U.S. Fish and Wildlife Service

Draft Recovery Plan for
Texas Hornshell
(*Popenaias popeii*)

Photo: USFWS, Charrish Stevens

Prepared by:

Charrish Stevens
U.S. Fish and Wildlife Service
Texas Coastal Ecological Service Field Office
Houston, Texas

For:

Southwest Region (Interior Region 6)
U.S. Fish and Wildlife Service
Albuquerque, New Mexico

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Disclaimer

The Endangered Species Act of 1973 (Act), as amended (16 U.S.C. 1531 et seq.), requires the development of recovery plans for listed species, unless such a plan would not promote the conservation of a particular species. In accordance with section 4(f)(1) of the Act and to the maximum extent practicable, recovery plans delineate such reasonable actions as may be necessary, based upon the best scientific and commercial data available, for the conservation and survival of listed species. Plans are published by the USFWS, and are sometimes prepared with the assistance of recovery teams, contractors, State agencies and others. Recovery plans do not necessarily represent the views, official positions, or approval of any individuals or agencies involved in the plan formulation, other than USFWS. They represent the official position of the USFWS only after they have been signed by the Regional Director (USFWS). Recovery plans are guidance and planning documents only; identification of an action to be implemented by any public or private party does not create a legal obligation beyond existing legal requirements. Nothing in this plan should be construed as a commitment or requirement that any Federal agency obligate or pay funds in any one fiscal year in excess of appropriations made by Congress for that fiscal year in contravention of the Anti-Deficiency Act, 31 U.S.C. 1341, or any other law or regulation. Approved recovery plans are subject to modification as dictated by new findings, changes in species status, and the completion of recovery actions.

Copies of all documents reviewed in development of this plan are available in the administrative record, located at the USFWS Texas Coastal Ecological Services Field Office, Houston, Texas. In addition, updates or revisions to the recovery plan will be available at the website below.

Recommended Citation and Availability

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An electronic copy of this recovery plan is available for free at:
https://ecos.fws.gov/ecp0/profile/speciesProfile?spcode=F02M

Hard copies of the recovery plan can also be requested from:

U.S. Fish and Wildlife Service
Texas Coastal Ecological Services Field Office
17629 El Camino Real, Suite 211
Houston, Texas 77058

Or

U.S. Fish and Wildlife Service
New Mexico Ecological Services Field Office
2105 Osuna Road NE
Albuquerque, New Mexico 87113

Approved: _______DRAFT____
Regional Director, Southwest Region, U.S. Fish and Wildlife Service

Date: ____

Introduction

On February 9, 2018, the USFWS listed Texas hornshell (THS) as an endangered species under the Endangered Species Act of 1973, as amended (16 U.S.C. 1531 et seq) (Act) (83 FR 5720 5735). A Species Status Assessment (SSA) report for Texas hornshell (USFWS 2018b, entire) was developed that thoroughly reviewed the species' taxonomy, natural history, habitats, ecology, populations, and range. The Texas hornshell SSA report is available by visiting: https://ecos.fws.gov/ServCat/DownloadFile/161479. The SSA report analyzes individual, population, and species requirements, factors affecting the species' survival, and current conditions to assess the species' current and future viability in terms of resilience, redundancy, and representation.

This streamlined Recovery Plan is derived from the SSA report and focuses primarily on the elements required under section 4(f)(1)(B) of the Act, which include:

(i) A description of such site-specific management actions as may be necessary to achieve the plan's goal for the conservation and survival of the species;

(ii) objective, measurable criteria which, when met, would result in a determination, in accordance with the provisions of this section, that the species be removed from the list; and

(iii) estimates of the time required and the cost to carry out those measures needed to achieve the plan's goal and to achieve intermediate steps toward that goal.

In cooperation with our partners, we have also prepared a Recovery Implementation Strategy (RIS), which serves as an operational plan for stepping down the higher-level recovery actions into specific tasks. Separate from the Recovery Plan, an RIS can be modified if monitoring reveals that expected results are not being achieved, consequently maximizing flexibility of recovery implementation.

Overview

The following is a brief overview of the natural history and status of the THS. Please refer to the SSA report (USFWS 2018b) for a full discussion and complete literature review with references cited.

The THS is a medium sized freshwater mussel that is native to the Rio Grande drainage in Texas, New Mexico, and Mexico (See Figure 1). Adult and juvenile THS occur in medium to large rivers, generally in crevices, undercuts, riverbanks, travertine shelves, and under large boulders that contain suitable amounts of small-grained substrate, such as clay, silt, and/or sand. THS in the Devils River population are typically found in gravel beds at the head of riffles and rapids. Appropriate THS habitats provide refuge from high flows associated with large flood events, a common occurrence in the historical range of the species (See Figure 1). Freshwater mussels, including THS, have a complex life history that requires the use of the water column and host fish for successful reproduction and metamorphosis into juvenile mussels. The life span of a typical THS is unknown, but assumed to be 15 or more years (USFWS 2018a).

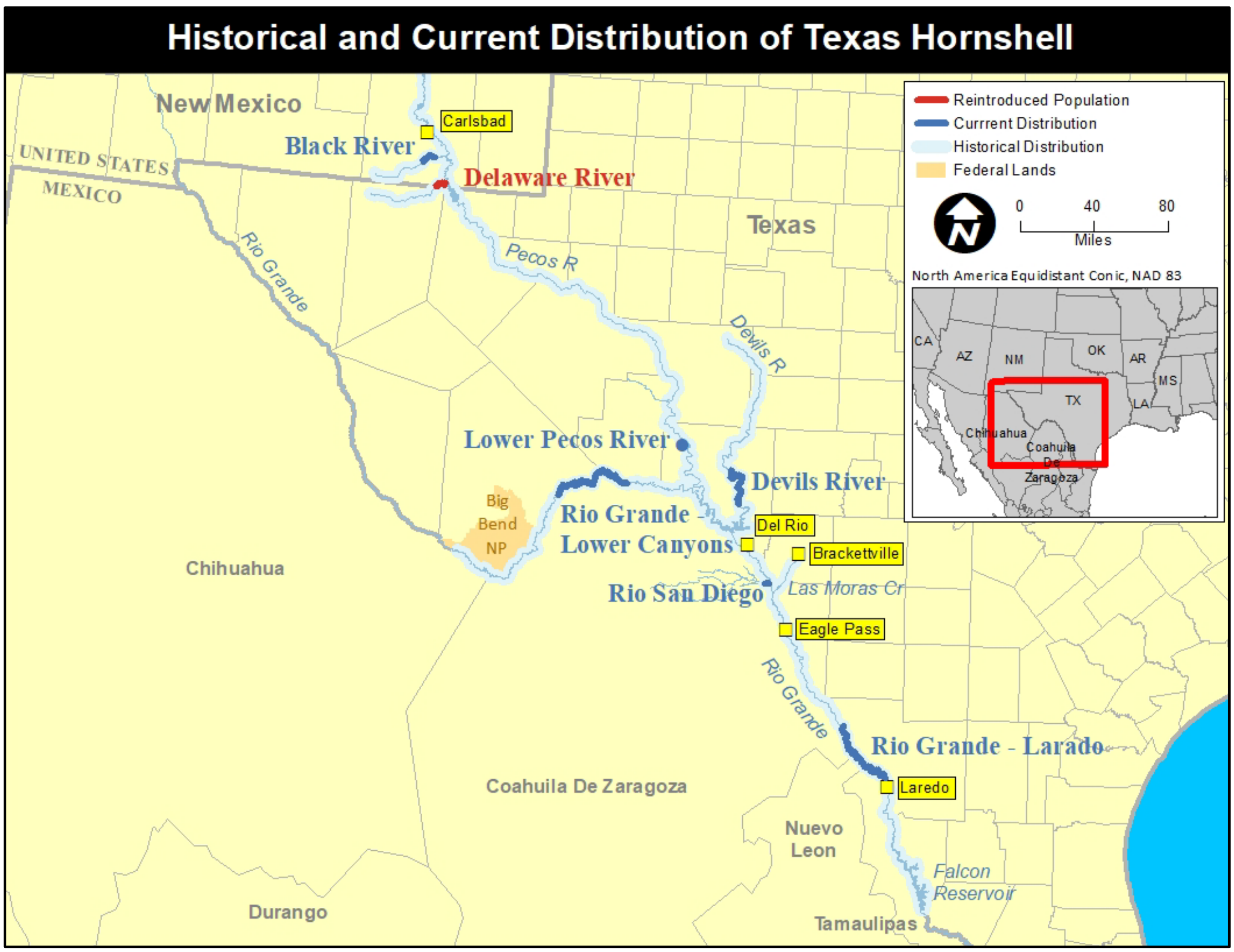

Figure 1. Historical and Current Distributions for THS

The THS has declined significantly in overall distribution, with the species currently occupying approximately 15% of its historical range[1] in the U.S. (See Figure 1). The resulting remnant stream populations[2] occupy relatively shorter reaches compared to presumed historical stream populations, and they are isolated from one another primarily by reservoirs and unsuitable water quality (i.e. saline waters) (USFWS 2018b). At the time of listing, there were five known stream populations within the species' historical range in the United States (U.S.) (Black River, Lower Pecos River, Rio Grande – Lower Canyons, Rio Grande – Laredo, and Devils River (USFWS 2018b). Subsequently, a small population was discovered in the confluence of Rio San Diego, Mexico (Hein *et al.* 2018), making for a total of six stream populations known within the historical range of the species.

Our assessment of species viability, defined as the likelihood of persistence over the long-term, is based on the concepts of resiliency, redundancy, and representation[3]. Overall, the extant stream populations occurring in those remaining areas have relatively good habitat and water quality. However, the stream populations vary considerably in terms of size and abundance. All extant populations show some evidence of recent reproduction, except the Pecos River population (USFWS 2018b). More information on the newly discovered population in Rio San Diego, Mexico is needed to determine its status. The Rio Grande populations are considered highly resilient, and the Devils and the Black River populations are moderately resilient. The Pecos River population has very low resiliency, due to current saline water conditions and the fact that only three old live adults have been found among several old dead THS shells (USFWS 2018a; USFWS 2018b). In addition, the three live individuals were removed permanently from the wild. As a result of current threats and removal of potentially the last remaining live individuals, the Pecos River population is unlikely to persist over the next ten years (USFWS

[1] Historical range (distribution) is defined as the Rio Grande River basin and its associated tributaries (Black, Delaware, Pecos, and Devils rivers, Las Moras Creek, and Rio San Diego) in Texas, New Mexico, and Mexico that historically supported THS populations.

[2] Population was defined previously in the THS SSA report. However, the USFWS determined use of the term stream population was more defining and brought more clarity. Stream population is a term used in a geographical sense and is defined as all living individuals in one river or stream. By using this term it is not implied that a mussel population is currently reproducing or that it is a distinct genetic unit. This term was used to divide THS populations into manageable, geographical units so measureable criteria could be created and applied toward recovery of the species (USFWS 2010).

[3] For a full discussion of the assessment, please refer to the THS SSA report.

2018b) and for recovery purposes is not considered a resilient population but rather a single live record.

The overall representation of THS is divided into two areas of genetic diversity: (1) the Black River stream population[4] and (2) Rio Grande and Devils River stream populations. The Rio San Diego is a tributary of the Rio Grande and is considered a part of the Rio Grande representation area. Within these two identified representation areas, the Black River exhibits no redundancy and has a unique allele frequency found only in that population, making it genetically distinct from other THS stream populations. The Rio Grande representation area has some redundancy, as four stream populations: Rio Grande – Lower Canyons, Rio Grande – Laredo, Devils River, and Rio San Diego. These stream populations are currently assumed to be genetically similar to one another. Future viability of the THS depends primarily on maintenance of existing isolated stream populations and restoration of new stream populations where feasible (USFWS 2018b).

The factors influencing the current and future health of THS stream populations include increased fine sediment, changes in water quality, loss of flowing water, and barriers to fish movement. These influences pose the largest risks to the future viability of this species and are primarily related to habitat changes such as the accretion of fine sediments, low water flows, and poor water quality. Furthermore, each of these factors are exacerbated by changing climatic conditions.

Recovery Vision

In terms of the 3Rs (see SSA report), the long-term viability of the THS as a species is dependent upon the maintenance and restoration of multiple (redundancy) healthy (resilient) stream populations distributed throughout its historical range in separate watersheds with appropriate population structure and genetic diversity (representation). Texas hornshell stream populations must be in sufficient number and distribution across its historical range to shield the species from losses in adaptive capacity from catastrophic droughts and high temperature events.

[4] Delaware population was not considered as an extant population but rather an experimental population of individuals that were pulled from the Black River population and reintroduced into a small segment of the Delaware River. Therefore, the SSA report did not consider the Black River to have redundancy, because there were only a few adult individuals surviving and no evidence of reproduction taking place.

Additionally, stream populations must be adequately protected from low water conditions and high saline waters.

Long-term conservation and recovery of the THS will have been achieved when at least seven healthy stream populations have been restored and/or maintained in separate watersheds across the two known areas of ecological and genetic representation. This would require the threats to the THS to be reduced to a level whereby the species is no longer in danger of extinction, or likely to become endangered in the foreseeable future, and can be removed from the Federal List of Endangered and Threatened Wildlife (List).

Recovery Strategy

The overall strategy for recovering the THS involves stemming any further range contraction in extant stream populations, restoring/managing watersheds and stream habitat to support additional resilient stream populations, and increasing redundancy and representation within those stream populations. More specifically, we describe objectives and actions intended to protect and manage water quality, water quantity, and other stream conditions. These actions are expected to provide the habitat and resources needed for THS, and its host fishes, to persist.

The recovery strategy primarily focuses on habitat restoration and preservation, and is predicated on an increased understanding of the relationship of THS life history requirements within the physical, chemical, and ecological conditions of their environments. Information on this species and its habitats (e.g. population dynamics, alterations in stream flow, and/or responses to identified threats) is important for providing for future science-based management decisions and conservation actions. Implementation of the recovery plan will necessitate adaptive management strategies to use the most up-to-date information as it becomes available. Texas hornshell recovery will involve cooperation among Federal, State, and local agencies, private landowners, academia, and other stakeholders. Therefore, the success of the recovery strategy presented below will rely heavily on the implementation of recovery actions conducted by, and through coordination with, our conservation partners in Texas, New Mexico, and Mexico.

Conservation measures will need to continue after recovery of THS in order to maintain recovered status. Human activities, water demands, and associated impacts will change over time within drainage watersheds. Therefore, it is essential to characterize and monitor aquatic habitats on a watershed scale and to delineate geographical management units (GMUs) of THS stream populations based on anthropogenic and natural barriers for recovery of watersheds. This will enable managers to respond to changing conditions rapidly, whether through negotiation and partnerships to alleviate threats (e.g. low flows, high salinity concentrations) or through relocation or husbandry and reintroduction of THS stream populations to appropriate areas. This approach will require monitoring established and reintroduced stream populations of THS and characterizing current conditions within their watersheds, along with routine periodic monitoring of THS stream populations and habitat conditions.

Geographical Management Units

A GMU is a special unit of the listed entity that is geographically or otherwise identifiable by man-made and natural barriers and may require different management or other considerations. For planning purposes, the range of the THS was divided into GMUs based on the following: (1) the presence of THS and/or its habitat within each unit; (2) independence of the area from others due to isolation or occurrence in a separate watershed; and/or (3) unit-based recovery criteria may be established based on local stressors and their effects on the species and habitat, which are not uniform throughout the range.

The GMUs identified in this plan follow occupied and unoccupied stream reaches outlined in the SSA report and include the Rio San Diego. This results in eight GMUs (see Fig. 2) with extant and historical populations of the THS within its historical distribution. Five of these GMUs have extant stream populations: Black River (Black Unit), Devils River (Devils Unit), Rio Grande – Lower Canyons (Lower Canyons Unit), Rio Grande – Laredo (Laredo Unit), and Rio San Diego (San Diego Unit). The remaining three GMUs would serve as potential reintroduction and or reestablished stream populations within the species' historical distribution: Delaware River (Delaware Unit), Lower Pecos River (Lower Pecos Unit), and Las Moras Creek (Las Moras Unit). A summary of these river segments can be found in the THS SSA report (USFWS 2018b) and Mexico population report (Hein *et al.* 2018). Other reintroduction units may be identified in the future if new information suggests that suitable conditions would support successful THS reintroductions.

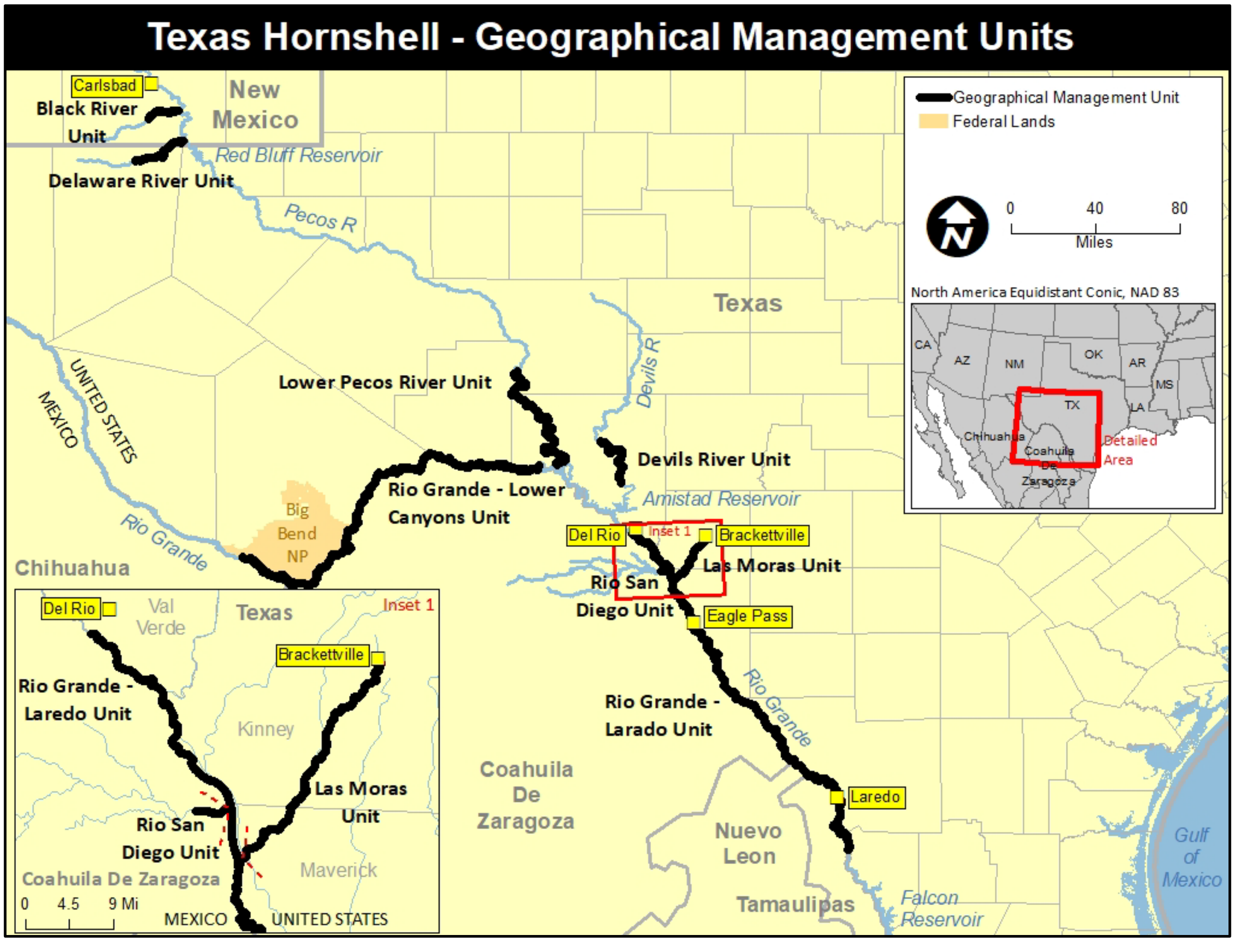

Figure 2. Texas Hornshell Geographical Management Units

For each of the identified GMUs, recovery will focus on: (1) Protecting, restoring, and enhancing habitat and habitat connectivity for existing THS and host fishes stream populations; (2) Expanding distribution of THS stream populations through natural and assisted population restoration and augmentation (3) Improving water quality in GMUs that display water quality degradation from high salinity, chemical spills, and/or effluent discharge; (4) Improving base flows[5] in GMUs degraded by low water conditions resulting from oil/gas production, drought, irrigation for agriculture/crops, and/or industrial/municipality use; and (5) Improving land management to decrease sedimentation run-off into GMUs degraded by excessive sedimentation.

[5] For purposes of this plan, base flow is defined as sustained flow of a stream in the absence of direct runoff. It includes natural and human-induced stream flows. Natural base flow is sustained largely by groundwater discharges (USGS 2019; https://www.usgs.gov/special-topic/water-science-school/science/dictionary-water-terms?qt-science_center_objects=0#qt-science_center_objects; accessed 4/1/2019). The minimum base flow needed for long-term viability will be determined through studies prescribed in the recovery plan.

The period required to improve the size and growth rates of THS populations is largely influenced by the species' life history and generation time. When all conservation actions have been accomplished, their effectiveness will be measured by the natural recruitment of new individuals, their growth to maturity, the increase in abundance to levels considered resilient, and maintenance of those levels of abundance without further human intervention (other than appropriate habitat management). Because the generation time is estimated to be 15 years or more, the criteria for downlisting and delisting are provided in 15 year increments.

Population and habitat characteristics representing resilient populations

A highly resilient THS population was defined in the SSA report as follows: occupies more than 50 miles of riverine habitats, has abundance exceeding 100 individuals per site (segments of river being surveyed) sampled or a density of 200 individuals/150 square meters (m^2), and exhibits evidence of reproduction, with more than 50% of sites[6] (segments of river being surveyed) having recent recruitment (juveniles measuring approximately 35 millimeters (mm) in shell length) and presence of gravid females during the breeding season. The following habitat elements contribute to a highly resilient THS population: rocky substrates with minimal accumulation of fine sediment, flowing water at a sufficient rate to remove excess sediment, and no known water quality degradations (USFWS 2018b).

A moderately resilient THS population was defined in the SSA report as follows: occupies more than 20 but less than 50 miles of riverine habitats, has abundance of 20 to 99 individuals per site (segments of river being surveyed) sampled, and exhibits evidence of reproduction, with 25-50% of sites (segments of river being surveyed) having recent recruitments of juveniles and presence of gravid females during the breeding season. The following habitat elements contribute to a moderately resilient THS population: rocky habitats present, some sediment accumulating on the stream bottom and some crevices, enough water flow but not sufficient to consistently remove excess sediment, and presence of water quality degradation but not at the level to put a population at risk of being extirpated (USFWS 2018b).

A THS population exhibiting low resiliency was defined in the SSA report as follows: occupies less than 20 miles of riverine habitat, has few rocky habitats occupied with fewer than

[6] For the purpose of this plan, site is being defined as mussel beds found within a segment of river being surveyed.

20 individuals per site (segments of river being surveyed) sampled, and fewer than 25 % of sites show signs of recruitment of juveniles and gravid females during breeding season. The following habitat elements contribute to a low resiliency THS population: few rocky habitats present with lots of fine sediment obscuring crevices that do remain, water is not flowing or very little water present, and water quality degradation persists at high enough levels to put the population at risk of being extirpated (USFWS 2018b).

Stream Length and Connectivity

Most freshwater mussels, including THS, are found in aggregations, called mussel beds, that vary in size from about 50 m^2 to greater than 5,000 m^2, separated by stream reaches in which mussels are absent or rare (Vaughn 2012). Resilient THS stream populations must occupy stream reaches sufficient in length such that stochastic events that affect individual mussel beds do not eliminate the entire stream population. Repopulation by fish infested with THS glochidia from neighboring mussel beds, if present and hydrologically connected, can allow the remaining stream population to recover from these events (USFWS 2018a).

The overall distribution of mussels is, in part, a function of the dispersal of their host fishes and the availability of suitable habitat. There is limited potential for immigration between populations other than through the movement of glochidia-infected host fish to a new habitat patch or to another mussel bed. Historically, the THS colonized new areas throughout the Rio Grande Basin and its associated tributaries in New Mexico, Texas, and Mexico through movement of infested host fish, with newly metamorphosed juveniles dropping off of host fish at new locations (USFWS 2018b). Today, the remaining extant stream populations are significantly fragmented and isolated from one another, such that dispersal of host fish and glochidia between them is extremely unlikely, if not impossible, because of existing contemporary barriers to host fish movement. The Black River population is isolated from the other populations by high salinity reaches of the Pecos River and Red Bluff Reservoir and is hundreds of river miles from the nearest extant population. Amistad Reservoir separates the three Texas populations, isolating them from one another (Rio Grande – Lower Canyons, Devils River, and Rio Grande – Laredo populations). No opportunity for interaction currently exists between any of the four extant GMUs in Texas and New Mexico. However, a population in Mexico was recently discovered in Rio San Diego near Jimenez (state of Coahuila), with the potential to interact with the Rio Grande-Laredo GMU (Hein *et al.* 2018).

Existing fish migration barriers such as low-water crossings, road crossings with culverts, and reinforced pipeline crossings can be repaired, removed, modified, or replaced with structures that are more conducive to fish migration and the passage of flowing water. Existing impoundments that are no longer in service upstream and downstream of occupied areas would ideally be removed, if feasible, to lengthen un-fragmented river segments, provide additional flow, and return the river to a more natural, historical condition. To remove the threat of further stream fragmentation, alternatives to further reservoir development within the THS historical range should be identified.

By improving connectivity of stream populations and habitat patches within and among GMUs and expanding occupied stream length within GMUs, the overall resiliency of THS populations will improve.

Stream Flow

The reduction and alteration of stream flow, a primary threat to the THS throughout its historical range, negatively affect THS survivability, reproduction, and occupied stream length. Therefore, measures to promote streamflow and seasonal discharge are necessary for the short- and long-term viability of this species and its host fishes. Maintaining consistent stream flows is important to provide a clean-swept habitat, with enough suitable substrate for THS to burrow into crevices, undercut riverbanks, travertine shelves, and large boulders. The species is not found in lakes or in pools without flow or in areas that are regularly dewatered.

Alternatives to new reservoir development, water management strategies that promote historical stream and pulse flows, and groundwater recharge are needed to ensure that suitable habitat conditions are present throughout the historical range of THS and its host fishes. Existing impoundments still in use and upstream of occupied areas may be able to provide some benefit to THS by adopting water release strategies and management plans to meet instream flow requirements during the spawning season of THS host fishes (river carpsucker, red shiner, and gray redhorse) and to establish a base flow to support THS flow needs. Groundwater and surface water conservation strategies should be implemented to the greatest extent possible to maximize the potential for surface water flows.

The effects of drought on THS may be intensified by climate change, land use change, and other human activities in the Rio Grande basin and its associated tributaries. The rivers inhabited by THS have some resiliency to drought because they are spring-fed (Black and Devils rivers) or very large (Rio Grande), but 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 (USFWS 2018b). Stream flow in the Rio Grande has been declining since the 1980s, and overall discharge is projected to continue to decline due to increased drought as a result of climate change (USFWS 2018b). A comprehensive Watershed Protection Plan for each GMU should be developed and implemented with our partners and stakeholders to conserve the species and promote sufficient stream flows during periods of drought. The plan should address short-term and long-term approaches that can be used to manage water quantity, water quality, and groundwater use under various scenarios of projected climate change. Water releases and reduction of groundwater pumping during periods of drought is particularly critical to help maintain base flows and water temperatures.

Better management of instream flows will not only ensure that adequate flowing water is present within a given watershed, but it will also allow for improved habitat, such as clean-swept suitable substrate and water parameters necessary for THS and its host fishes. These improved conditions will increase the resiliency of THS stream populations and its host fishes and allow for population expansion and increased reproduction and recruitment within GMUs.

Water Quality

Degradation of water quality in sections of the Rio Grande basin and its associated tributaries has been identified as a primary threat to THS. Freshwater mussels, as a group, are sensitive to changes in water quality parameters, such as dissolved oxygen, salinity, ammonia, and pollutants (see THS SSA report for more information) (Table 1). Habitats with appropriate parameter levels are considered suitable. Significant reduction of water quality results in mortality of individuals and has the potential to affect THS at the population and species level during periods of drought. Specifically, point source pollution and elevated salinity levels result in individual THS and host fish mortality, and they have the potential to affect THS stream populations. Sources of water quality degradation include, but are not limited to: (1) groundwater salinization, (2) concentrated animal feeding operations, (3) hazardous materials spills, (4) irrigated cropland runoff, and (5) municipal and industrial wastewater.

Table 1 – Generalized Water Quality Needs for Texas Hornshell

Water Quality Needs	References
• **Low salinity (below 0.9ppt)**	Randklev *et al.* 2017; Carman 2007, p. 7
• **Low ammonia (0.3 – 0.7mg/L total ammonia as N at pH 8)**	Augspurger *et al.* 2003, p. 2574
• **Low levels of copper and other contaminants**	Carman 2007, p. 7
• **Water quality criteria for ambient Dissolved Oxygen concentrations: benchmarks for warm water fish** ➢ **30 day mean for other life stages – 5.5 mg/L** ➢ **7 day mean for early life stages – 6.0 mg/L** ➢ **7 day mean minimum for other life stages – 4.0 mg/L** ➢ **1 day minimum for early and other life stages – 5.0 mg/L and 3.0 mg/L**	EPA 1986, p. 34
• **Water temperature (benchmarks for Central TX mussels)** ➢ **Average LT50 values for 24-h: 31.6/7ºC/88.8ºF** ➢ **Average LT05 values for 24-h: 27.9ºC/82.2ºF**	Khan *et al.*2019, p. 6

Water quality measures that may help protect THS habitat from the threat of water quality degradation need to be defined and implemented. In general, water quality protection measures should either improve or prevent further reduction of surface water quality. Sources of petroleum contamination and other pollutants should be identified and steps taken to reduce the likelihood of future contamination. A plan for responding to major spills of hazardous materials and pollutants within the Rio Grande basin should be developed. The plan should include contingencies to minimize the effects of a contaminant spill on THS populations through protocols needed to "rescue" individuals in response to a contaminant spill, such as the draft THS emergency contingency plan that is in place for the Black River population in New Mexico.

If water quality is improved, water quality protection measures are established, best management practices are implemented, and instream flows are improved, then the resiliency of THS populations and its host fishes will improve in GMUs that are effected by poor water quality and quantity. This, in turn, will improve redundancy by ameliorating the stressors and allowing for natural recruitment into areas that were once uninhabitable due to poor water quality and/or low flows.

Abundance and Reproduction

The USFWS measures THS abundance by the number of mussel beds within a stream population and the estimated density of THS within each (USFWS 2018a; USFWS 2018b). Mussel abundance in a given stream reach is a product of the number of mussel beds and the density of mussels within those beds. For THS stream populations to be resilient, there must be many mussel beds of sufficient densities (~200 individuals per 150 m²) such that local stochastic events do not necessarily eliminate the mussel bed, allowing the overall stream population to recover from any single event. At the moment, the number of mussel beds needed for a stream population to remain moderately resilient or better is unknown; however, Recovery Actions 1.1, 1.2, 1.6, and 1.7 and activities associated with those actions will inform this unknown. Densities similar to the Black and Rio Grande – Laredo stream populations are considered to be relatively high, and it is assumed that they are generally sufficient to support resilient stream populations (USFWS 2018b).

Resilient THS stream populations must also be reproducing and recruiting young individuals into the reproducing population. Population size and abundance reflects previous influences on the population and habitat, while reproduction and recruitment reflect population trends that may be stable, increasing, or decreasing (USFWS 2018a; USFWS 2018b). Reproduction for this species is verified by repeatedly capturing 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 (generally March – August (Smith *et al.* 2003)).

Surveying and Monitoring

Continued survey efforts should take place throughout the THS historical range to confirm whether additional stream populations exist and to better understand patterns of abundance and spatial distribution. A long-term monitoring program should be developed and implemented throughout the THS range, specifically within the identified GMUs. THS stream populations should be regularly surveyed to help guide and evaluate species conservation efforts, and assess the impacts of new or on-going threats. Surveys provide valuable trend information that can signal the need for adaptive management. Therefore, if monitoring has shown that a portion of the population in a particular GMU is declining, management decisions for these sites can be more informed and effective. Monitoring for THS should focus on population parameters such as genetic composition, relative abundance, density, distribution, age class structure, and reproduction. Monitoring these population parameters will help the USFWS track progress towards recovery and evaluate the effectiveness of the recovery strategy.

Translocation and Captive Propagation

Timely reestablishment of THS in historically occupied stream reaches is likely to require artificial translocation of individuals from existing stream populations. Because multiple distinct stream populations exist, it is important to know the genetic composition of each stream population before using it as stock to reestablish or augment reestablished stream populations. This can be accomplished by the use of a genetic management plan aimed at maintaining natural genetic diversity among and within different GMUs. Long-term species management will require an understanding of each stream population's characteristics and factors that affect its viability. Studies should develop and use techniques that minimize sacrifice of individuals from natural populations. This may include salvage and analysis of individuals killed incidentally; nonlethal analysis of individuals using small, excised tissue samples; production of an experimental, cultured population; and development of such techniques using more common surrogate species. A successful captive propagation program should be used to produce individuals for scientific research to eliminate the need to take individuals from wild populations. Use of a captive propagation program to place propagated individuals into the wild will be re-evaluated in the future if it is found that translocation of individuals from other GMUs to reestablish or augment sites is not successful.

Recovery Goals and Objectives

The ultimate goal of the recovery actions outlined in this plan is to recover THS to the point that protections afforded by the Act are no longer necessary. Recovery is likely to be a long-term, challenging process because THS are currently reduced to isolated and fragmented stream populations, with a high severity of threats affecting them and their habitat. Therefore, an intermediate goal for this plan is to improve the status of this species to the point that it could be reclassified from endangered to threatened. A threatened species is one that is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range.

The objectives of this plan are to ensure long-term viability of THS by stabilizing and protecting existing and new THS stream populations, host fish populations, and stream population and habitat connectivity, and by restoring and enhancing the habitats and watersheds necessary to support resilient THS stream populations.

Recovery Criteria

This section delineates objective, measurable criteria which, when met, would result in a determination that the species be removed from the endangered species list. The criteria will be achieved by reducing or removing threats to the species' habitat, as well as conserving and establishing resilient stream populations throughout the species' range, as determined by monitoring of biological parameters.

The THS range was divided into GMUs on the basis of our current understanding of the geographic extent of existing stream populations. Stream populations were used to develop measurable recovery criteria for downlisting and delisting. As described in the SSA report, mussels naturally occur in relatively small patches of suitable habitat separated by typically longer reaches of unsuitable habitat. This trait lends itself to defining more protective and measureable recovery criteria for the THS. Current levels of isolation and fragmention make THS susceptible to local extirpation. Requiring multiple stream populations in separate watersheds throughout the species' historical range to meet recovery criteria thus ensures the persistence of stream populations in each watershed. At the moment, it is unknown how many mussel beds are needed to support a moderately to highly resilient stream population.

Downlisting Criteria

Based on the best available scientific information, downlisting of THS to threatened status should be considered when three highly resilient and three moderately to highly resilient stream populations are maintained or acquired, and the following criteria have been met:

(1) Through protection[7] of existing stream populations, successful establishment of reintroduced stream populations, and/or the discovery of additional stream populations, at least six stream populations exist: five extant stream populations (three high resiliency and two moderate resiliency) in separate GMUs (Lower Canyons-Rio Grande, Laredo-

[7] For the purpose of this plan, protection is defined as preserving populations of the species, its life history requirements, and habitats, sufficient to maintain the species and its habitat in their baseline condition or an improved state, as reflected in population levels, year-class composition, distribution, effective population size, and other primary indicators of biological health and environmental quality. Complete protection includes prevention, elimination, or exclusion of present and foreseeable threats. Determination of essential biological requirements, verification of condition through monitoring, and the performance of additional measures may be needed to ensure continued maintenance of the species, its host fishes, and their habitats (USFWS 2004).

Rio Grande, Devils River, Black River, and Rio San Diego) and one additional stream population in moderate resiliency within its historical distribution and associated GMUs (Lower Pecos River, Delaware River, or Las Moras Creek)[8].

(2) Each stream population in Criterion 1 exhibits evidence of recruitment, continued persistence, and positive or stable population trends (as evidenced by population size measured with sufficient precision to detect change of ±25 percent). In addition, unaided recruitment equals or exceeds mortality over a projected 45-year span, which is the expected minimum time to complete 3 generations (as defined in the Recovery Strategy section).

(3) Adequate flows in streams supporting both THS and its host fishes within at least six stream populations, one per GMU, have been ensured through state and local groundwater management plans, water conservation plans, drought contingency plans, regulations, or equivalent binding documents.

(4) Flows from dam releases are managed so that scouring events are minimized or eliminated and allow for cleansing flows to maintain suitable THS and host fishes habitats.

(5) Habitats necessary for THS and host fishes occupation are maintained or restored throughout at least six stream populations, one per GMU.

(6) Protection of surface and ground water quality is ensured in at least six stream populations, one per GMU, by demonstrated compliance with water quality standards and implementation of water quality controls.

(7) Hazardous material impacts are reduced or minimized in at least six stream populations, one per GMU, by demonstraing the development and implementation of a hazardous spill plan.

(8) All planned and existing municipal discharges located within at least six stream populations, one per GMU, meet water quality standards protective of THS and its host fishes.

[8] Each stream population must exist in a separate GMU so that a single stochastic event, such as a toxic spill or disease outbreak, will not affect more than one stream population. Criterion 1 is based on best available information and the best professional judgement of species experts, and may be revised based on additional biological, demographic, or genetic information obtained through Recovery Action 1.

(9) Excessive sedimentation is reduced by proper land management and erosion control measures within watersheds of at least six stream populations, one per GMU.

(10) Connectivity is increased by incorporating fish passages and/or removal of anthropogenic barriers within at least six stream populations, one per GMU, to allow for the free movement of all life-stages of THS host fishes.

In criteria 3-10, it is not currently feasible to identify the specific threats to individual stream populations and thresholds at which those threats are reduced to the level at which criteria 1 and 2 are achieved. However, the thresholds for criteria 3-10 will be defined through the implementation of key actions in the plan as follows. Step 1: Identify threats and develop a monitoring plan for current and potential threats to THS stream populations (Action 1.3). Step 2: Define measureable criteria for alleviating/reducing each of those threats and prioritize threats according to effects on stream populations (Actions 1.4 and 2.1 – 3.3). Step 3: Apply the appropriate recovery actions outlined in this plan to alleviate/reduce threats. Step 4: Track the progress of recovery implementation (Action 6.2).

Delising Criterion

Based on the best available scientific information, THS should be considered for removal from the endangered species list when the overall delisting goal of four highly resilient and three moderately to highly resilient stream populations are maintained or acquired and the following criterion has been met:

(11) All downlisting criteria have been met and sustained, within at least seven stream populations (four with high resiliency and three with moderate to high resiliency), one per GMU, and have remained stable or increasing for an additional projected 45 year span (three additional generations, as described in the Recovery Strategy section); this is a total of at least 90 years (six generations)[9]. Recovery Actions

The following is a list of the site-specific management actions as may be necessary to achieve the plan's goal for the conservation and survival of the species. *Priority 1* actions are defined as those actions that must be taken to prevent extinction or to prevent the

[9] The completion of six generations should indicate that the species is able to withstand extreme weather and climatic events over time. This represents the minimum number of generations required to detect demographic trends; however, a longer time frame may be necessary if a clear trend has not yet been observed.

species from declining irreversibly in the foreseeable future. *Priority 2* actions are those that must be taken to prevent a significant decline in population size or habitat quality or some other significant negative impact. *Priority 3* actions are all other actions that are necessary to provide for full recovery of the species. The assignment of priorities does not imply that some recovery actions are of low importance, but instead implies that lower priority items may be deferred while higher priority items are being implemented.

Please refer to Table 2 for a clear association among recovery actions and the threats addressed by these actions. Specific tasks required to implement these recovery actions are detailed in the Recovery Implementation Strategy (RIS) (USFWS 2019b). Implementation of the recovery actions will involve participation from State and Federal agencies, non-federal landowners, non-governmental organizations, academia, and the public. Implementation of this recovery plan is voluntary and dependent on the cooperation and commitment of numerous partners in conservation.

Recovery Actions

1.0	**Protect, restore, and enhance existing and new THS and host fish populations, connectivity, and habitats throughout the species' historical range (increases resiliency and redundancy).** Recovery actions 1.1 to 1.7 are designed to collect the necessary updated information to manage THS and host fishes populations and their habitat for natural ecosystem functions in all GMUs. The knowledge gained in monitoring and research studies should be used in an adaptive management approach to provide new strategies for THS recovery.
1.1	Further delineate the current status and distribution of THS throughout its historical range. **(Priority 2)**
1.2	Institute a monitoring program to assess performance of THS populations within GMUs supporting extant (Black, Rio Grande-Lower Canyons and Laredo, Devils rivers, and Rio San Diego Units) and reestablished (Delaware, Lower Pecos, and/or Las Moras Units) stream populations **(Priority 2)**
1.3	Identify current and potential threats within all GMUs **(Priority 1)**
1.4	Carry out regulatory and voluntary projects using existing programs to protect the species and habitat, restore degraded habitat, improve watersheds to reduce erosion and sedimentation, and improve connectivity within and between all GMUs **(Priority 1)**
1.5	Research population and community ecology for THS and its host fishes in all GMUs **(Priority 2)**.
1.6	Research population genomics of THS among and within extant GMUs **(Priority 2)**.
1.7	Characterize resiliency of THS within each GMU **(Priority 2)**.

2.0	**Ensure protection of flow regimes required for long-term persistence of THS, its habitat, and host fishes throughout the THS historical range (increases resiliency).**
2.1	Determine flow requirements for population performance of THS and its host fishes in GMUs supporting extant stream populations **(Priority 1)**.
2.2	Investigate regional hydrology (source of recharge zones of the aquifers that support stream flows) for ground water management and conservation for all GMUs **(Priority 1)**.
2.3	Develop and implement an emergency response strategy for mussel kills and major drought /low water conditions for extant stream populations **(Priority 2)**.
2.4	Purchase, lease, or otherwise utilize water rights to provide the necessary flow regimes identified in Recovery Action 2.1 **(Priority 2)**.
3.0	**Ensure adequate water quality in all GMUs, with an emphasis on GMUs supporting extant stream populations (Black, Rio Grande-Lower Canyons and Laredo, Devils rivers and Rio San Diego GMUs).**
3.1	Determine sensitivities and exposures to various contaminants suspected to have adverse effects to all life stages of THS and its host fishes. **(Priority 1)**.
3.2	Determine sensitivities to low dissolved oxygen, salinity, extremes in temperature, pH, and other water quality parameters of all life stages of THS and its host fishes **(Priority 1)**.
3.3	Develop and implement management plans to retain and promote adequate water quality for all GMUs **(Priority 1)**.
4.0	**Identify suitable sites for THS reintroduction and implement habitat restoration and THS reintroduction within GMUs identified in historical range (e.g., Lower Pecos, Delaware, and Las Moras Units).**
4.1	Identify suitable streams for future reintroduction of THS within the historical range (e.g., Lower Pecos, Delaware, and Las Moras Units) and implement reintroduction **(Priority 2)**.
4.2	Identify and implement habitat restoration at sites identified in Action 4.1. **(Priority 2)**.
5.0	**Initiate educational and public outreach actions to heighten awareness of THS as an endangered species, and solicit help from partners and stakeholders with recovery actions throughout the species' historical range.**
5.1	Identify and engage stakeholders throughout the historical range **(Priority 2)**.
6.0	**Conduct periodic reviews and track recovery progress throughout the THS historical range.**
6.1	Evaluate the status of the species in terms of recovery criteria **(Priority 3)**.
6.2	Review new information every five years and update the THS Recovery Plan as needed **(Priority 3)**.

Table 2. Factors affecting the survival of THS (USFWS 2018a) and associated recovery actions and criteria.

ESA Listing Factors		Threats Description	Recovery Actions	Recovery Criteria
Factor A	The present or threatened destruction, modification, or curtailment of its habitat or range	Increased fine sediment	1, 2, 5	1-6 and 9
		Water quality impairment	1, 2, 3, 5	1-3 and 6-9
		Loss of flowing water	1, 2, 5	1-6
Factor C	Disease or predation	Increased predation	1, 2, 5,	1 and 3
Factor D	Inadequacy of existing regulatory mechanisms to address identified threats	Existing regulatory mechanisms either ameliorate or exacerbate threats described above.	1, 2, 3, 5	1, 3-4, and 6-10
Factor E	Other natural or manmade factors affecting its continued existence	Barriers to fish movement	1	1, 3, and 10
		Climate changes	1, 2, 3, 5	1-6

Estimated Time and Costs to Achieve Recovery

Table 3 summarizes estimates of the time required and the cost to carry out those measures needed to achieve the plan's goal and to achieve intermediate steps toward that goal The table is derived from the more detailed (activity-level) estimates of time and costs shown in the Recovery Implementation Strategy. The USFWS intends to update the implementation strategy annually, in coordination with our conservation partners, by incorporating new pertinent information. Cost estimates include only project specific contracts, staff, or operations costs in excess of base budgets, as well as volunteer and in-kind support. They do not include budgeted amounts that support ongoing agency staff responsibilities. This recovery plan does not commit the USFWS or any partners to carry out a particular recovery action or expend the estimated funds. The USFWS estimates that the full implementation of these actions would improve the status of THS so that it could be reclassified as a threatened species (criteria 1-10) after the span of at least 45 years (3 generations) following the adoption of this plan. The persistence of four highly resilient and three moderately to highly resilient populations throughout the historical range of THS (criterion 11, plus 1-10) would be assessed during another 45 year span (an additional 3 generations) following the downlisting from endangered to threatened.

Table 3. Estimated Time and Costs of Recovery Actions for the Texas Hornshell

Action	Costs ($1,000) and Time Frames (Years)							
	1 - 5	6 - 10	11 - 15	16 - 20	21 - 25	26 - 45	45 - 90	Total
1	$17,845	$15,780	$15,020	$15,420	$15,420	$60,880	$114,005	$254,370
2	$29,855	$28,420	$3,075	$28,315	$27,940	$111,760	$227,160	$481,765
3	$1,600	$0	$0	$0	$0	$0	$0	$1,600
4	$30	$2,865	$2,515	$2,515	$2,515	$10,060	$22,635	$43,135
5	$91	$65	$65	$65	$65	$260	$65	$676
6	$105	$105	$105	$105	$105	$420	$1,105	$2,050
Totals:	$49,526	$47,235	$46,020	$46,020	$46,020	$183,380	$364,970	$783,596

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