

Recovery Implementation Strategy for the Southern Edwards Aquifer Springs and Associated Aquatic Ecosystems

Fountain darter (*Etheostoma fonticola*), Peck's cave amphipod (*Stygobromus pecki*), Comal Springs riffle beetle (*Heterelmis comalensis*), Texas wild-rice (*Zizania texana*), San Marcos salamander (*Eurycea nana*), Texas blind salamander (*Eurycea rathbuni*), and Comal Springs dryopid beetle (*Stygoparnus comalensis*)



Southwest Region
U.S. Fish and Wildlife Service
Albuquerque, NM

MAY 2025
Version 1.1

Purpose and Disclaimer

The recovery implementation strategy (RIS) is the third part of the U.S. Fish and Wildlife Service's (USFWS) 3-part recovery planning framework for threatened and endangered species, and it consists of an easily updateable operational plan that is separate and complimentary to the Recovery Plan for the Southern Edwards Aquifer Springs and Associated Aquatic Ecosystems, Second Revision (USFWS 2025a, entire). The RIS includes recovery activities, which detail the on-the-ground information about who, what, when, and how recovery efforts will be implemented by the USFWS and our recovery partners to complete the recovery actions contained in a recovery plan. The RIS also identifies the Endangered Species Act (ESA) statutorily required recovery actions (actions) from the recovery plan that are implemented by the recovery activities (activities). Recovery actions cannot be added or revised in the RIS; these can only be modified through a recovery plan revision. Identification of an activity that can be implemented by any public or private party does not create a legal obligation beyond existing legal requirements. Nothing in this RIS should be construed as a commitment or requirement that any Federal agency obligate or pay funds in any 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.

The RIS may be revised at any time during recovery implementation, whenever experience and information gained call for a change in approach, therefore maximizing flexibility of recovery implementation. Any cost listed as \$0 in Table 2 are covered under existing Federal, State, or partner programs and salaried staff time. For further reading, a Species Biological Report, which provides information on each species' biology, status, and a discussion of factors limiting their viability, is available online for each species profile page below (USFWS 2025b, entire).

Acknowledgements

We are grateful to the people who have contributed their expertise, perspectives, and dedication to these species' recovery efforts over the last four decades. In particular, we would like to express our gratitude to the previous Recovery Team members, the Permittees and staff of the Edwards Aquifer Recovery Implementation Plan - Habitat Conservation Plan, the local communities within the recovery area, and the general public.

In addition to the people identified above, the following USFWS staff reviewed and provided comments on previous drafts of this RIS: Katie Bockrath, Ph.D., Justin Crow, Randy Gibson, Chris Hathcock, and Desiree Moore (San Marcos Aquatic Resources Center); Pete Diaz (Texas Fish and Wildlife Conservation Office); Karen Myers, Christina Williams, and Michael Warriner (Austin Ecological Services Field Office); and Beth Forbus, Angela Anders, Ph.D., Brian Small, and Gary Pandolfi (Southwest Regional Office).

Cover page images courtesy of Jennifer Idol (The Underwater Designer), Mark Enders (City of San Marcos), Anna Huff (The Meadows Center for Water and the Environment), Katie Bockrath, Ph.D. (USFWS), and with kind permission from the Edwards Aquifer Authority.

Notes

This version of the Recovery Implementation Strategy are updates from Version 1.0. The changes from Version 1.0 (July 2024) to Version 1.1 (May 2025) are minor and do not substantially change the activities listed in this document.

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Recommended Citation and Electronic Availability

U.S. Fish and Wildlife Service. 2025. Recovery Implementation Strategy for the Southern Edwards Aquifer Springs and Associated Aquatic Ecosystems. U.S. Fish and Wildlife Service, Southwest Region, Albuquerque, New Mexico, USA. Version 1.1. 13 pp.

An electronic copy of this RIS will be made available at each species profile page on the USFWS Environmental Conservation Online System (ECOS):

- [ECOS species profile webpage for Comal Springs dryopid beetle;](#)
- [ECOS species profile webpage for Comal Springs riffle beetle;](#)
- [ECOS species profile webpage for fountain darter;](#)
- [ECOS species profile webpage for Peck's cave amphipod;](#)
- [ECOS species profile webpage for San Marcos salamander;](#)
- [ECOS species profile webpage for Texas blind salamander;](#) and
- [ECOS species profile webpage for Texas wild-rice](#)

Recovery Action Priority Number Relation to Recovery Activities

The USFWS assigns recovery action priority numbers (1-3) to rank recovery actions as required by the ESA, as follows:

- Priority 1: An action that must be taken to prevent extinction or to prevent the species from declining irreversibly.
- Priority 2: An action that must be taken to prevent a significant decline in species population/habitat quality, or some other significant negative impact short of extinction.
- Priority 3: All other actions necessary to provide for full recovery of the species.

Recovery activities are not assigned independent priority numbers. They correspond with the recovery action priority number of their related action. 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 the Recovery Plan for a clear association among listing factors, threats, and recovery actions affecting the survival of the southern Edwards Aquifer springs and associated aquatic ecosystem species (USFWS 2025a, entire).

1.0 Recovery Activities

1. Recovery Action 1: Ensure Adequate Water Quantity and Quality within the Southern Edwards Aquifer and Management Units. Priority 1.

- Recovery Activity 1-1: Gather information necessary to determine water quantity needed at each Management Unit. Information needs to be gathered and evaluated to ensure adequate water quantity to the Management Units at levels that protect the species and their habitat. This will involve monitoring of aquifer levels and springflow under normal and drought conditions, modeling the impact of current and future droughts combined with groundwater pumping on aquifer levels and springflows, and incorporating any new information into water quantity requirements for each species at each Management Unit. Implement measures to provide adequate water quantity. Continuous flow monitoring should be implemented at Fern Bank Springs as part of this activity.
- Recovery Activity 1-2: Implement measures to provide adequate water quantity. To protect habitat, a comprehensive water management plan or equivalent would protect water quantity. This should include a regional aquifer management plan and the protection of aquifer recharge features. Long-term commitments need to be in place to ensure that these protections will continue in perpetuity. The plan must also identify how regional water needs will be met while considering the water limitations during severe droughts in the future. Considering comprehensive water planning should help ensure that the aquifer is not depleted due to lack of alternative water sources or adequate drought planning.
- Recovery Activity 1-3: Evaluate the effectiveness of measures to provide adequate water quantity. Long-term water quantity monitoring should evaluate how well the implemented measures are protecting water quantity, especially during droughts. This monitoring campaign will include using the aquifer level, springflow, and groundwater pumping data collected by local groundwater conservation districts, Texas Water Development Board, U.S. Geological Service, and other entities. These data will be placed into a management framework that identifies critical aquifer levels and associated on-the-ground habitat conditions. This information should also be used to update the Contingency Plan for springflow triggers to salvage species for the refugia if needed. Projected frequency of droughts and groundwater levels used in models should be validated with data collected during future drought conditions.
- Recovery Activity 1-4: Model effects of projected future land use changes on water quality and aquifer recharge, and whether additional land protection is needed. Increasing development and associated impervious cover in the contributing, recharge, and artesian zones of the Edwards Aquifer threatens water quality, may affect recharge, and increases the risk of catastrophic spills. Modeling these effects is necessary to consider for preventing water quality degradation and whether land preservation in the contributing and recharge zones is needed.

- Recovery Activity 1-5: Develop and implement effective measures to avoid chronic water quality degradation, contaminant spills, and maintain aquifer recharge. Measures to avoid or limit spills and chronic water quality degradation should be developed, implemented, and when needed, modified to ensure their effectiveness. These measures could involve land acquisition, conservation easements, best management practices, impervious cover regulations, buffer zones, outreach programs, and numerous other tools. Plans should also be developed to reduce the risk of spill and reduce the impacts of spills through containment to avoid contaminants entering groundwater. This activity should also evaluate the effectiveness of these measures.
 - Recovery Activity 1-6: Monitor the physical and chemical constituents (sediment, nutrients, ions, and contaminants) present during baseflow and stormflow conditions at the springs. Information should be collected on the physical and chemical constituents of greatest concern during baseflow and stormflow conditions. This research should also be designed to evaluate the effectiveness and modify, if necessary, the measures that avoid or minimize water quality degradation.
 - Recovery Activity 1-7: Consult with environmental agencies on effects of wastewater discharges. Use interagency consultation to evaluate the combined effects of permitted wastewater discharges and future permitted discharges in the recharge and contributing zone on water quality in the Management Units. Implement conservation measures as part of the consultations to protect water quality.
2. Recovery Action 2. Protect and Restore Habitat in Waters and on Lands Within and Adjacent to the Management Units. Priority 1.
- Recovery Activity 2-1: Control non-native species. Control or eliminate non-native species spread that outcompete native flora and fauna and reduce the adaptive capacity and resiliency of listed species' populations within the Management Units. Additionally, proactive measures to reduce conditions preferred by non-native species should be a long-term priority. Regulations to prevent the spread or introduction of non-native species should be enforced through TPWD and the USFWS. Private landowners should be educated on illegal activity reporting and on the prevention of introducing non-native species that may adversely affect the habitats within the Management Units.
 - Recovery Activity 2-2: Reduce human disturbance in habitat. Reduce unintentional disturbance from recreation using measures such as designated access points and prohibiting access in sensitive areas. Intentional disturbance (e.g., from vegetation removal and littering) could be reduced from education, availability of alternatives that would prevent the disturbance, and from legal enforcement.
 - Recovery Activity 2-3: Develop and implement habitat management plans. Management plans should include descriptions of on-the-ground projects and activities necessary to improve or maintain adequate high-quality habitat in which the species' populations can be resilient. This may include erosion control strategies and reducing mechanical disturbances in coordination with local jurisdictions, resource management agencies, and

private landowners. Land development effects should be minimized using best management practices. Sediment removal projects, in coordination of resource management agencies and industries, should minimize disturbance to the habitat where possible, to enhance areas of diminished habitat value. The habitat can be evaluated to determine if it has degraded to the point where specific habitat restoration projects would be beneficial to improve habitat. Adjacent riparian zones should be included in the habitat management plans to protect aquatic habitat. Additionally, the habitat management plans should include abatement strategies for existing threats and measures to identify undetected threats as new information becomes available.

- Recovery Activity 2-4: Protect and restore habitat at Fern Bank and Hueco springs. Access to these springs is needed to evaluate habitat restoration needs. Easements or other conservation agreements could be used to protect these springs from human disturbance.
 - Recovery Activity 2-5: Evaluate the efficacy of recovery activities in protecting and restoring species habitat. Plans and activities should be reviewed and revised as needed based on outcomes from activities and new information.
3. Recovery Action 3: Establish and Implement a Captive Population Management Plan and Reintroduction Plan. Priority 1 for San Marcos salamander, Texas blind salamander, Texas wild-rice; Priority 2 for Comal Springs riffle beetle, Comal Springs dryopid beetle, Peck's cave amphipod, fountain darter.
- Recovery Activity 3-1: Determine optimal conditions for captive breeding of each listed species. Ensure that each species has captive conditions that maximize life expectancy and reflect or exceed life expectancy of wild individuals. Ensure that under captive conditions, most individuals successfully reproduce and offspring from most broods survive until maturity and also reproduce. Until the optimal conditions have been determined for a species, large numbers of a species should not be kept in captivity because they will not be useful for the activities outlined in 3.3 or provide a safeguard against extinction.
 - Recovery Activity 3-2: Maintain captive breeding programs of each of the listed species. Captive breeding programs for each species will be maintained until threats to the species are ameliorated and delisting is achieved. The program is intended to achieve the goals of the plan described in 3-3. However, captive breeding programs should be established even if the plan has not yet been created to safeguard against extinction.
 - Recovery Activity 3-3: Develop and implement a comprehensive strategy for each species. This includes developing and updating Captive Propagation, Contingency, and Reintroduction Plans to ensure their long-term survival. Regular reassessment and adjustments (e.g., annually) are essential.

The Captive Propagation plans should be consistent with the USFWS “Policy Regarding Controlled Propagation of Species Listed Under the Endangered Species Act” (USFWS and NOAA 2000, entire). The plan should address four captive rearing situations: 1) captive rearing during non-crisis times in the event of a rapidly developing crisis when there is no time to collect wild animals, 2) collection and captive rearing of animals as a response to a rapidly developing crisis in which there is time to collect additional wild animals, 3) collection and captive rearing of animals in response to a slowly developing crisis, and 4) captive rearing of animals during non-crisis times without a developing crisis (i.e., standard operating procedures). The plans should balance the needs of the captive refugia with those of the wild populations through employing strategies that minimize the need for collecting wild individuals, while still fulfilling plan objectives.

The Contingency Plans should establish the protocols needed to respond to crisis situations, including the emergency threat of water quantity (springs drying or limited flow), water quality (contaminant events such as oil spills), habitat fragmentation or isolation, or habitat loss. Contingency planning should be regularly updated, independent of the completion of genetic, breeding, and reintroduction studies.

To mitigate the risk of extirpation before further collections can be made, the plans must address: maintaining and reproducing the species in captivity for multiple generations, maintain a sufficient captive population with genetic diversity representative of the wild for an extended period without the possibility of additional collections in case of extirpation from the wild, managing diseases and parasites in captivity, and incorporating strategies to avoid artificial selection that could reduce successful reintroductions.

The Reintroduction Plans should adhere to standard guidelines for reintroduction plans (e.g., Association of Zoos & Aquariums). They should outline the process and circumstances under which the captive population(s) would be reintroduced into the wild, address research needed to improve reintroduction success (White et al. 2015, entire), consider the possibility of multiple reintroduction attempts, address contingency plans if reintroduction is unsuccessful, and include a post-release monitoring plan. The plan should be developed in coordination with agencies, permittees, and academic experts to ensure collection efforts maintain genetic diversity and population viability.

An existing contingency plan exists (USFWS 1996, entire) for managing salvage collections from the wild, though it requires substantial updates to align with current knowledge of the species.

Additionally, a Participation Plan should be developed in coordination with the USFWS that outlines the level of commitment that partner facilities will implement this plan (i.e., long-term versus short-term holding facilities), personnel willing to collect and transport animals, research to be conducted, and level of information to be collected. These plans should be updated regularly.

4. Recovery Action 4: Promote Edwards Aquifer Species Conservation and Recovery through outreach, education, and cooperation. Priority 3.

- Recovery Activity 4-1: Provide outreach and education to local communities. Partners and management agencies will conduct outreach through events and engaging social media posts. Additionally, events and workshops hosted to the local community (e.g., tribes, local governments, citizens, and associations within the taxon's range) should use strategies to seek out broad participation, including those that may not pursue conservation-focused events. Development and installation of interpretive signage should be considered to improve public awareness and appreciation for the ecosystems that the seven species depend on and conservation of aquifer and aquatic habitats in general.
 - Recovery Activity 4-2: Promote cooperation and provide incentives and education for private landowners, land managers, and businesses. All habitat within Management Units in which land managers, landowners, and businesses are the primary caretaker should be incentivized and provided with education on the significance of their cooperation for the recovery of these species. Incentives are encouraged to engage landowners in activities that would improve or restore habitat. This can be achieved through obtaining conservation agreements (e.g., Conservation Benefit Agreements, Habitat Conservation Plans, and easements) whenever possible to protect natural attributes of the property from disturbance, participation or permission for the monitoring of populations, and adaptive management for agreements with businesses.
5. Recovery Action 5: Establish and Implement Effective Disease and Parasite Protocols. Priority 2.
- Recovery Activity 5-1: Investigate largemouth bass virus in fountain darters. Evaluate whether the virus affecting fountain darters is largemouth bass virus or a novel virus using genetic sequencing. Develop captive techniques to treat this virus and reduce mortality of infected individuals.
 - Recovery Activity 5-2: Control parasites in fountain darters and salamanders in captivity. Develop captive techniques to treat parasites, reduce mortality, and increase reproduction from infected individuals.
 - Recovery Activity 5-3: Monitor parasite prevalence at Management Units and assess whether it affects resiliency of wild populations. This action should also investigate the relationship between population trends and parasite prevalence and assess health of infected individuals to determine the extent that parasites are affecting individual fitness.
 - Recovery Activity 5-4: Control parasites at Management Units if needed. Based on monitoring results, techniques to reduce parasites in the wild may need to be implemented such that the parasites are do not decrease the resiliency of the population.
6. Recovery Action 6. Monitor Progress Toward Criteria within the Management Units: Priority 3.
- Recovery Activity 6-1: Create and implement a monitoring plan to evaluate habitat quality and population resiliency of each species at each Management Unit. This should include mark/recapture or other population-level analyses to provide population estimates when feasible, as well as the use of other techniques, such as abundance estimates and

eDNA. Data should be statistically analyzed for trends in population and habitat quality over time. Population viability analysis should be performed at each Management Unit. Monitoring data should also be analyzed to evaluate the extent that climate change affects groundwater recharge, water temperature and water quality in species habitat.

- Recovery Activity 6-2: Determine data needs for monitoring. Due to the subterranean nature of some of the listed species, it may not be possible to obtain adequate data to assess population size. Other estimates may be needed as surrogates in these cases. For subterranean species populations, presence/absence detection through eDNA sampling may provide suitable information in place of formal monitoring due to the inaccessibility of this habitat, access to private properties where species could occupy, and survey difficulties that result in repeatable detection accuracies. New monitoring techniques that provide better population estimates for subsurface species, and how springflows and groundwater levels affect subsurface habitat, should be used if they become available.

Table 1. Partner acronyms or abbreviations used in Table 2.

Acronym or Abbreviation	Full Name
NB	City of New Braunfels
SM	City of San Marcos
EAA	Edwards Aquifer Authority
GBRA	Guadalupe-Blanco River Authority
NGO	Non-governmental organization
NRCS	Natural Resource Conservation Service
PVT	Private Landowners
SAWS	San Antonio Water System
SMRF	San Marcos River Foundation
TCEQ	Texas Commission on Environmental Quality
TPWD	Texas Parks and Wildlife Department
TWDB	Texas Water Development Board
TXST	Texas State University- which includes The Meadows Center for Water and the Environment and The Edwards Aquifer Research and Data Center
EPA	United States Environmental Protection Agency
UNIV	University or other research institution
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Survey

Table 2. Recovery activities, potential partners, and time and cost estimates for all seven species, where applicable. Cost estimates are rounded for simplicity. Costs for potential land conservation as part of 1-5 are not included because they would be dependent on the results of 1-4. Costs are not included for 6-2 because it is opportunistic based on whether new monitoring options become available. Costs listed as \$0 are expected to use existing staff time to evaluate information that is available or will become available through other activities.

Recovery Activity	Potential Partners	Time Estimate (Years)	Cost Estimate
1-1 Gather information necessary to determine water quantity needed at each Management Unit	EAA, NB, NGO, PVT, SAWS, SM, TXST, UNIV, USGS	15	\$4,052,000
1-2 Implement measures to provide adequate water quantity	EAA	65	\$291,135,000
1-3 Evaluate the effectiveness of measures to provide adequate water quantity	EAA, NGO, TWDB, UNIV, USGS	5	\$0
1-4 Model effects of projected future land use changes on water quality and aquifer recharge, and whether additional land protection is needed	EAA, NGO, UNIV, USGS	5	\$3,900,000
1-5 Develop and implement effective measures to avoid chronic water quality degradation, contaminant spills, and maintain aquifer recharge	EAA, EPA, PVT, TCEQ	15	\$4,693,000
1-6 Monitor the physical and chemical constituents present during baseflow and stormflow conditions at the springs	EAA, EPA, GBRA, NB, PVT, SM, TCEQ, USGS	65	\$2,851,000
1-7 Consult with environmental agencies on effects of wastewater discharges	EPA, TCEQ	65	\$0
2-1 Control non-native species	EAA, SM, SMRF, NB, NGO, PVT, TPWD, TXST	65	\$4,649,000
2-2 Reduce human disturbance in habitat	EAA, SM, NB, NGO, PVT, TXST	65	\$3,640,000
2-3 Develop and implement habitat management plans	EAA, SM, NB, NGO, TPWD, TXST, UNIV	65	\$48,909,000
2-4 Protect and restore habitat at Fern Bank and Hueco springs	EAA, NGO, NRCS, PVT, TPWD, USFWS	10	\$3,224,000

Recovery Activity	Potential Partners	Time Estimate (Years)	Cost Estimate
2-5 Evaluate the efficacy of recovery activities in protecting and restoring species habitat	EAA, NGO, TPWD, TXST, UNIV, USFWS, USGS	65	\$0
3-1 Determine optimal conditions for captive breeding of each listed species	EAA, TXST, UNIV, USFWS	10	\$1,781,000
3-2 Maintain captive breeding programs of each of the listed species	EAA, USFWS	65	\$51,160,000
3-3 Develop and implement a comprehensive Captive Propagation and Contingency Plan and Reintroduction Plan for each species	EAA, TXST, TPWD, UNIV, USFWS	65	\$4,920,000
4-1 Provide outreach and education to local communities	EAA, NB, NGO, SAWS, SM, SMRF, TXST, TPWD	65	\$37,050,000
4-2 Promote cooperation and provide incentives and education for private landowners, land managers, and businesses	EAA, NB, NGO, NRCS, SAWS, SM, TWPD	65	\$0
5-1 Investigate largemouth bass virus in fountain darters	EAA, TXST, UNIV, USFWS	10	\$500,000
5-2 Control parasites in fountain darters and salamanders in captivity	EAA, USFWS	65	\$293,000
5-3 Monitor parasite prevalence at Management Units and assess whether it affects resiliency of wild populations	EAA, NB, SM, SMRF, TPWD, TXST, UNIV, USFWS	65	\$292,000
5-4 Control parasites at Management Units if needed	EAA, NB, SM, TPWD, TXST, UNIV, USFWS	65	\$1,788,000
6-1 Create and implement monitoring plan to evaluate habitat quality and population resiliency of each species at each Management Unit	EAA, NB, SM, TPWD, TXST, UNIV	65	\$69,853,000
6-2 Determine data needs for monitoring	USFWS	65	\$0

2.0 Literature Cited

- U.S. Fish and Wildlife Service (USFWS). 1996. San Marcos/Comal/Edwards Aquifer rare, threatened, and endangered species contingency plan. Revised version dated May 1996. 59 pp.
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