to also degrade as older individuals die out of the population.

The loss of older individuals, coupled with only low levels of observed reproduction, would lead to greatly reduced abundance and recruitment in the upstream and downstream segments. The Salina Mucket declines to ‘Very Low’ condition but maintains its currently known range extent 25 years into the future. Finally, at the 50-year time-step, we anticipate the upstream and downstream population segments, comprised of 61 rmi (98 rkm) and 50 rmi (80 rkm) respectively, to become extirpated. This accounts for an 83% reduction in the species range from 133 rmi (214 rkm) to only 22 rmi (35 rkm) of occupied stream. This range reduction is projected due to a continued loss of water quantity and water quality from the Rio Conchos and springs in the area which degrade to a very low condition. Death of older individuals and severely limited recruitment would continue to reduce the resiliency and condition of the species overall. The Salina Mucket 50 years into the future is projected to be in ‘Very Low’ overall condition, with an estimated occupied area of only 22 rmi (35 rkm). See Table 6.1 for an overview of each population segment and overall condition at each future time-step. Figure 6.1 displays the Salina Mucket current and future conditions under Scenario 1 across the species’ current and historical range.

The extirpated populations (Rio Grande near Laredo and Rio Salado basin (Mexico) (Table 6.1) continue to decline in habitat factors under Scenario 1. The Salina Mucket has no natural ability to recolonize these areas given they are isolated from the current population (via host fish migration) by Lake Amistad, and no current or planned efforts to translocate or propagate the species exist. For the extirpated populations, given we had no current abundance or distributional data to demarcate population segments, we assigned conditions (using the six population and habitat factors, Chapter 4, Table 4.2) to the entire extirpated reach.

	Salina Mucket – Rio Grande Lower Canyons -- Scenario 1 Continuation/Moderate Effects								
			Population Factors			Habitat Factors			
	Population	**Stream Reach**	**Habitat Quantity**	**Abundance**	**Reproduction**	**Substrate**	**Flowing Water**	**Water Quality**	**Overall**
Current	**Rio Grande – Lower Canyons**	**Overall**	**High**	**Low**	**Low**	**Moderate**	**Moderate**	**Moderate**	**Low**
		Upstream		Low	Low	Moderate	Moderate	Low	
		Middle		Low	Low	Moderate	Moderate	Moderate	
		Downstream		Low	Low	Moderate	Moderate	Moderate	
	Rio Grande – Laredo	**Overall**	Extirpated	Extirpated	Extirpated	Moderate	Moderate	Moderate	Extirpated
	Rio Salado (Mexico)	**Overall**	Extirpated	Extirpated	Extirpated	Low	Low	Low	Extirpated
10 years	**Rio Grande – Lower Canyons**	**Overall**	**High**	**Low**	**Low**	**Moderate**	**Moderate**	**Moderate**	**Low**
		Upstream		Low	Low	Moderate	Low	Low	
		Middle		Low	Low	Moderate	Moderate	Moderate	
		Downstream		Low	Low	Moderate	Moderate	Moderate	
	Rio Grande – Laredo	**Overall**	Extirpated	Extirpated	Extirpated	Moderate	Moderate	Moderate	Extirpated
	Rio Salado (Mexico)	**Overall**	Extirpated	Extirpated	Extirpated	Low	Low	Low	Extirpated
25 years	**Rio Grande – Lower Canyons**	**Overall**	**High**	**Very Low**	**Low**	**Moderate**	**Low**	**Low**	**Very Low**
		Upstream		Very Low	Very Low	Low	Low	Low	
		Middle		Low	Low	Moderate	Low	Low	
		Downstream		Very Low	Very Low	Moderate	Moderate	Moderate	
	Rio Grande – Laredo	**Overall**	Extirpated	Extirpated	Extirpated	Moderate	Low	Low	Extirpated
	Rio Salado (Mexico)	**Overall**	Extirpated	Extirpated	Extirpated	Low	Low	Low	Extirpated
50 years	**Rio Grande – Lower Canyons**	**Overall**	**Moderate**	**Very Low**	**Very Low**	**Moderate**	**Low**	**Low**	**Very Low**
		Upstream		Extirpated	Extirpated	Low	Very Low	Very Low	
		Middle		Very Low	Very Low	Moderate	Low	Low	
		Downstream		Extirpated	Extirpated	Moderate	Low	Low	
	Rio Grande – Laredo	**Overall**	Extirpated	Extirpated	Extirpated	Low	Low	Low	Extirpated
	Rio Salado (Mexico)	**Overall**	Extirpated	Extirpated	Extirpated	Very Low	Very Low	Very Low	Extirpated

Table 6.1. Salina Mucket population resiliency for the Rio Grande - Lower Canyons population under Scenario 1 – Continuation/Moderate. Individual population status currently and 10, 25, and 50 years into the future.

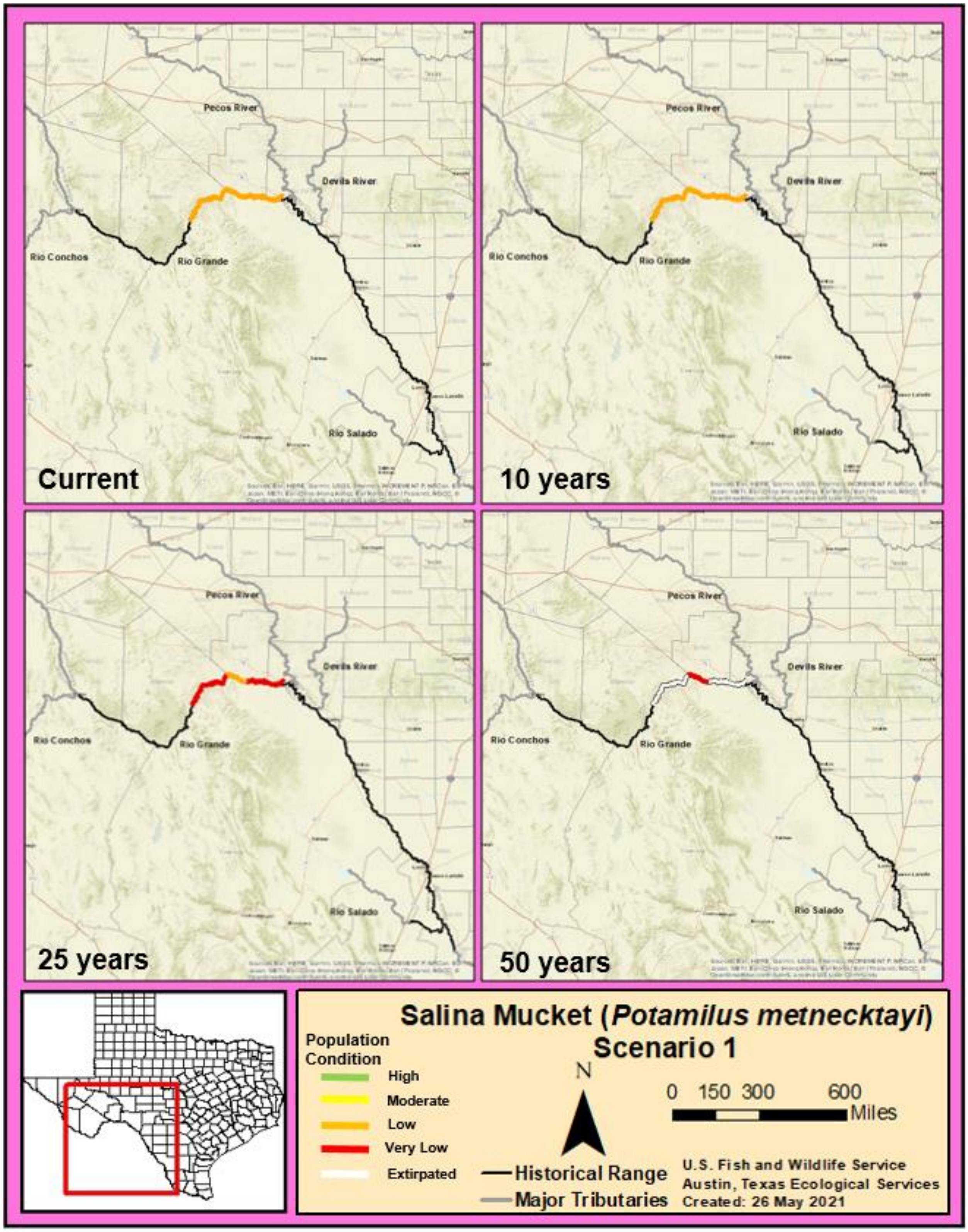

Figure 6.1 Salina Mucket population condition under Scenario 1 – Continuation/Moderate. Population status, shown by population segment, currently and 10, 25, and 50 years into the future.

6.2.1.2 Representation

As identified above (Chapter 4.2.3), we consider the Salina Mucket to have representation in the form of genetic diversity in only one area: the Rio Grande – Lower Canyons. We do not expect any significant variation within this population as the localized habitat and stressors are all very similar. In Scenario 1, the current level of representation would be maintained for 25 years, with the representation decreasing at 50 years when the population size is reduced. At 50 years, the upstream and downstream population segments are projected to be extirpated and the remaining population segment would be in 'Very Low' condition. Overall representation would decrease from current levels as the occupied range of the species decreases.

6.2.1.3 Redundancy

Salina Mucket has no redundancy, currently or into the future, as only one known extant population exists. Given the species is isolated from historically occupied areas by Lake Amistad and cannot recolonize naturally through travel of inoculated host fish, we do not project an increase in redundancy into the future. Further, no current or planned efforts are underway to propagate, translocate, or reintroduce the species to areas within its historical range.

6.2.2 Scenario 2 – Severe Effects

6.2.2.1 Resiliency

Rio Grande – Lower Canyons – In Scenario 2 (Severe Effects), we project the population would experience a severe reduction in streamflow due to groundwater extraction and drought as result of climate change, and management of the Rio Conchos would not provide sufficient surface flow rates to maintain the current population segments. Stream flow reductions would have large impacts to this population as the continued persistence of the species is driven largely by water availability. In the next decade, we expect water quantity and quality declines in the upstream segment of this population as the inflows from the Rio Conchos and associated Edwards-Trinity aquifer springs decline quickly. The population factors for the Salina Mucket would remain largely unchanged in the first decade. Conversely, the water quality and water quantity factors would decline to 'Low' condition as Rio Conchos surface flows and spring flows in the Rio Grande decline. This leads to increased sedimentation, elevated stream temperature, and lowered dissolved oxygen levels. The species remains in 'Low' condition overall 10 years from now under Scenario 2. However, 25 years into the future, we anticipate the effects of low water quality and quantity to further reduce the resiliency of this population where the species is less dense, the upstream and downstream segments. Additionally, the continued effects of degraded water quality and quantity likely exceed thermal tolerances for the species during drought, reducing already limited recruitment, which results in the upstream and downstream segments declining into 'Very Low' condition. Given the Salina Mucket has an average lifespan of about 9 years, we expect the population abundance to also degrade as older individuals die out of the population. The loss of older individuals, coupled with only low levels of reproduction, lead to greatly reduced abundance and recruitment in the upstream and downstream segments. The Salina Mucket declines to 'Very Low' condition but, maintains its currently known range extent 25 years into the future. Finally, at the 50-year time-step, we anticipate the upstream and downstream population segments, comprised of 61 rmi (98 rkm) and 50 rmi (80 rkm) respectfully, are extirpated. This reduces the current population length from 133 rmi (214 rkm) occupied to approximately 22 rmi (35 rkm) remaining. This accounts for a projected loss of 83% of the species current range. Extirpation is projected due to continued loss of water quantity and water quality from the Rio Conchos and springs in the area which degrades to a 'Very Low' condition. The upstream and downstream population segments are no longer of sufficient condition to maintain populations of Salina Mucket. Death of older individuals and severely limited recruitment would continue to reduce the resiliency and condition of the species overall. The Salina Mucket, 50 years into the future, is projected to be in 'Very Low' overall condition with a severely reduced range of only 22 rmi (35 rkm) of remaining occupied stream. See Table 6.2 for an overview of each population segment, and overall condition, at each future time-step. Figure 6.2 displays the Salina Mucket population conditions under each time-step of Scenario 2 across the species current and historical range.

The extirpated populations (Rio Grande near Laredo and Rio Salado basin (Mexico) (Table 6.2) would continue to decline in habitat factors under Scenario 2. The Salina Mucket has no natural ability to recolonize these areas given they are isolated from the current population (via host fish migration) by Lake Amistad, and no current or planned efforts to translocate or propagate the species exist. For the extirpated populations, given we had no current abundance or distributional data to demarcate population segments, we assigned conditions (using the six population and habitat factors) to the overall extirpated populations.

	Salina Mucket – Rio Grande Lower Canyons -- Scenario 2 Severe Effects								
			Population Factors			Habitat Factors			
	Population	**Stream Reach**	**Habitat Quantity**	**Abundance**	**Reproduction**	**Substrate**	**Flowing Water**	**Water Quality**	**Overall**
Current	**Rio Grande – Lower Canyons**	**Overall**	**High**	**Low**	**Low**	**Moderate**	**Moderate**	**Moderate**	**Low**
		Upstream		Low	Low	Moderate	Moderate	Low	
		Middle		Low	Low	Moderate	Moderate	Moderate	
		Downstream		Low	Low	Moderate	Moderate	Moderate	
	Rio Grande – Laredo	**Overall**	Extirpated	Extirpated	Extirpated	Moderate	Moderate	Moderate	Extirpated
	Rio Salado (Mexico)	**Overall**	Extirpated	Extirpated	Extirpated	Low	Low	Low	Extirpated
10 years	**Rio Grande – Lower Canyons**	**Overall**	**High**	**Low**	**Low**	**Moderate**	Low	Low	**Low**
		Upstream		Low	Low	Low	Low	Low	
		Middle		Low	Moderate	Moderate	Low	Low	
		Downstream		Low	Low	Moderate	Low	Low	
	Rio Grande – Laredo	**Overall**	Extirpated	Extirpated	Extirpated	Moderate	Moderate	Moderate	Extirpated
	Rio Salado (Mexico)	**Overall**	Extirpated	Extirpated	Extirpated	Low	Low	Low	Extirpated
25 years	**Rio Grande – Lower Canyons**	**Overall**	**High**	**Very Low**	**Very Low**	**Moderate**	**Low**	**Low**	**Very Low**
		Upstream		Very Low	Very Low	Low	Very Low	Very Low	
		Middle		Low	Low	Moderate	Low	Low	
		Downstream		Very Low	Very Low	Moderate	Low	Low	
	Rio Grande – Laredo	**Overall**	Extirpated	Extirpated	Extirpated	Moderate	Low	Low	Extirpated
	Rio Salado (Mexico)	**Overall**	Extirpated	Extirpated	Extirpated	Very Low	Very Low	Very Low	Extirpated
50 years	**Rio Grande – Lower Canyons**	**Overall**	**Moderate**	**Very Low**	**Very Low**	**Low**	**Low**	**Low**	**Very Low**
		Upstream		Extirpated	Extirpated	Low	Very Low	Very Low	
		Middle		Very Low	Very Low	Low	Low	Very Low	
		Downstream		Extirpated	Extirpated	Low	Low	Low	
	Rio Grande – Laredo	**Overall**	Extirpated	Extirpated	Extirpated	Low	Low	Low	Extirpated
	Rio Salado (Mexico)	**Overall**	Extirpated	Extirpated	Extirpated	Very Low	Very Low	Very Low	Extirpated

Table 6.2 Salina Mucket population resiliency for the Rio Grande - Lower Canyons population under Scenario 2 – Severe Effects. Individual population status currently and 10, 25, and 50 years into the future.

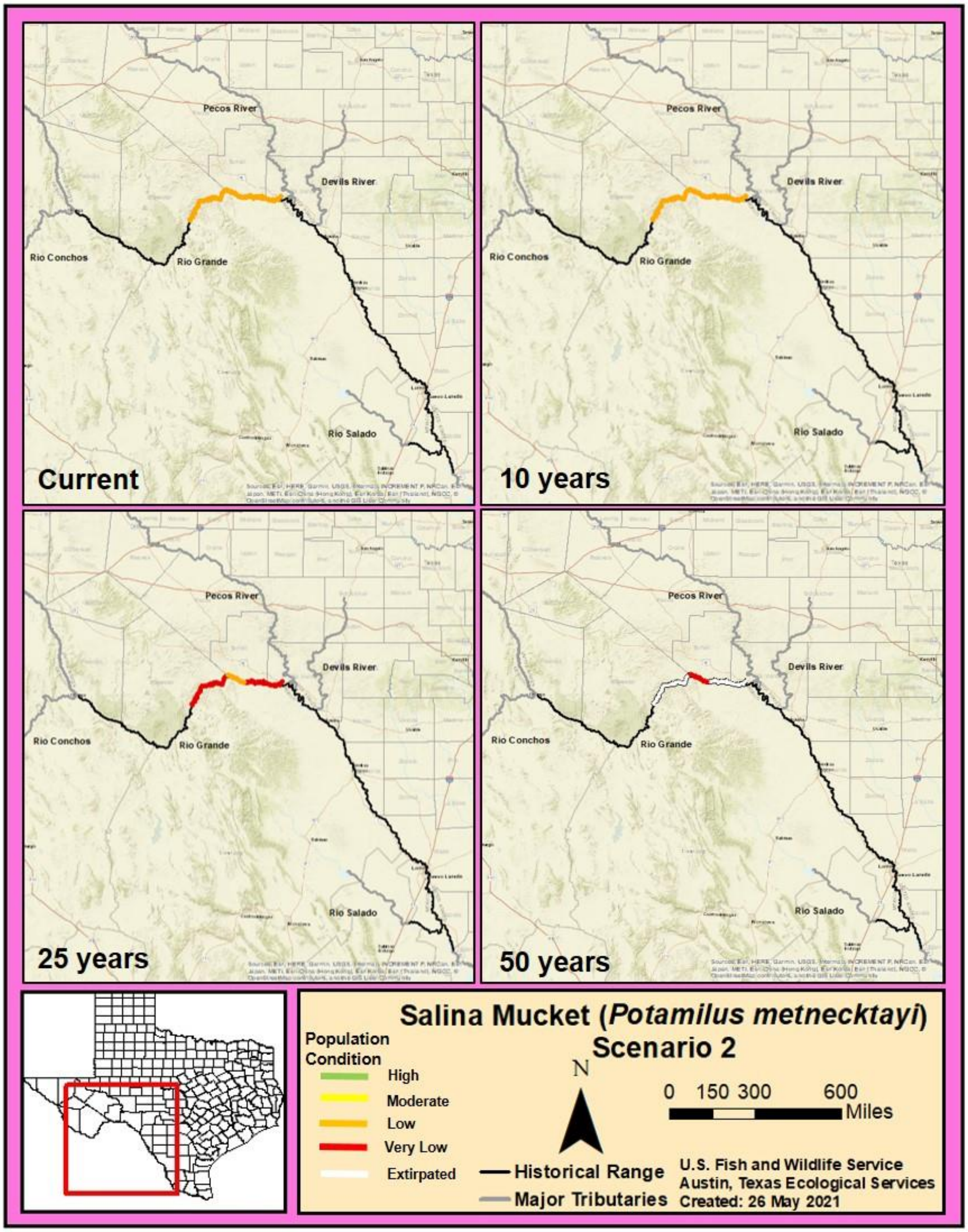

Figure 6.2 Salina Mucket population condition under Scenario 2 – Severe Effects. Population condition, show by population segment, currently and 10, 25, and 50 years into the future.

6.2.2.2 Representation

As identified previously (Chapter 4.2.3), we consider the Salina Mucket to have representation in the form of genetic diversity in only one area: the Rio Grande – Lower Canyons. do not expect any significant variation within this population as the localized habitat and stressors are all very similar. In Scenario 2, the current level of representation would be maintained for 25 years, with the representation decreasing at 50 years when the population size is reduced by over 80%. At 50 years, the upstream and downstream population segments are projected to be extirpated, and the remaining population segment would be in 'Very Low' condition. Overall representation would decrease from current levels as the occupied range of the species decreases.

6.2.2.3 Redundancy

The Salina Mucket has no redundancy currently or into the future as only one known extant population exists. Given the species is isolated from historically occupied areas by Lake Amistad and cannot recolonize naturally through travel of inoculated host fish, we do not project an increase in redundancy into the future. Further, no current or planned efforts are underway to propagate, translocate, or reintroduce the species to areas within its historical range.

6.3 Mexican Fawnsfoot

For the Mexican Fawnsfoot, we projected the species future condition under two Scenarios, Scenario 1 (Continuation/Moderate Effects) and Scenario 2 (Severe Effects) (see section 6.1.1). However, for Scenario 2 (Severe Effects) we split the Scenario into two plausible options, Scenario 2A and 2B. This is unique to Mexican Fawnsfoot as a proposed weir in the upstream vicinity of Laredo would impact the remaining Mexican Fawnsfoot population. Under Scenario 2A, the weir is not constructed but under Scenario 2B, the weir is constructed 25 years into the future.

6.3.1 Scenario 1 – Continuation/Moderate Effects

6.3.1.1 Resiliency

Rio Grande – Laredo – In Scenario 1 (Continuation/Moderate Effects), the low water weir is not constructed. However, we project water flow would marginally decline due to upstream water management (managed releases from Lake Amistad) and drought due to climate change. This declining stream flow would decrease water quality, increase sedimentation, and therefore reduce population abundance. Human population growth in the Rio Grande near Laredo would contribute to additional water withdrawals for municipal and industrial uses as well as increased discharges into the river from waste treatment plants. Overall, the current population would remain in similar condition for the next 10 years. The middle population segment is projected to decline in reproduction from 'Moderate' condition to 'Low' as older individuals die-off, and remaining individuals have lowered recruitment success. The Mexican Fawnsfoot would remain at an overall 'Low' condition.

At 25 years into the future, the combined effects of climate change, water withdrawals, drought, and declining habitat take an increased toll on Mexican Fawnsfoot's resilience. Under this scenario, we project all reproduction of the species declines to 'Very Low' condition. Sedimentation and declining water quality and quantity would continue to impact the two downstream population segments, and the habitat factors there would also decline from 'Moderate' to 'Low' condition. The middle population segment would continue to have a 'Low' number of individuals reported, but the rest of the species range is nearly extirpated, with only isolated individuals remaining. This contributes to the species overall condition declining to 'Very Low' at the 25-year time-step.

Finally, at 50 years into the future, the combined effects of ongoing stressors coupled with the die-off of the limited individuals remaining results in the likely extinction of the Mexican Fawnsfoot. Given the degraded condition of the population and limited recruitment, the species would be unable to maintain itself past 50 years in the future. Any living individuals that may persist past the 50-year time-step would be solitary individuals with no reproductive output and would eventually die-off due to natural or anthropogenic causes. We would not consider these solitary individuals as a functioning population, and for these reasons anticipate the species will be extinct at this time-step. See Table 6.3 for an overview of each population segment, and overall condition, at each future time-step. Figure 6.3 displays the Mexican Fawnsfoot population conditions under each time-step of Scenario 1 across the species current and historical range.

The extirpated populations (Rio Grande near Laredo and Rio Salado basin (Mexico) (Table 6.2) would continue to decline in habitat factors under Scenario 2. The Salina Mucket has no natural ability to recolonize these areas given they are isolated from the current population (via host fish migration) by Lake Amistad, and no current or planned efforts to translocate or propagate the species exist. For the extirpated populations, given we had no current abundance or distributional data to demarcate population segments, we assigned conditions (using the six population and habitat factors) to the overall extirpated populations.

	Mexican Fawnsfoot – Rio Grande Laredo – Scenario 1 Continuation/Moderate Effects								
			Population Factors			Habitat Factors			
	Population	**Stream Reach**	**Habitat Quantity**	**Abundance**	**Reproduction**	**Substrate**	**Flowing Water**	**Water Quality**	**Overall**
Current	**Rio Grande – Laredo**	**Overall**	**High**	**Very Low**	**Low**	**Moderate**	**Moderate**	**Moderate**	**Low**
		Upstream		Very Low	Low	Moderate	Moderate	Moderate	
		Middle		Low	Moderate	Moderate	Moderate	Moderate	
		Downstream		Very Low	Low	Moderate	Moderate	Moderate	
	Rio Grande – above Lake Amistad	**Overall**	Extirpated	Extirpated	Extirpated	Very Low	Very Low	Moderate	Extirpated
	Rio Salado (Mexico)	**Overall**	Extirpated	Extirpated	Extirpated	Very Low	Very Low	Very Low	Extirpated
10 years	**Rio Grande – Laredo**	**Overall**	**High**	**Very Low**	**Low**	**Moderate**	**Moderate**	**Moderate**	**Low**
		Upstream		Very Low	Low	Moderate	Moderate	Moderate	
		Middle		Low	Low	Moderate	Moderate	Moderate	
		Downstream		Very Low	Low	Moderate	Moderate	Low	
	Rio Grande – above Lake Amistad	**Overall**	Extirpated	Extirpated	Extirpated	Very Low	Very Low	Moderate	Extirpated
	Rio Salado (Mexico)	**Overall**	Extirpated	Extirpated	Extirpated	Very Low	Very Low	Very Low	Extirpated
25 years	**Rio Grande – Laredo**	**Overall**	**High**	**Very Low**	**Very Low**	**Moderate**	**Moderate**	**Moderate**	**Very Low**
		Upstream		Very Low	Very Low	Moderate	Moderate	Moderate	
		Middle		Low	Very Low	Low	Low	Low	
		Downstream		Very Low	Very Low	Low	Low	Low	
	Rio Grande – above Lake Amistad	**Overall**	Extirpated	Extirpated	Extirpated	Very Low	Very Low	Moderate	Extirpated
	Rio Salado (Mexico)	**Overall**	Extirpated	Extirpated	Extirpated	Very Low	Very Low	Very Low	Extirpated
50 years	**Rio Grande – Laredo**	**Overall**	Extirpated	Extirpated	Extirpated	**Low**	**Low**	**Low**	**Extirpated**
		Upstream		Extirpated	Extirpated	Moderate	Moderate	Moderate	
		Middle		Extirpated	Extirpated	Low	Low	Low	
		Downstream		Extirpated	Extirpated	Low	Low	Low	
	Rio Grande – above Lake Amistad	**Overall**	Extirpated	Extirpated	Extirpated	Very Low	Very Low	Moderate	Extirpated
	Rio Salado (Mexico)	**Overall**	Extirpated	Extirpated	Extirpated	Very Low	Very Low	Very Low	Extirpated

Table 6.3 Mexican Fawnsfoot population resiliency for the Rio Grande – Laredo population under Scenario 1 – Continuation/Moderate. Individual population status currently and 10, 25, and 50 years into the future.

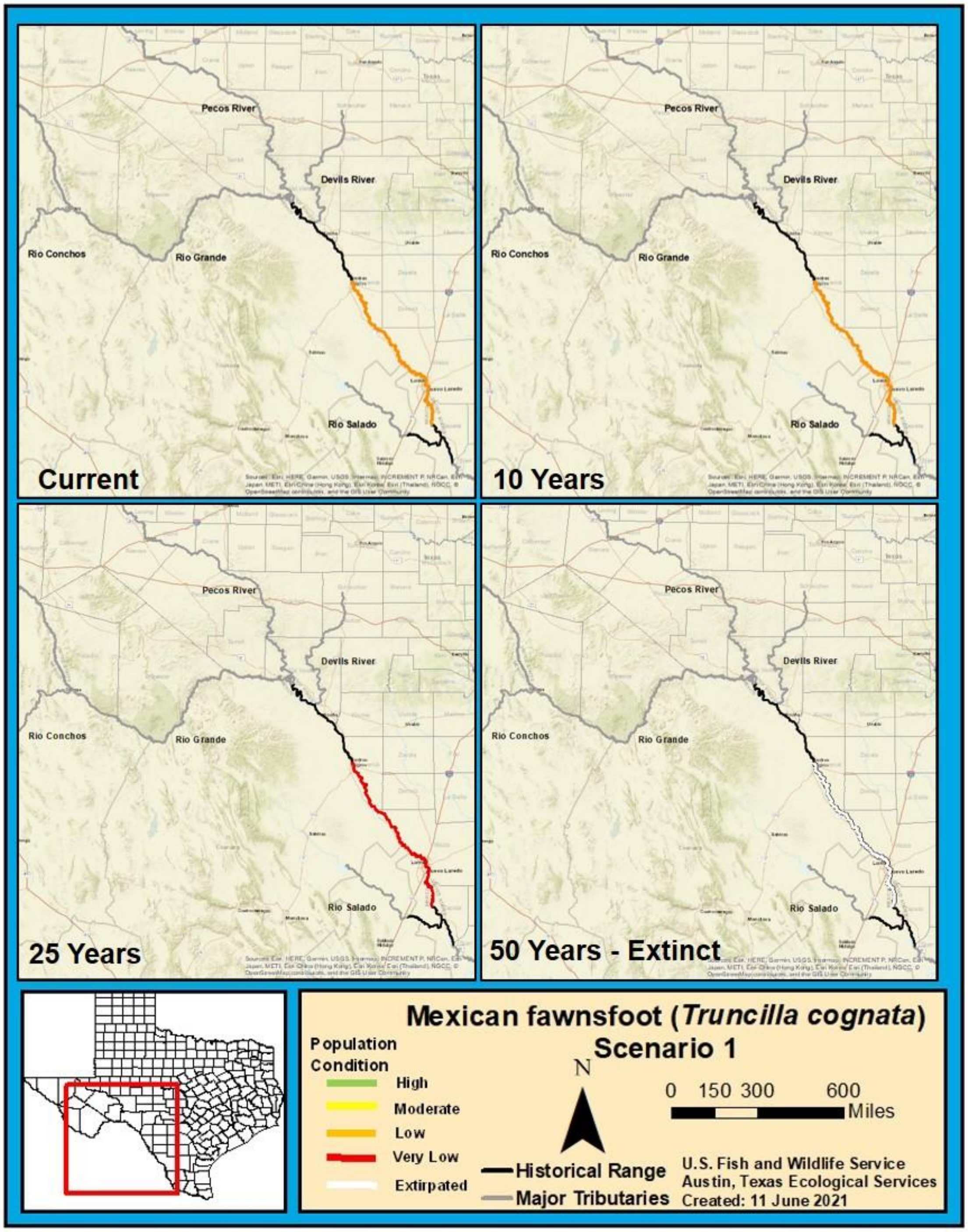

Figure 6.3 Mexican Fawnsfoot population condition under Scenario 1 – Continuation/Moderate Effects. Population condition, shown by population segment, currently and 10, 25, and 50 years into the future.

6.3.1.2 Representation

As identified previously (Chapter 4.3.3), we consider the Mexican Fawnsfoot to have representation in the form of genetic diversity in only one area: the Rio Grande - Laredo. We do not expect any significant variation within this population as the localized habitat and stressors are all very similar. In Scenario 1 (Continuation/Moderate Effects), the current level of representation would be maintained for 25 years, with the representation decreasing at 50 years when the population size is reduced. At 50 years, the species would lose its remaining representation when the last remaining population is likely extinct.

6.3.1.3 Redundancy

The Mexican Fawnsfoot has no redundancy currently or into the future as only one known extant population exists. Given the species is isolated from historically occupied areas by Lake Amistad and Falcon Lake and cannot recolonize naturally through travel of inoculated host fish, we do not project an increase in redundancy into the future. Further, no current or planned efforts are underway to propagate, translocate, or reintroduce the species to areas within its historical range. We project the species will likely be extinct in 50 years and as such, would have no redundancy.

6.3.2 Scenario 2A – Severe Effects (no weir)

6.3.2.1 Resiliency

Rio Grande – Laredo – In Scenario 2A (Severe Effects, no weir), the low water weir in the upstream vicinity of Laredo would not be constructed. However, water flow would experience a moderate to large reduction due to upstream water management (managed releases from Lake Amistad), drought due to climate change, withdrawals, and diversions. As flows from upstream in the basin are likewise diminished, the baseflow in the Laredo reach of the Rio Grande would diminish as less water is available overall. These flow declines would lead to high levels of sedimentation and decreased water quality. Moreover, given the Mexican Fawnsfoot's primary utilization of riffle habitats (topographic high points in streams), the species' habitat will likely be impacted before the river ceases to flow. We expect more frequent and severe desiccation of mussel beds containing Mexican Fawnsfoot to occur, which results in animals being severely stressed or desiccated and killed. Human population growth in the Rio Grande near Laredo would lead to additional water withdrawals for municipal and industrial uses, as well as increased discharges into the river from waste treatment plants. Overall, the current population would remain in similar condition for the next 10 years. The middle segment population is projected to decline in reproduction from 'Moderate' to 'Low' condition. This is a result of mussels succumbing to desiccation, and older individuals die-off, and the remaining population exhibiting lowered recruitment success. The Mexican Fawnsfoot would remain at an overall of 'Low' condition.

At 25 years into the future, we project the combined effects of climate change, water withdrawals, drought, and declining habitat would take increased toll on Mexican Fawnsfoot's resilience. Under this scenario, all reproduction of the species would degrade to 'Very Low' condition, which indicates a non-reproductively viable population that is persisting through the lifespan of current individuals. Sedimentation and declining water quality and quantity would continue to impact the two downstream population segments, and habitat factors in these segments would decline from 'Moderate' to 'Low' condition. The middle population segment would continue to have a 'Low' number of individuals, but the rest of the species range would be nearly extirpated, with only isolated individuals remaining. This would contribute to the species overall condition declining to 'Very Low' at the 25-year time-step.

Finally, at 50 years into the future, we project the combined effects of severe stressors coupled with the die-off of the limited individuals remaining would likely result in the species becoming extinct. If individuals were to persist past 50 years, they would be isolated, solitary individuals unable to reproduce and would not constitute a population. These individuals would die-off from natural and/or anthropogenic changes. Therefore, we consider the species would be extinct at this time-step. See Table 6.4 for an overview of each population segment and overall condition at each future time-step. Figure 6.4 displays the Mexican Fawnsfoot population conditions under each time-step of Scenario 2A (no weir) across the species current and historical range.

Extirpated populations (Rio Grande above Lake Amistad and Rio Salado basin (Mexico) (Table 6.4) would continue to decline in habitat factors under Scenario 2A. The Mexican Fawnsfoot has no natural ability to recolonize these areas given they are isolated from the current population (limited host fish migration) by Lake Amistad and Falcon Lake, and no current or future planned efforts to translocate or propagate the species exist. For the extirpated populations, given we had no current abundance or distributional data to demarcate population segments, we assigned conditions (using the six population and habitat factors) to the overall extirpated populations.

	Mexican Fawnsfoot – Rio Grande Laredo – Scenario 2A (no weir) Severe Effects								
			Population Factors			Habitat Factors			
	Population	**Stream Reach**	**Habitat Quantity**	**Abundance**	**Reproduction**	**Substrate**	**Flowing Water**	**Water Quality**	**Overall**
Current	**Rio Grande – Laredo**	**Overall**	**High**	**Very Low**	**Low**	**Moderate**	**Moderate**	**Moderate**	**Low**
		Upstream		Very Low	Low	Moderate	Moderate	Moderate	
		Middle		Low	Moderate	Moderate	Moderate	Moderate	
		Downstream		Very Low	Low	Moderate	Moderate	Moderate	
	Rio Grande – above Lake Amistad	**Overall**	Extirpated	Extirpated	Extirpated	Very Low	Very Low	Moderate	Extirpated
	Rio Salado (Mexico)	**Overall**	Extirpated	Extirpated	Extirpated	Very Low	Very Low	Very Low	Extirpated
10 years	**Rio Grande – Laredo**	**Overall**	**High**	**Very Low**	**Low**	**Moderate**	**Moderate**	**Moderate**	**Low**
		Upstream		Very Low	Low	Moderate	Moderate	Moderate	
		Middle		Low	Low	Moderate	Moderate	Moderate	
		Downstream		Very Low	Low	Moderate	Moderate	Moderate	
	Rio Grande – above Lake Amistad	**Overall**	Extirpated	Extirpated	Extirpated	Very Low	Very Low	Moderate	Extirpated
	Rio Salado (Mexico)	**Overall**	Extirpated	Extirpated	Extirpated	Very Low	Very Low	Very Low	Extirpated
25 years	**Rio Grande – Laredo**	**Overall**	**High**	**Very Low**	**Very Low**	**Low**	**Low**	**Low**	**Very Low**
		Upstream		Very Low	Very Low	Moderate	Moderate	Moderate	
		Middle		Low	Very Low	Low	Low	Low	
		Downstream		Very Low	Very Low	Low	Low	Low	
	Rio Grande – above Lake Amistad	**Overall**	Extirpated	Extirpated	Extirpated	Very Low	Very Low	Moderate	Extirpated
	Rio Salado (Mexico)	**Overall**	Extirpated	Extirpated	Extirpated	Very Low	Very Low	Very Low	Extirpated
50 years	**Rio Grande – Laredo**	**Overall**	Extirpated	Extirpated	Extirpated	**Low**	**Low**	**Low**	**Extirpated**
		Upstream		Extirpated	Extirpated	Moderate	Moderate	Moderate	
		Middle		Extirpated	Extirpated	Low	Low	Low	
		Downstream		Extirpated	Extirpated	Low	Low	Low	
	Rio Grande – above Lake Amistad	**Overall**	Extirpated	Extirpated	Extirpated	Very Low	Very Low	Moderate	Extirpated
	Rio Salado (Mexico)	**Overall**	Extirpated	Extirpated	Extirpated	Very Low	Very Low	Very Low	Extirpated

Table 6.4 Mexican Fawnsfoot population resiliency for the Rio Grande – Laredo population under Scenario 2A – Severe Effects. Individual population status currently and 10, 25, and 50 years into the future.

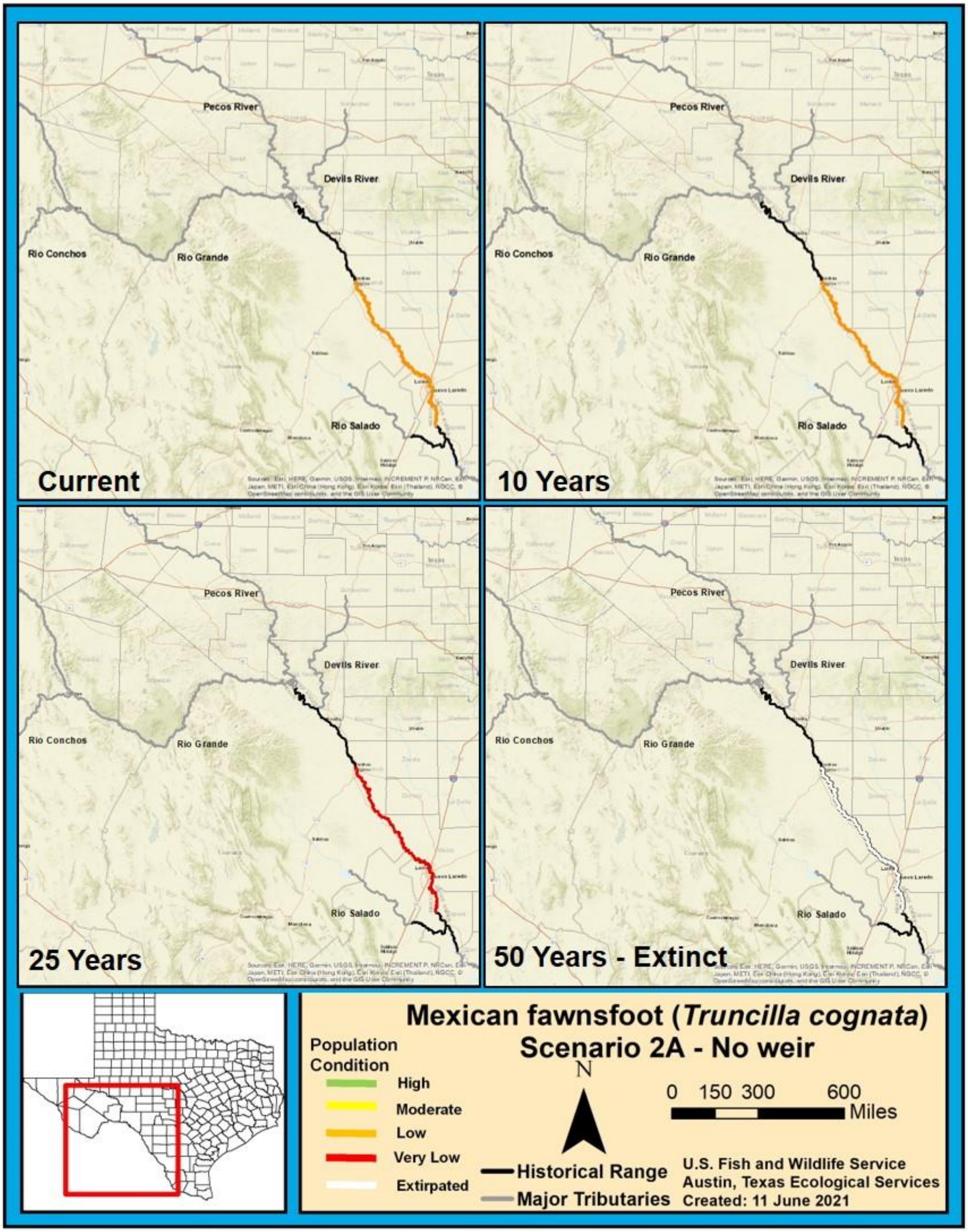

Figure 6.4 Mexican Fawnsfoot population condition under Scenario 2A – Severe Effects. Population condition, shown by population segment, currently and 10, 25, and 50 years into the future.

6.3.2.2 Representation

As identified previously (Chapter 4.3.3), we consider the Mexican Fawnsfoot to have representation in the form of genetic diversity in only one area: the Rio Grande - Laredo. We do not expect any significant variation within this population as the localized habitat and stressors are all very similar. In Scenario 2A (Severe Effects), the current level of representation is maintained for 25 years, with the representation expected to decrease at 50 years when the population is eliminated. At 50 years, the species would lose its remaining representation when the last remaining population becomes extinct.

6.3.2.3 Redundancy

The Mexican Fawnsfoot has no redundancy currently or into the future as only one known extant population exists. Given the species is isolated from historically occupied areas by Lake Amistad and Falcon Lake and cannot recolonize naturally through travel of inoculated host fish, we do not project an increase in redundancy into the future. Further, no current or planned efforts are underway to propagate, translocate, or reintroduce the species to areas within its historical range. We project the species will likely be extinct in 50 years and as such, would have no redundancy.

6.3.3 Scenario 2B – Severe Effects (weir constructed)

6.3.3.1 Resiliency

Rio Grande – Laredo – In Scenario 2B (Severe Effects, weir constructed), we project the low-water weir is constructed near the City of Laredo at the 25-year time-step. This proposed weir would be placed just upstream of the Nuevo-Laredo International Bridge (World Trade Bridge) upstream of Laredo, Texas. This location is approximately in the center of the middle population segment of Mexican Fawnsfoot, which is the most dense and well populated portion of the species known range. The proposed weir would eliminate approximately 7% (14 rmi or 22 rkm) of currently occupied habitat (Rio Grande Regional Water Planning Group 2010, p. 4-74). We project the species condition in the upstream and downstream population segments to be very similar to Scenario 2A, as the weir construction primarily influences the middle population segment. Similarly, overall water flow would experience a moderate to large reduction due to upstream water management (managed releases from Lake Amistad), drought due to climate change, and withdrawals and diversions. These flow declines would lead to high levels of sedimentation and decreased water quality. Moreover, given the Mexican Fawnsfoot primarily utilizes riffle habitats (topographic high points in streams), the species habitat would likely be impacted before the river ceases to flow. We expect more frequent and severe desiccation of mussel beds containing Mexican Fawnsfoot to occur. Human population growth in the Rio Grande near Laredo would contribute to additional water withdrawals for municipal and industrial uses as well as increased discharges into the river from waste treatment plants. Overall, the current population would remain in similar condition for the next 10 years. The middle population segment is projected to decline in reproduction from ‘Moderate’ to ‘Low’ condition, as older individuals die-off and remaining individuals provide lowered recruitment success. The Mexican Fawnsfoot would remain at an overall ‘Low’ condition.

At 25 years, the weir would be completed, and we project that the inundated area results in the loss of approximately 14 river miles of habitat in the middle population segment as the species cannot tolerate impoundments. The hydrological alteration of the river would lead to severe changes in flow rate, sedimentation, and scour downstream of the weir, which we project leads to additional losses of instream habitat and mussels. The weir construction is expected to lead to the extirpation of the middle population segment, which is the largest, densest segment of known Mexican Fawnsfoot. Additionally, in the upstream and downstream segments, all reproduction of the species would degrade to a 'Very Low' condition, which indicates a non-reproductively viable population that is persisting through the lifespan of current individuals. These population segments would further be isolated from one another by the newly constructed weir dam. Sedimentation and declining water quality and quantity would continue to impact the two downstream population segments and the habitat factors there would also decline from 'Moderate' to 'Low' condition. In summary, at the 25-year time step, the middle population segment is expected to be extirpated, and the upstream and downstream populations would remain in 'Very Low' condition. This accounts for a range reduction of 18% or loss of 33 rmi (53 rkm) and the densest known remaining Mexican Fawnsfoot beds.

Finally, at 50 years into the future, we project that the combined effects of the severe stressors, weir construction, and die-off of the limited individuals remaining will result in the species becoming extinct. If any individuals were to persist past 50 years, they would be isolated, solitary individuals that are unable to reproduce and would not constitute a population. These individuals would die-off from a combination of natural and anthropogenic changes; therefore, we consider the species to be extinct at this time-step. See Table 6.5 for an overview of each population segment, and overall condition, at each future time-step. Figure 6.5 displays the Mexican Fawnsfoot population conditions under each time-step of Scenario 1 across the species current and historical range.

The extirpated populations (Rio Grande above Lake Amistad and Rio Salado basin, Mexico) (Table 6.5) would continue to decline in habitat factors under Scenario 2B. The Mexican Fawnsfoot has no natural ability to recolonize these areas given they are isolated from the current population (limited host fish migration) by Lake Amistad and Falcon Lake, and no current or planned efforts to translocate or propagate the species exist. For the extirpated populations, given we had no current abundance or distributional data to demarcate population segments, we assigned conditions (using the six population and habitat factors) to the overall extirpated populations.

	Mexican Fawnsfoot – Rio Grande Laredo – Scenario 2B (weir) Severe Effects								
			Population Factors			Habitat Factors			
	Population	**Stream Reach**	**Habitat Quantity**	**Abundance**	**Reproduction**	**Substrate**	**Flowing Water**	**Water Quality**	**Overall**
Current	**Rio Grande – Laredo**	**Overall**	**High**	**Very Low**	**Low**	**Moderate**	**Moderate**	**Moderate**	**Low**
		Upstream		Very Low	Low	Moderate	Moderate	Moderate	
		Middle		Low	Moderate	Moderate	Moderate	Moderate	
		Downstream		Very Low	Low	Moderate	Moderate	Moderate	
	Rio Grande – above Lake Amistad	**Overall**	Extirpated	Extirpated	Extirpated	Very Low	Very Low	Moderate	Extirpated
	Rio Salado (Mexico)	**Overall**	Extirpated	Extirpated	Extirpated	Very Low	Very Low	Very Low	Extirpated
10 years	**Rio Grande – Laredo**	**Overall**	**High**	**Very Low**	**Low**	**Moderate**	**Moderate**	**Moderate**	**Low**
		Upstream		Very Low	Low	Moderate	Moderate	Moderate	
		Middle		Low	Low	Moderate	Moderate	Moderate	
		Downstream		Very Low	Low	Moderate	Moderate	Moderate	
	Rio Grande – above Lake Amistad	**Overall**	Extirpated	Extirpated	Extirpated	Very Low	Very Low	Moderate	Extirpated
	Rio Salado (Mexico)	**Overall**	Extirpated	Extirpated	Extirpated	Very Low	Very Low	Very Low	Extirpated
25 years	**Rio Grande – Laredo**	**Overall**	**High**	**Very Low**	**Very Low**	**Low**	**Low**	**Moderate**	**Very Low**
		Upstream		Very Low	Very Low	Moderate	Moderate	Moderate	
		Middle		Extirpated	Extirpated	Very Low	Very Low	Moderate	
		Downstream		Very Low	Very Low	Low	Low	Low	
	Rio Grande – above Lake Amistad	**Overall**	Extirpated	Extirpated	Extirpated	Very Low	Very Low	Moderate	Extirpated
	Rio Salado (Mexico)	**Overall**	Extirpated	Extirpated	Extirpated	Very Low	Very Low	Very Low	Extirpated
50 years	**Rio Grande – Laredo**	**Overall**	Extirpated	Extirpated	Extirpated	**Low**	**Low**	**Moderate**	**Extirpated**
		Upstream		Extirpated	Extirpated	Moderate	Moderate	Moderate	
		Middle		Extirpated	Extirpated	Very Low	Very Low	Moderate	
		Downstream		Extirpated	Extirpated	Low	Low	Low	
	Rio Grande – above Lake Amistad	**Overall**	Extirpated	Extirpated	Extirpated	Very Low	Very Low	Moderate	Extirpated
	Rio Salado (Mexico)	**Overall**	Extirpated	Extirpated	Extirpated	Very Low	Very Low	Very Low	Extirpated

Table 6.5 Mexican Fawnsfoot population resiliency for the Rio Grande – Laredo population under Scenario 2B (weir) – Severe Effects. Individual population status currently and 10, 25, and 50 years into the future.

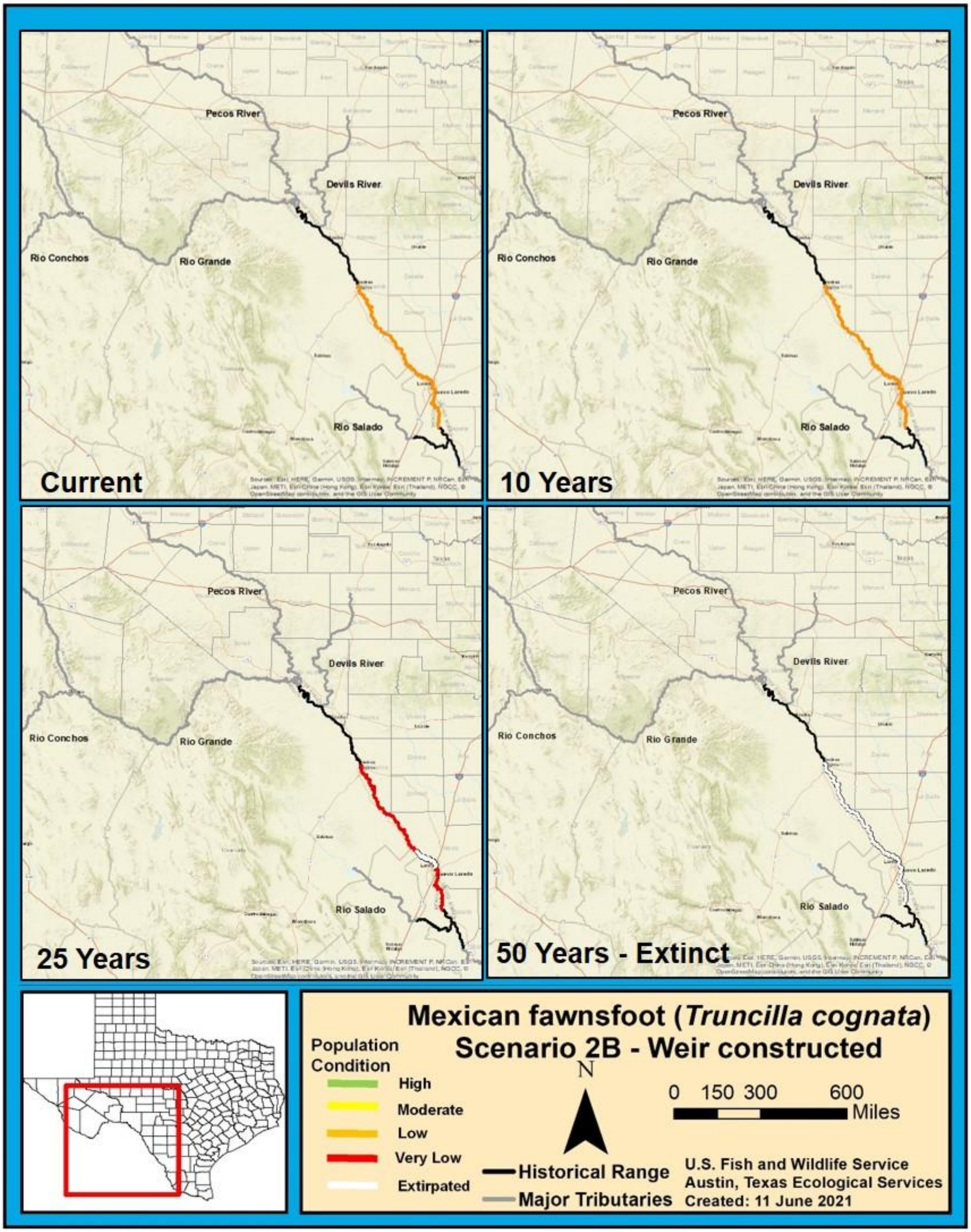

Figure 6.4 Mexican Fawnsfoot population condition under Scenario 2B (weir) – Severe Effects. Population condition, shown by population segment, currently and 10, 25, and 50 years into the future.

6.3.3.2 Representation

As identified above (Chapter 4.3.3), we consider the Mexican Fawnsfoot to have representation in the form of genetic diversity in only one area: the Rio Grande - Laredo. We do not expect any significant variation within this population as the localized habitat and stressors are all very similar. In Scenario 2B (Severe Effects), the current level of representation would be maintained for 10 years with the representation decreasing at 25 years when the middle population segment is extirpated due to weir construction. At 50 years, the species would lose its remaining representation when the last population segments become extinct.

6.3.3.3 Redundancy

The Mexican Fawnsfoot has no redundancy currently or into the future as only one known extant population exists. Given the species is isolated from historically occupied areas by Lake Amistad and Falcon Lake and cannot recolonize naturally through travel of infested host fish, we do not project an increase in redundancy into the future. Further, no current or planned efforts are underway to propagate, translocate, or reintroduce the species to areas within its historical range. We project the species will likely be extinct in 50 years and as such, would have no redundancy.

6.4 Status Assessment Summary

We used the best available scientific information to forecast the likely future condition of the two Rio Grande mussels, Salina Mucket and Mexican Fawnsfoot. The goal of this report is to describe the viability of these species in terms of resiliency, representation, and redundancy. We considered a range of potential future scenarios that we think are important influences on the status of the species. The results of this analysis described the range of possible future scenarios the Rio Grande mussels are likely to experience.

The Rio Grande mussels face a variety of risks from loss of stream flow, sedimentation, water quality decline, and inundation across their range in the Rio Grande. These risks, when compounded, play a significant role in the future viability of both species. If populations lose resiliency, they are more vulnerable to extirpation, with resulting losses in representation and redundancy. Haag (2012, p. 396) stated "The chances for long-term survival of many small, isolated populations should be considered tenuous at best, regardless of life history traits or other species attributes".

Under Scenario 1 – Continuation/Moderate Effects, we would expect the Salina Mucket and Mexican Fawnsfoot to face a variety of ongoing stressors (e.g. altered hydrology, decreased water quality and quantity, reduced recruitment, and die-off of older individuals) that continue to degrade and reduce their already limited populations. As such, 50 years into the future, we anticipate the Salina Mucket to be reduced to a very limited population size (approximately 22 rmi (35 rkm)) with an extremely high risk of extirpation and anticipate the Mexican Fawnsfoot to be extinct at or near 50 years into the future.

Under Scenario 2 – Severe Effects, we expect the stressors and risks to the Rio Grande mussels to become severe in a shorter time span. Under Scenario 1, we anticipate the Salina Mucket will only persist as solitary and isolated individuals scattered across the middle population segment, which, puts the species at incredibly high risk of extirpation. For the Mexican Fawnsfoot, we projected two versions of this scenario where a low-water weir is not or is constructed within the densest Mexican Fawnsfoot population segment. The effects of altered hydrology, climate change, drought, and human growth in the region far outpace the ability of the species to adapt and persist. For the Mexican Fawnsfoot, we project the species will be extinct under both options (i.e. weir or no weir) 50 years into the future. The weir construction likely accelerates extinction of this species by inundating the best remaining mussel beds.

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