Recovery Implementation Strategy for Texas hornshell (*Popenaias popeii*)

Photo Credit: Charrish Stevens, USFWS

U.S. Fish and Wildlife Service

Southwest Region

Texas Coastal Ecological Services Field Office

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This Recovery Implementation Strategy (RIS) corresponds to the THS Recovery Plan (Recovery Plan, U.S. Fish and Wildlife Service [USFWS] 2020) and describes in greater detail how the site-specific, prioritized actions outlined in the recovery plan will be implemented, and estimates the time and costs to complete recovery. The RIS may be revised at any time during the recovery process, whenever experience and information gained call for a change in tactics, therefore maximizing flexibility of recovery implementation. The Service plans to update the RIS on an annual basis at a minimum. As used here, "actions" are broad measures that clearly describe what needs to be done to accomplish the goal of long-term viability. "Activities" are the detailed, on-the-ground tactical steps needed to implement the higher-level recovery actions.

Prioritized recovery actions from the Recovery Plan and their associated activities are listed below (Table 1).

- *Priority 1* actions and activities are defined as those that must be taken to prevent extinction or to prevent the species from declining irreversibly in the foreseeable future.
- *Priority 2* actions and activities 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 and activities are all other measures that are expected to provide for full recovery of the species.

The assignment of priorities does not imply that some actions and activities 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, activities, and the threats they address. Please refer to Table 3 for the Recovery Implementation schedule and projected costs over a 90 year time frame.

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Acronyms Used:

BI	Business and Industries
BMP	Best Management Practices
CCA	Candidate Conservation Agreement
CCAA	Candidate Conservation Agreement with Assurances
CCG	County and City Governments (Water masters)
CWA	Clean Water Act
EQIP	Environmental Quality Incentive Program
ESA	Endangered Species Act
FA	Other federal agencies (U.S. Army Corps of Engineers, U.S. Forest Service, U.S. Department of transportation, U.S. Environmental Protection Agency, U.S. Geological Survey, Bureau of Land Management, Natural Resources Conservation Service)
FERC	Federal Energy Regulation Commission
FIP	Forestry Incentives Program
FWCA	Fish and Wildlife Coordination Act
GIS	Geographical Information System
GMU	Geological Management Units
HCP	Habitat Conservation Plan
NGO	Non-Governmental Organizations (The Nature Conservancy, Freshwater Mollusk Conservation Society)
PL	Private Landowners
RSU	Research and State Universities
SCA	State Conservation Agencies (Texas Parks and Wildlife Department, New Mexico Department of Game and Fish)
SDOT	State Departments of Transportation (Texas and New Mexico)
SIP	Stewardship Incentive Program
SRA	State Regulatory Agencies (Texas Commission of Environmental Quality, Rail Road Commision, River Authorities, New Mexico State Land Office)
THS	Texas hornshell
USDA CRP	United States Department of Agriculture Conservation Reserve Program
USEPA	United States Environmental Protection Agency
USFWS	U.S. Fish and Wildlife Service
USFWS PFWP	USFWS Partners for Fish and Wildlife Program
WRP	Wetland Reserves Program

Table 1. Recovery Actions and Activities

Recovery Action 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 Action 1.1 Further delineate the current status and distribution of THS throughout its historical range (Priority 2)	
Activity Number	Activity
	Description
1.1.1	Conduct surveys of extant stream populations of THS.
	Spatial distribution and abundance will inform future recovery activities and inform the Service the number of local populations that are currently present in the five extant stream populations.
1.1.2	Conduct surveys for additional stream populations where the species may potentially occur such as Lower Pecos in Texas, Las Moras Creek in Texas, Delaware River in Texas , Red Bluff Draw in New Mexico, Rio Grande upstream of Presidio in Texas, upper Rio San Diego, Rio Sabinas, Rio Salado, and Rio San Juan, in Mexico and others.
	Locating additional stream populations may play an important role in meeting recovery criteria and preserving genetically distinct stream populations. In addition, this may help us understand the number of local populations that additional GMUs may be able to support based on habitat and host fish findings.
Recovery Action 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).	
1.2.1	Develop a monitoring plan for THS that includes goals, standardized protocols, and frequency of activities.
	This involves the development of standardized sampling protocols for sampling methodologies for freshwater mussel surveys that are species specific and specific to demographics being sampled. This plan would help with understanding changes in abundance, distribution, demography, and genetic variation needed to track recovery progress. In addition, this information will help to determine the number of local populations each extant stream population may need in order to be resilient long-term. The plan would also include capturing fish diversity and abundance data to monitor identified fish hosts' abundance and presence at populations being monitored.
1.2.2	Develop a monitoring plan for THS habitat that includes goals, standardized protocols, and frequency of activities.
	Understanding changes in water quality, water quantity, and habitat availability is needed to track recovery progress and to understand the needs of local populations within extant GMUs to achieve sustainable resiliency. The plan would also include documenting host fish habitat presence or absence and host fish habitat conditions at populations being monitored.
1.2.3	Establish and maintain long-term monitoring sites within each identified GMU that contains extant THS populations.
	It is essential that monitoring plans are implemented promptly to measure progress toward recovery and monitor the needs of each local population identified within stream populations and GMUs.
1.2.4	Establish and maintain long-term monitoring sites within each re-established stream population in identified GMUs.
	It is essential that monitoring plans are implemented promptly to measure progress toward recovery and to monitor local populations within newly established stream populations and to determine the number of local populations needed to ensure the newly established stream populations are moderately to highly resilient in order to meet recovery criteria.

Recovery Action 1.3 Identify current and potential threats within all GMUs (Priority 1)	
1.3.1	Determine threats within each GMU
	Threats, such as increased fine sediment (Factor A), water quality impairment (Factor A), loss of flowing water (Factor A), barriers to fish movement (Factor E), and increased predation (Factor C), are likely to vary among GMUs. These factors are all exacerbated by effects of climate change (Factor E) and current regulatory mechanisms may be ameliorating or exacerbating these factors (Factor D). Determining specific threats within GMUs will inform management decisions.
1.3.2	Develop and maintain a GIS database to map threats, habitat conditions, land use, and existing conservation efforts with respect to the location and status of THS populations within each identified GMU.
	The creation of this database will inform assessments to determine the distribution of threats in watersheds relative to existing populations. This database is a component of Action 1.4 and will help the Service and its partners to prioritize threats before coordinating actions to alleviate them and focus efforts to restore habitat in keys areas within GMUs. This database will also provide mapping for completed recovery actions to help track recovery (see Action 6.2).
1.3.3	Identify additional management actions and research needs in response to the findings of Activity 1.3.1
	This will include actions to address threats that were unknown at the time of listing and are discovered while assessing current and potential threats from Activity 1.3.1. In order to understand how those threats may be affecting the THS and its host fish, we may need additional research and will adjust management actions as needed.
Recovery Action 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).	
1.4.1	Utilize regulations to work towards meeting the recovery criteria.
	The Service will collaborate with other regulatory agencies to use existing legislation, regulations, and programs (e.g. ESA, CWA, FWCA, wetland and water quality regulations, stream alteration regulations, FERC relicensing, etc.) to protect the THS, its host fish, and habitat.
1.4.2	Generate involvement by carrying out projects with diverse stakeholders in voluntary conservation programs.
	The recovery of the THS will not be possible without soliciting outside help. The assistance of federal and state agencies, conservation groups, and local governments will be essential in implementing the recovery of the THS. Of equal importance is the assistance of private landowners, local industries, businesses, and farming communities to meet recovery goals. The role played by the Service, research universities and state conservation agencies will be vital in fostering diverse partnerships needed to restore habitat and improve surface lands, through existing programs (e.g. Section 7(a)(1) of ESA, Section 6 of the ESA, land acquisition, USFWS PFWP, CCA/As, HCP, USEPA Non-point source Program, USDAs CRP, EQIP, FIP, SIP, and WRP) to the extent that the THS and its host fishes will benefit. The role of private landowners and businesses cannot be emphasized enough as most of the land in GMUs occupied by the THS is privately owned. Participants in cooperative programs may include a broad variety of public and private parties. The total cost of action completion will be determined by the amount of private and governmental participation. These activities will be done in conjunction with outreach described under Action 5.
Recovery Action 1.5 Research population and community ecology for THS and its host fishes in all GMUs (Priority 2).	
1.5.1	Investigate the biology, habitat use, and ecology of the THS early life stages within all GMUs.

	Because of the complex life cycle of the THS, knowledge of feeding ecology, habitat use, glochidial development time and temperatures is needed.
1.5.2	Investigate the biology, habitat use, and ecology of adult THS within all GMUs.
	This activity will provide information regarding the relationships between environmental conditions and reproductive life history, feeding ecology, parasites and diseases.
1.5.3	Investigate the biology, habitat use, and ecology of the host fishes in all GMUs.
	This activity will identify physiological and ecological fish hosts, and their habitat use and dispersal within each GMU.
1.5.4	Map and delineate potential mesohabitat for THS and host fishes within all GMUs.
	This activity will help identify threats, connectivity issues, and inform Actions 2.0 and 4.0.
1.5.5	Develop and optimize captive propagation techniques in support of scientific research and in order to reestablish a population in case of catastrophic extirpation.
	Wild populations are vulnerable and continual removal of adults is not sustainable. Stochastic and/or catastrophic events may require use of captive raised individuals.
Recovery Action 1.6 Research population genomics of THS among and within extant GMUs (Priority 2).	
1.6.1	Determine genetic differentiation among and within stream populations (that have been identified) of THS.
	This activity will quantify genetic variation and gene flow, and identify genome-environment interactions.
Recovery Action 1.7 Characterize resiliency of THS within each GMU (Priority 2).	
1.7.1	Determine the population structure within each GMU.
	This activity will help identify the relationship and connectivity among extant stream and local populations.
1.7.2	Determine rates of patch extirpation and recolonization within each GMU.
	Understanding patch dynamics is critical for determining resiliency.
1.7.3	Within each GMU determine whether the goal is to restore a functional metapopulation or panmictic population for the extant stream populations.
	Each GMU may have a natural population structure that differs from other GMUs and should be managed accordingly.
1.7.4	Within each GMU determine either 1) the number of local populations needed to maintain a resilient metapopulation; or 2) the stream length and population size needed to maintain a resilient panmictic population.
	Management goals may vary among GMUs based on population structure.
Recovery Action 2.0 Ensure protection of flow regimes required for long-term persistence of THS, its habitat, and host fishes throughout the THS historical range (increase resiliency).	
Recovery Action 2.1 Determine flow requirements for population performance of THS and its host fishes in GMUs supporting extant stream populations (Priority 1).	
2.1.1	Characterize flow regimes and geomorphology required to maintain extant stream populations.
	Characterizing subsistence, base, high flow pulses, and over bank flows at stream populations within extant GMUs will inform management decisions. Cross sections of the river from bank to bank would also need to be evaluated to ensure that identified flow requirements can be supported by river channel.

2.1.2	Make management recommendations for flow regimes from Activity 2.1.1 to maintain THS stream populations and fish hosts habitats.
	This includes working with stakeholders to develop and implement identified flow regimes and geomorphologies needed to maintain and improve THS and host fish populations and habitats.
2.1.3	Identify physical structures that negatively impact flow dynamics, THS and host fish populations, or habitat.
	Examples include low head dams, diversion structures, low water crossings, large dams, etc. These will be included on the threats map developed from activity 1.3.2.
2.1.4	Modify previously identified physical structures or mitigate their effects using information gathered from activity 2.1.1.
	This could include prescribing flow recommendations, enhancing fish passage, etc., in collaboration with stakeholders.
2.1.5	Determine tolerance of THS and host fishes to changes in stream flow and increases in turbidity and sedimentation.
	These studies will include an analysis of short-term, long-term, and indirect effects of these stressors on reproduction and all life stages. This activity may include risk assessments per GMU, if needed.
2.1.6	Develop management recommendations for reducing sedimentation from activity 2.1.4.
	This would include working with stakeholders to develop and implement BMPs.
Recovery Action 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).	
2.2.1	Characterize ground water and surface water interactions in each GMU.
	This knowledge is important to inform management decisions.
2.2.2	Identify negative impacts of groundwater use on surface flows.
	This activity would focus on areas where there is excessive pumping that depletes surface flows and identify additional impacts.
2.2.3	Modify or mitigate impacts of groundwater use.
	This would include working with stakeholders to develop and implement BMPs.
Recovery Action 2.3 Develop and implement an emergency response strategy for mussel kills and major drought/low water conditions for extant stream populations (Priority 2).	
2.3.1	Identify triggers for mobilization for emergency response.
	Such triggers may include low flow and water quality triggers, chemical spills, other stochastic events. Potentially use advanced warning systems, such as Biological Early Warning Systems.
2.3.2	Identify contacts for response team and holding locations.
	Such as, federal and state resource agencies and research universities; areas within river systems or fishery centers.
2.3.3	Develop a holding and repatriation strategy.
	This should be correspond with captive propagation techniques identified in activity 1.5.5.
2.3.4	Develop a strategy to assess the causes and extent of mortality following a mussel kill event.
	Understanding these impacts will inform repatriation and prevention of future kill events.

Recovery Action 2.4 Purchase, lease, or otherwise utilize water rights to provide the necessary flow regimes identified in Recovery Action 2.1 (Priority 2).	
2.4.1	Evaluate existing water rights and water rights administration to understand potential threats or opportunities to support flow regime requirements that were identified in Activities 2.1.1 and 2.1.2.
	This can be done by identifying current water rights in Texas and New Mexico throughout the historic range of THS to determine the amount of water that would be present in the system if all rights were to be used to their fullest extent. This will help determine if there is enough water in the systems if all rights were used to their maximum capacity. Identify which water rights are no longer being used or are not being used fully. Determine if there are opportunities to use some water rights toward supporting flow regimes recommended in within each GMU.
2.4.2	Work with water rights owners to identify opportunities for water rights leases, purchases, or donations.
	After the analysis of water rights usage and identification of potential water rights owners to approach for conservation usage, contact owners to assess their interest in leasing, purchasing, or donating their unused water rights toward the conservation or reestablishment of identified flow regime requirements in all GMUs. This would involve working with State and Federal agencies, as well as, City and County officials, water masters, oil and gas industry, land owners, and water rights holders.
2.4.3	Develop a conservation program approved by the appropriate state engineers to protect water rights used to provide the needed flow regimes for THS, its host fishes, and habitat maintenance.
	This would involve working with research universities, state agencies, and water masters that issue water rights and develop and use water management plans. The Service would work closely with these entities to ensure the species' needs are included and attained.
Recovery Actions 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).	
Recovery Action 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).	
3.1.1	Determine tolerance to various contaminants and combinations of contaminants suspected to have adverse effects to the THS and host fishes (e.g. hydrocarbons, ammonia, chlorine, and heavy metals; mixtures such as production water, herbicides, and pesticides).
	These studies will include an analysis of acute and chronic effects (lethal and sublethal) to all life stages including glochidia, artificially propagated juveniles, and adults (or adult surrogate species).
3.1.2	Conduct field studies to determine seasonal ambient exposure conditions of contaminants evaluated in Activities 3.1.1
	These studies will be conducted within stream reaches currently occupied by the THS. Results will be entered into the GIS database discussed in Action 1.3 and used to map sources of contaminants within specific watersheds.
Recovery Action 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).	
3.2.1	Determine tolerance to low dissolved oxygen, salinity, extremes in pH and temperature, and other water quality parameters.
	These studies will include an analysis of acute and chronic effects (lethal and sublethal) to all life stages including glochidia, artificially propagated juveniles, and adults (or adult surrogate species).

3.2.2	Conduct field studies to monitor seasonal patterns in environmental parameters evaluated in activities 3.2.1.
	These studies will be conducted within stream reaches currently occupied by the THS. Results will be entered into the GIS database discussed in Action 1.3 and will characterize seasonal patterns in environmental parameters within specific watersheds.
Recovery Action 3.3 Develop and implement management plans to retain and promote adequate water quality (Priority 1).	
3.3.1	Identify sources (point and nonpoint) and causes of pollution and environmental stressors.
	This will include pollution of both surface and ground waters.
3.3.2	Determine effectiveness of current water quality regulations and guidelines.
	This will include development of risk assessments in light of local, state, federal, and international regulations and guidelines
3.3.3	Work with stakeholders to modify regulations and guidelines as needed or mitigate the effects of pollution.
	This will include working with stakeholders to develop and implement BMPs
Recovery Action 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).	
Recovery Action 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).	
4.1.1	Based on findings from activity 1.1.2, identify and prioritize suitable sites where repatriation or required translocations of THS may take place.
	Environmental and hydrologic factors must be considered when identifying such sites. Translocations may be necessary in response to linear projects, such as bridges, pipelines, road construction, etc.
4.1.2	Identify potential source populations that may be utilized as needed for reintroduction, propagation, and research.
	Environmental, demographic, and genetic factors must be considered when identifying such populations.
4.1.3	Develop and maintain a GIS database of threats, habitat conditions, land use, and existing conservation efforts with respect to the locations and populations identified in activities 4.1.1 and 4.1.2 for reintroduction/translocation.
	This database should be integrated with mapping efforts described in above actions.
4.1.4	Develop and implement a site-specific reintroduction plan as opportunities become available.
	This plan should carefully consider site-specific environmental factors as well as the demographic and genetic factors of the source populations and must include subsequent monitoring activities.

Recovery Action 4.2 Identify and implement habitat restoration at sites identified in Action 4.1. (Priority 2)	
4.2.1	Based on findings from Recovery Actions in 4.0, identify sites for habitat restoration.
	This may include habitat studies to assess the suitability of sites considered for restorations.
4.2.2	Work with landowners and other stakeholders to determine feasibility of habitat restoration identified in Activity 4.2.1.
	Based on the identified suitable sites for restoration and the willingness of those landowners/stakeholders identified, the Service will work with them to determine the appropriate restoration efforts that can take place to improve the overall health of the site, system, and THS and host fish habitat.
4.2.3	Work within FERC relicensing framework to modify flow regimes based on findings in Action 2.1.
	This may include working with FERC and other stakeholders on dams that are coming due for dam operation relicensing (e.g. water releases). This involves looking at various flow release scenarios that are supportive of THS and its host fishes needs for instream flows and maintenance of suitable habitat.
4.2.4	Carry out cooperative projects to protect, improve, or restore unoccupied THS habitat in identified sites.
	This may include working with programs within the USFWS (FWS PFWP), USEPA Non-Point Source Program, and USDAs incentive programs, as well as any state resource agencies that manages water quality, quantity, or land use. These types of programs provide additional means of developing cooperative projects that could be used to protect the river environment.
5.0 Initiate educational and public outreach actions to heighten awareness of THS as an endangered species, and solicit help from stakeholders with recovery actions throughout the species' historical range.	
Recovery Action 5.1 Identify and engage stakeholders throughout the historical range (Priority 2).	
5.1.1	Utilize contacts with government agencies, NGOs, and civic organizations to identify additional stakeholders.
	This can be carried out while conducting other activities; use current stakeholder contacts to reach out to additional stakeholders that may have an interest in assisting the Service with THS recovery.
5.1.2	Engage stakeholders in the recovery process of various recovery actions that have been identified throughout the historical range.
	This will be done by reaching out to stakeholders separately to gauge interests and capabilities of addressing actions with the Service and other stakeholders.
5.1.3	Develop outreach materials (e.g. brochures, web pages, videos, posters) and give presentations on the THS and its host fishes for general distribution to targeted schools, stream teams, and other interested groups.
	This can be carried out by working with TPWD and NMDGF and NGOs to develop such materials and present to public.

5.1.4	Develop and distribute a handout on all available land owner cost share incentive programs that could be applied to the THS in critical GMUs.
	The Service would collaborate with state agencies in NM and TX to reach out to private land owners who may be interested in these programs to assist with some on the ground recovery activities involving private lands.
Recovery Action 6.0 Conduct periodic reviews and track recovery progress throughout the THS historical range.	
Recovery Action 6.1 Evaluate the status of THS in terms of recovery criteria (Priority 3).	
6.1.1	Utilize recovery plans module in ECOS to track recovery implementation.
	Because threats to the THS vary widely among occupied sites, a database is needed to guide and track recovery implementation. The database will help organize recovery to focus the most appropriate recovery efforts on the most important populations. The strategic recovery implementation database will be maintained as a living document throughout the recovery process and will be a matrix consisting of key extant and historical populations (those required to meet Recovery Criteria 1, 2, and 10) along with identified threats, criteria for reducing threats, needed recovery actions, and completed recovery actions.
Recovery Action 6.2 Review new information every five years and update the THS Recovery plan as needed (Priority 3).	
6.2.1	Review new information and update the plan as needed.
	This involves working with the species experts to assess progress on recovery activities, and to determine if initial criteria set are still achievable, and if actions/activities will answer management questions. This assessment should indicate whether we are moving toward recovery of the species and whether more time is needed for recovery.

Table 2. Factors affecting the survival of Texas hornshell (USFWS 2018b) and associated recovery actions, activities, and criteria.

ESA Listing Factors		Threats Description	Recovery		
			Actions	Activities	Criteria
Factor A	The present or threatened destruction, modification, or curtailment of its habitat or range	Increased fine sediment	1, 2, 5	1.1.1 - 1.1.2, 1.2.1- 1.2.4, 1.3.1 – 1.3.3, 1.4.1 – 1.4.2, 1.5.1 – 1.5.5, 1.6.1, 1.7.1 – 1.7.4, 2.1.1- 2.2.6, 2.2.1 – 2.2.3, 2.3.1 – 2.3.4, 5.1.1 – 5.1.4	1-6 and 9
		Water quality impairment	1, 2, 3, 5	1.1.1 - 1.1.2, 1.2.1- 1.2.4, 1.3.1 – 1.3.3, 1.4.1 – 1.4.2, 1.5.1 – 1.5.5, 1.6.1, 1.7.1 – 1.7.4, 2.1.1- 2.2.6, 2.2.1 – 2.2.3, 2.3.1 – 2.3.4, 3.3.1 – 3.3.2, 5.1.1 – 5.1.4	1-3 and 6-9
		Loss of flowing water	1, 2, 5	1.1.1 - 1.1.2, 1.2.1- 1.2.4, 1.3.1 – 1.3.3, 1.4.1 – 1.4.2, 1.5.1 – 1.5.5, 1.6.1, 1.7.1 – 1.7.4, 2.1.1- 2.2.6, 2.2.1 – 2.2.3, 2.3.1 – 2.3.4, 5.1.1 – 5.1.4	1-6
Factor C	Disease or predation	Increased predation	1, 2, 5,	1.1.1 - 1.1.2, 1.2.1- 1.2.4, 1.3.1 – 1.3.3, 1.4.1 – 1.4.2, 1.5.1 – 1.5.5, 1.6.1, 1.7.1 – 1.7.4, 2.1.1- 2.2.6, 2.2.1 – 2.2.3, 2.3.1 – 2.3.4, 5.1.1 – 5.1.4	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	1.1.1 - 1.1.2, 1.2.1- 1.2.4, 1.3.1 – 1.3.3, 1.4.1 – 1.4.2, 1.5.1 – 1.5.5, 1.6.1, 1.7.1 – 1.7.4, 2.1.1- 2.2.6, 2.2.1 – 2.2.3, 2.3.1 – 2.3.4, 3.3.1 – 3.3.2, 5.1.1 – 5.1.4	1, 3-4, and 6-10
Factor E	Other natural or manmade factors affecting its continued existence	Barriers to fish movement	1	1.1.1 - 1.1.2, 1.2.1- 1.2.4, 1.3.1 – 1.3.3, 1.4.1 – 1.4.2, 1.5.1 – 1.5.5, 1.6.1, 1.7.1 – 1.7.4	1, 3, and 10
		Climate changes	1, 2, 3, 5	1.1.1 - 1.1.2, 1.2.1- 1.2.4, 1.3.1 – 1.3.3, 1.4.1 – 1.4.2, 1.5.1 – 1.5.5, 1.6.1, 1.7.1 – 1.7.4, 2.1.1- 2.2.6, 2.2.1 – 2.2.3, 2.3.1 – 2.3.4, 3.3.1 – 3.3.2, 5.1.1 – 5.1.4	1-6

Table 3. Recovery Implementation Schedule and Project Costs.

Activity	Description	Priority[i]	Addresses Threats	Responsible Party	Estimated Time (Years)	Cost estimates ($1,000) and time frames (years)										
						1 - 5	6 - 10	11 - 15	16 - 20	21 - 25	26 - 30	31 - 35	36 - 40	41- 45	46 - 90	Total
1.1.1	Conduct surveys of extant stream populations in which the status of THS is unknown.	2	A, C, D, E	USFWS, RSU, SCA	3	450	0	0	0	0	0	0	0	0	0	450
1.1.2	Conduct surveys for additional stream populations where the species may potentially occur such as Lower Pecos in Texas, Las Moras Creek in Texas , Delaware River in Texas , Red Bluff Draw in New Mexico, Rio Grande upstream of Presidio in Texas, upper Rio San Diego, Rio Sabinas, Rio Salado, and Rio San Juan, in Mexico and others.	2	A, C, D, E	USFWS, RSU, SCA	3	450	0	0	0	0	0	0	0	0	0	450
1.2.1	Develop a monitoring plan for THS that includes goals, standardized protocols, and frequency of activities.	2	A, C, D, E	USFWS, RSU, SCA	Continuous	75	10	10	10	10	10	10	10	10	90	245
1.2.2	Develop a monitoring plan for THS habitat that includes goals, standardized protocols, and frequency of activities.	2	A, C, D, E	USFWS, RSU, SCA	Continuous	75	10	10	10	10	10	10	10	10	90	245

1.2.3	Establish and maintain long-term monitoring sites within each identified GMU that contains extant THS stream populations.	2	A, C, D, E	USFWS, RSU, SCA	Continuous	350	300	150	300	300	150	300	300	150	2100	4400
1.2.4	Establish and maintain long-term monitoring sites within each re-established stream populations in identified GMUs.	2	A, C, D, E	USFWS, RSU, SCA	Continuous	350	300	150	300	300	150	300	300	150	2100	4400
1.3.1	Determine threats within each GMU.	1	A, C, D, E	USFWS, RSU, SCA	Continuous	100	100	50	100	100	50	100	100	50	700	1450
1.3.2	Develop and maintain a GIS database to map threats, habitat conditions, land use, and existing conservation efforts with respect to the location and status of THS populations within each identified GMU.	1	A, C, D, E	USFWS, RSU, SCA	Continuous	120	25	25	25	25	25	25	25	25	225	545
1.3.3	Identify additional management actions and research needs associated with the findings of Activity 1.3.1.	1	A, C, D, E	USFWS, RSU, SCA	Continuous	100	100	50	100	100	50	100	100	50	700	1450
1.4.1	Ensure regulatory compliance is consistent with recovery criteria.	1	A, C, D, E	USFWS, RSU, SCA, SDOT, CCG, NGO, PL, BI, FA, SRA	Continuous	3000	3000	3000	3000	3000	3000	3000	3000	3000	27000	54000

1.4.2	Generate involvement by carrying out projects with diverse stakeholders in voluntary conservation programs.	1	A, C, D, E	USFWS, RSU, SCA, SDOT, CCG, NGO, PL, BI, FA, SRA	Continuous	9000	9000	9000	9000	9000	9000	9000	9000	9000	81000	162000
1.5.1	Investigate the biology, habitat use, and ecology of the THS early life stages within all GMUs.	2	A, D, E	USFWS, RSU, SCA	3	90	0	0	0	0	0	0	0	0	0	90
1.5.2	Investigate the biology, habitat use, and ecology of adult THS within all GMUs.	2	A, D, E	USFWS, RSU, SCA	3	90	0	0	0	0	0	0	0	0	0	90
1.5.3	Investigate the biology, habitat use, and ecology of the host fishes in all GMUs.	2	A, D, E	USFWS, RSU, SCA	3	240	0	0	0	0	0	0	0	0	0	240
1.5.4	Map and delineate potential mesohabitat for THS and host fishes within all GMUs.	2	A, E	USFWS, RSU, SCA	3	90	0	0	0	0	0	0	0	0	0	90
1.5.5	Develop and optimize captive propagation techniques in support of scientific research and in case of catastrophic extirpation.	2	A, C, D, E	USFWS, RSU, SCA	45	3090	2575	2575	2575	2575	2575	2575	2575	2575	0	23690
1.6.1	Determine genetic differentiation among and within stream populations (that have been identified) of THS.	2	E	USFWS, RSU, SCA,	3	110	220	0	0	0	0	0	0	0	0	330
1.7.1	Determine the population structure within each GMU.	2	A, E	USFWS, RSU, SCA,	3	135	0	0	0	0	0	0	0	0	0	135
1.7.2	Determine rates of patch extirpation and recolonization within each GMU.	3	A, D, E	USFWS, RSU, SCA,	10	80	80	0	0	0	0	0	0	0	0	160

1.7.3	Within each GMU determine whether the goal is to restore a functional metapopulation or panmictic population for the extant stream populations.	2	A, D, E	USFWS, RSU, SCA,	1	0	0	0	0	0	0	0	0	0	0	0
1.7.4	Within each GMU determine the number of local populations needed to maintain a resilient metapopulation or stream length and population size needed to maintain a resilient panmictic population.	2	A, D, E	USFWS, RSU, SCA,	1	0	60	0	0	0	0	0	0	0	0	60
2.1.1	Characterize flow regimes and geomorphology required to maintain extant stream populations.	1	A, C, D, E	USFWS, RSU, SCA, FA	4	400	0	0	0	0	0	0	0	0	0	400
2.1.2	Make management recommendations for flow regimes from Activity 2.1.1 to maintain THS stream populations and fish hosts habitats.	1	A, C, D, E	USFWS, RSU, SCA, FA	1	0	30	0	0	0	0	0	0	0	0	30
2.1.3	Identify physical structures that negatively impact flow dynamics, THS and host fish populations, or habitat.	1	A, D, E	USFWS, RSU, SCA, FA	1	150	0	0	0	0	0	0	0	0	0	150
2.1.4	Modify previously identified physical structures or mitigate their effects using information gathered from activity 2.1.1.	1	A, C, D, E	USFWS, RSU, SCA, FA	45	2700	2700	2700	2700	2700	2700	2700	2700	2700	0	24300
2.1.5	Determine tolerance of THS and host fishes to changes in stream flow and increases in turbidity and sedimentation.	1	A, D, E	USFWS, RSU, SCA, FA	3	255	0	0	0	0	0	0	0	0	0	255

2.1.6	Make management recommendations for reducing sedimentation from activity 2.1.5.	1	A, D, E	USFWS, RSU, SCA, FA	1	90	0	0	0	0	0	0	0	0	0	90
2.2.1	Characterize ground water and surface water interactions in each GMU.	1	A, D, E	USFWS, FA, RSU,SCA, CCG, SRA	6	525	75	0	0	0	0	0	0	0	0	600
2.2.2	Identify negative impacts of groundwater use on surface flows.	1	A, C, D, E	USFWS, FA, RSU,SCA, CCG, SRA	Continuous	0	0	0	0	0	0	0	0	0	0	0
2.2.3	Modify or mitigate impacts of groundwater use.	1	A, C, D, E	USFWS, FA, RSU,SCA, CCG, SRA	10 to 20	375	375	375	375	0	0	0	0	0	0	1500
2.3.1	Identify triggers for mobilization for emergency response.	2	A, E	USFWS, RSU, SCA	1	60	0	0	0	0	0	0	0	0	0	60
2.3.2	Identify contacts for response team and holding locations.	2	A, E	USFWS, RSU, SCA	1	10	0	0	0	0	0	0	0	0	0	10
2.3.3	Develop a holding and repatriation strategy.	2	A, E	USFWS, RSU, SCA	2	30	0	0	0	0	0	0	0	0	0	30
2.3.4	Develop a strategy assessing the causes and extent of mortality following a mussel kill event.	2	A, D, E	USFWS, RSU, SCA	2	120	0	0	0	0	0	0	0	0	0	120
2.4.1	Evaluate existing water rights and water rights administration to understand potential threats or opportunities to support flow regime requirements that were identified in Activities 2.1.1 and 2.1.2.	2	A, D, E	NGO, USFWS, FA, SCA, SRA, CCG, BI	Continuous	200	200	200	200	200	200	200	200	200	1800	3600

2.4.2	Work with water right owners to identify opportunities for water right leases, purchases, or donations.	2	A, E	NGO, USFWS, FA, SCA, SRA, CCG, BI	Continuous	25000	25000	25000	25000	25000	25000	25000	25000	25000	360	225360
2.4.3	Develop a State Engineer-approved conservation program to protect water rights used to provide the needed flow regimes for THS, its host fishes, and habitat maintenance.	2	A, C, D, E	NGO, USFWS, FA, SCA, SRA, CCG, BI	Continuous	40	40	40	40	40	40	40	40	40	225000	225360
3.1.1	Determine tolerance to various contaminants and combinations of contaminants suspected to have adverse effects to the THS and host fishes (e.g. hydrocarbons, ammonia, chlorine, and heavy metals; mixtures such as production water, herbicides, and pesticides).	1	A, D	USFWS, RSU, SCA	2	400	0	0	0	0	0	0	0	0	0	400
3.1.2	Conduct field studies to determine seasonal ambient exposure conditions of contaminants evaluated in Activities 3.1.1.	1	A, D	USFWS, RSU, SCA	2	400	0	0	0	0	0	0	0	0	0	400
3.2.1	Determine tolerance to low dissolved oxygen, salinity extremes in pH and temperature, and other water quality parameters.	1	A, D	USFWS, RSU, SCA	2	0	0	0	0	0	0	0	0	0	0	0
3.2.2	Conduct field studies to monitor seasonal patterns in environmental parameters evaluated in activities 3.2.1	1	A, D	USFWS, RSU, SCA	2	0	0	0	0	0	0	0	0	0	0	0

3.3.1	Identify sources (point and nonpoint) and causes of pollution and environmental stressors.	1	A, D	USFWS, RSU, SCA, SRA, FA, CCG, BI	2	400	0	0	0	0	0	0	0	0	0	400
3.3.2	Determine effectiveness of current water quality regulations and guidelines.	1	A, D	USFWS, RSU, SCA, SRA, FA, CCG, BI	2	400	0	0	0	0	0	0	0	0	0	400
3.3.3	Work with stakeholders to modify regulations and guidelines as needed or mitigate the effects of pollution.	1	A, D	USFWS, RSU, SCA, SRA, FA, CCG, BI	Continuous	0	0	0	0	0	0	0	0	0	0	0
4.1.1	Based on findings from activity 1.1.2, identify and prioritize suitable sites where repatriation or required translocations of THS may take place.	2	A, C, D, E	USFWS, RUS, SCA	1	0	0	0	0	0	0	0	0	0	0	0
4.1.2	Identify potential source populations that may be utilized as needed for reintroduction, propagation, and research.	2	A, C, D, E	USFWS, RUS, SCA	2	0	0	0	0	0	0	0	0	0	0	0
4.1.3	Develop and maintain a GIS database of threats, habitat conditions, land use, and existing conservation efforts with respect to those locations identified in activities 4.1.1 and 4.1.2 for reintroduction/translocation.	2	A, C, D, E	USFWS, RUS, SCA, PL	continuous	30	15	15	15	15	15	15	15	15	135	285
4.1.4	Develop and implement site-specific reintroduction plan as opportunities become available.	2	A, C, D, E	USFWS, RUS, SCA, PL, NGO	2	0	350	0	0	0	0	0	0	0	0	350

4.2.1	Based on findings from Recovery Actions in 4.0, identify sites for habitat restoration.	2	A, C, D, E	USFWS, RUS, SCA, PL, NGO	2	0	0	0	0	0	0	0	0	0	0	0
4.2.2	Work with landowners and other stakeholders to determine feasibility of habitat restoration identified in Activity 4.2.1	2	A, C, D, E	USFWS, RUS, SCA, PL, NGO	Continuous	0	0	0	0	0	0	0	0	0	0	0
4.2.3	Work within FERC relicensing framework to modify flow regimes based on findings in Action 2.1	2	A, C, D, E	USFWS, RUS, FA, SCA,SRA	Continuous	0	0	0	0	0	0	0	0	0	0	0
4.2.4	Carry out cooperative projects to protect, improve, or restore unoccupied THS habitat in identified streams.	2	A, C, D, E	USFWS, RUS, SCA, PL, NGO	Continuous	0	2500	2500	2500	2500	2500	2500	2500	2500	22500	42500
5.1.1	Utilize contacts with government agencies, NGOs, and civic organizations to identify additional stakeholders.	3	A, D, E	USFWS, SCA, RSU	2	16	0	0	0	0	0	0	0	0	0	16
5.1.2	Engage stakeholders in the recovery process of various recovery actions that have been identified throughout the historical range.	3	A, D, E	USFWS, SCA, RSU	Continuous	15	15	15	15	15	15	15	15	15	15	150
5.1.3	Develop outreach materials (e.g. brochures, web pages, videos, posters) and give presentations on the THS and its host fishes for general distribution to targeted schools, stream teams, and other interested groups.	3	A, D, E	USFWS, SCA, RSU	Continuous	50	50	50	50	50	50	50	50	50	50	500

5.1.4	Develop and distribute a handout on all available land owner cost share incentive programs that could be applied to the THS in critical GMUs.	3	A, D, E	USFWS, SCA, RSU	2	10	0	0	0	0	0	0	0	0	0	10
6.1.1	Utilize recovery plans module in ECOS to track recovery implementation.	3	A, C, D, E	USFWS	Continuous	75	75	75	75	75	75	75	75	75	675	1350
6.2.1	Review new information and update the plan as needed	3	A, C, D, E	USFWS, SCA, RSU	Continuous	30	30	30	30	30	30	30	30	30	270	540
6.3.1	Develop a post-delisting monitoring plan to monitor recovered status of all THS stream populations.	3	A, C, D, E	USFWS, SCA, RSU	2	0	0	0	0	0	0	0	0	0	160	160
Total Costs for Recovery per time year frame and Total Costs for Recovery of the species[1]:						49776	47235	46020	46420	46045	45645	46045	46045	45645	364970	783846

[1] Cost estimates include total contributions from all sources and include both cash and voluntary, in-kind support. In addition, cost estimates were based on the following USFWS Recovery Plans and Fish Passages and dam removals:

1. Ouachita Rock pocketbook (*Arkansai wheeleri*) Recovery Plan, 2004
2. Scaleshell (*Leptodea leptodon*) Recovery Plan, 2010
3. Devils River Minnow (*Dionda diabolic*) Recovery Plan, 2005
4. Rio Grande Silvery Minnow (*Hybognathus amarus*), 1999
5. Recovery Plan for twelve Vermont Freshwater Mussel species, 2002
6. Kansas Recovery Plan for Freshwater Mussels of Upper Osage River system, Kansas, 2003
7. Recovery Plan for Georgia pigtoe Mussel (*Pleurobema hanleyianum*), Interrupted rocksnail (*leptoxis foreman*), and Rough hornsnail (*Pleurocera foreman*), 2014
8. Higgins Eye Pearlymussel (*Lampsilis* higginsii) Recovery Plan, 2004
9. Wisconsin Department of Natural Resources Fish Passage at Dams Strategic Analysis, 2018
10. Lower Yellowstone Intake Diversion Dam Fish Passage Project, Appendix D, 2016
11. Estimating the Marginal Cost of Dam Removal, 2017

Literature Cited:

Blachly, B. and Uchida, E. 2017. Estimating the Marginal Cost of Dam Removal. Environmental and Natural Resource Economics Working Papers. Paper 2. 11pp.

Wisconsin Department of Natural Resources. 2018. Fish Passage at Dams Strategic Analysis. 151 pp.

U.S. Department of the Interior, Bureau of Reclamation and U.S. Army Corps of Engineers. 2016. Lower Yellowstone Intake Diversion Dam Fish Passage Project, Final Environmental Impact Statement, Appendix D – Fish Passage Connectivity Index and Cost Effectiveness and Incremental Cost Analysis. 106 pp.

Obermyer, B.K. 2002. Recovery plan (working draft) for freshwater mussels in the upper Osage River system, Kansas. Kansas Department of Wildlife and Parks, Pratt, Kansas. 47 pp.

O'Brien, C. 2002. Recovery plan for twelve Vermont freshwater mussel species. 42 pp.

U.S. Fish and Wildlife Service. 2004. Higgins Eye Pearlymussel (*Lampsilis higginsii*) Recovery Plan: First Revision. Ft. Snelling, Minnesota. 126 pp.

U. S. Fish and Wildlife Service. 2004. Ouachita Rock Pocketbook (*Arkansia wheeleri*, Ortmann and Wlaker, 1912) Recovery Plan. Albuquerque, New Mexico. vi + 83p. + A-1-85p.

U.S. Fish and Wildlife Service. 2005. Devils River Minnow (*Dionda diabolic*) Recovery Plan. U.S. Fish and Wildlife Service, Albuquerque, New Mexico. 123 pp.

U. S. Fish and Wildlife Service. 2010. Rio Grande Silvery Minnow (*Hybognathus amarus*) Recovery Plan, First Revision. Albuqureque, NM. viii + 210 pp.

U.S. Fish and Wildlife Service. 2010. Scaleshell Mussel Recovery Plan (*Leptodea leptodon*). U.S. Fish and Wildlife Service, Fort Snelling, Minnesota. 118 pp.

U.S. Fish and Wildlife Service. 2014. Recovery Plan for the Georgia pigtoe mussel, Interrupted rocksnail, and Rough hornsnail. Atlanta, Georgia. 55 pp.

U.S. Fish and Wildlife Service. 2020. Draft recovery plan for Texas hornshell (*Popenaias popeii*). U.S. Fish and Wildlife Service, Southwest Region, Albuquerque, New Mexico. 26 pages.